SOUTH ST. LUCIE COUNTY
HURRICANE AND STORM DAMAGE REDUCTION PROJECT

2006 OFFSHORE GEOTECHNICAL INVESTIGATIONS TO IDENTIFY SAND SOURCES

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St. Lucie County, Florida

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SOUTH ST. LUCIE COUNTY
HURRICANE AND STORM DAMAGE REDUCTION PROJECT

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INTRODUCTION

In order to support the design of a beach restoration project, St. Lucie County authorized Coastal Planning & Engineering, Inc. (CPE) to conduct a marine sand search investigation. These investigations combined review of the local coastal geological framework, seismic reflection profiles, sidescan sonar imagery, bathymetry, and magnetometer surveys. These combined surveys were used to identify a nearshore sand source with about 9.2 million cubic yards of beach compatible sands. The sandy deposits, which occur in State of Florida waters offshore the project area, form an important natural resource that can be exploited in support of the beach nourishment restoration project.

The project area is located about 10 miles north of the St. Lucie Inlet, in Southeast Florida (Figure 1). Sand resources in this region occur in the form of large shore oblique sandy shoals located 2 to 4 miles offshore and smaller shore oblique to shore transverse shoals about 0.5 to 2 miles offshore (Figure 1). This report presents the results of offshore geophysical and geotechnical investigations that lead to the identification of a sand borrow site offshore of the project area. Permits from the State (FDEP) and Federal (USACE Jacksonville District and MMS) agencies were obtained to conduct offshore geophysical and geotechnical investigations. Geological background and analysis of legacy data are discussed first, followed by a description of field activities, analysis of results from field measurements, and finally definition of the characteristics of the sand source.

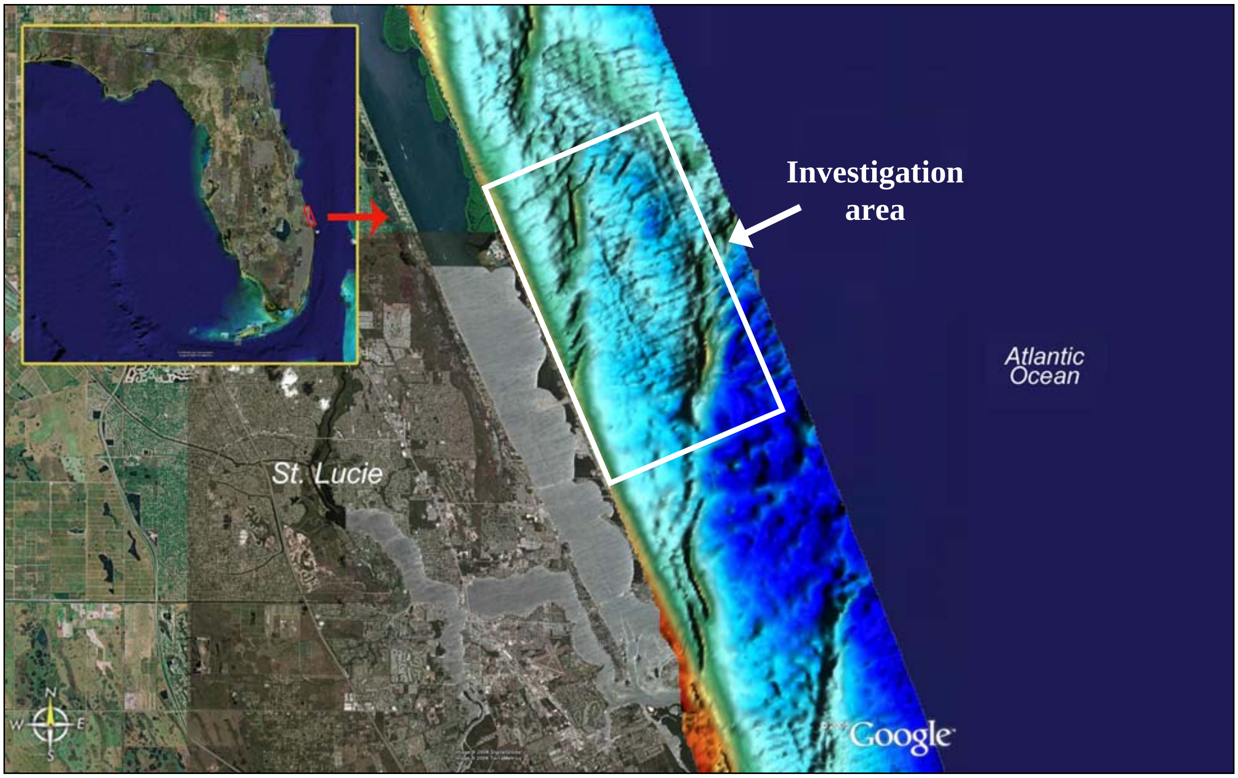


Figure 1. Location diagram of the St. Lucie project area (white-lined box). The composite image combines a 3D bathymetric model (created from historical NOAA-GEODAS bathymetric data) an aerial photography obtained from Google Earth Pro®.

GEOLOGICAL BACKGROUND

General background information relating to the occurrence of sand resources on the inner continental shelf off of St. Lucie County, Florida, requires some basic understanding of shelf evolution and geodynamics. The continental shelf off the east coast of Florida is a drowned (flooded) coastal plain that was exposed subaerially and submerged in many eustatic cycles of sea-level change. The shelf thus shares terrestrial and marine sediments in thick sedimentary sequences that date back to the initiation of continental drift when North and South America rifted away from Africa in the Jurassic Period (206 to 144 Ma, mega annum or million years). The present configuration, morphology, and surficial sedimentary cover of the inner shelf thus results from a long, complicated history that is briefly summarized here as background.

Geological Development of the South-Central Atlantic Coast of Florida

The northern boundary of the basement structure supporting the Florida Platform was a linear structural basin located between the Peninsular Arch and the Paleozoic (4500 to 544 Ma) rocks of the southeastern United States. This structural zone originally was related to a suture zone and accreted continental terrane associated with the final closing of the Iapetus Ocean (proto-Atlantic Ocean). During the Jurrasic Period (when seafloor rifting and continental drift separated the Americas from Africa), the initial carbonate stratigraphic sequences onlapped from the south onto the Peninsular Arch basement rocks. As the Peninsular Arch became covered with shallow water carbonates during the Early Cretaceous (146 to 65 Ma) (due to subsidence and sea-level rise) to form the Suwannee Saddle and the seaway that flooded it (variously called the Suwannee Strait, Channel or Seaway; the Gulf Trough; or the Georgia Channel System) (Hine, 1997), this basin and seaway were paramount in maintaining the carbonate sediment producing environment to the south.

There are two fundamentally different views concerning the topographic complexity of the early basement structure underlying the Florida-Bahamas region. In one view, Mullins and Lynts (1977) postulated that the Bahamas Bank formed during the Jurassic on top of rift-generated horst-and-graben topography (the so-called “graben hypothesis”). During long-term subsidence associated with the regional passive margin setting, carbonate derived sedimentation on the megabank kept pace, forming thick (up to 14 km) shallow-water limestones. Sheridan *et al*. (1988) and Leg 101 Scientific Party postulated a great, contiguous carbonate megabank, extending from the West Florida Escarpment (in the Gulf of Mexico) to the Blake-Bahamas Escarpment, had formed by the Late Jurassic on a basement terrane not segmented into large horsts and grabens (the so-called “megabank hypothesis”). Whether horst-and-graben or megabank, karst developed in Paleocene, Eocene, and Oligocene limestones to produce subsurface and exposed sinkholes and local stratigraphic deformation in the form of folds and sags (Meisburger and Field, 1971; Popenoe *et al*., 1984). These folds have about 80 m of subsurface relief. Karstification (dissolution) proceeded during the late Oligocene (38 to 24 Ma) to early Miocene (24 to 5 Ma) low stands of sea level. These structures probably control modern coastal morphology and shelf topography from Cape Canaveral to the St. Lucie River estuary.

Features of the Continental Shelf

The St. Lucie study area, occurring on the southern extension of the major physiographic unit identified by Uchupi (1968) as the East Coast Shelf, is bounded by the shore and the 3-mile limit to the east (which marks the boundary between State and Federal waters). The Florida Hatteras Slope occurs to the east. The East Coast shelf is a gently seaward-sloping submarine plain bordering the Atlantic coast from near Cape Cod to the Florida Keys. The south-central Florida Atlantic shelf area is part of the southeastern shelf. Following Price’s (1954) geomorphological terminology, Meisburger and Field (1971) subdivided the Florida shelf into three main units: shoreface (low water line to about – 40 ft), inner shelf plain (-40 to -75 ft MLW), and outer shelf that is transitional from the ‘flat’ inner shelf to the top of the Florida-Hatteras Slope lying at -80 to -230 ft LMW. The slope break generally falls between the 70 and 80-ft depth contour.

Subbottom features of the inner shelf were interpreted from zigzag reconnaissance seismic surveys (Meisburger and Field, 1971). The shallowest reflector, light gray or white calcarenite or sediment containing calcarenite fragments, lies just below the shelf surface and outcrops at -60 to -70 ft MLW. The calcarenite layer dips seaward at about 1 on 1300 slope and is parallel to the general dip of the surface of the inner-shelf zone.

Shoreface Zone

The shoreface zone between North Palm Beach and Cape Canaveral is a relatively narrow terrace-like feature that extends from mean low water to depths of -30 to -40 ft. This 1000 to 1500 yd wide zone dips seaward on a slope of 1 on 80. Shoals that occur in the segment between Hobe Sound and Vero Beach, often extend into the shoreface. Coquina outcrops alongshore and on the inner shelf suggests that the shoreface may be partly composed of consolidated or semi-consolidated coquina rock of the Anastasia Formation. There is often 5 to 10 ft of sediment over the coquina rock in the shoreface zone (Meisburger and Field, 1971).

Inner Shelf Plain

According to Meisburger and Field (1971), the inner shelf plain is characterized by an extremely gentle seaward slope, narrow depth range (between -40 to -70 ft), and its general alignment parallel to the shoreline. Morphologically, the inner-shelf plain consists of a series of platforms or step-like flats (areas of reduced gradient), gentle slopes leading from one level to the next, and shoals. The features are bathymetrically subdued, not topographically prominent. Shoal ridges and hills are most extensively developed south of Sebastian Inlet. These shoals are linear and most are aligned in a northeasterly direction. In profile, inner-shelf shoals show a smooth regular surface with both symmetrical and asymmetrical cross-sectional forms. Where asymmetrical, the steeper flanks face east or southeast (seaward). Analyses of seismic reflection profiles indicate that the shoals are superposed on the surface of the flat.

Outer-Shelf Zone

This is dominantly a zone of discontinuous broken topography of generally low relief (10 to 20 ft). The seafloor is characterized by rocky or coral reef patches, ridges, ledges, cliffs, and depressions. Linear trends of ridges or abruptly steepening slopes are typical of this zone. Although these features are discontinuous and highly irregular, some ridges are fairly persistent at water depths of 70 to 90 ft MLW.

Sediments on the Continental Shelf off Ft. Pierce

Surface sediments in the Ft. Pierce area, based on color and gross composition, in usual stratigraphic sequence, group into five main types: (A) clean, poorly sorted, brown shelly sand; (B) gray, fairly well sorted, calcareous sand; (C) silty gray sand and shelly gravel; (D) clean, light gray, fine to medium-grained, well-sorted calcareous sand; and (E) white to light gray, generally poorly sorted, calcareous mud, sand, or gravel that is often lithified (Meisburger and Field, 1971). Interpretations of sediment distribution patterns are based on common factors creating similarities in sediment type viz. (1) deposit age, (2) provenance (sediment source area), (3) environment and circumstances of deposition, and (4) post-depositional history. Additionally, quartzose fine sands and silty cohesive very fine sands are widely distributed throughout the shoreface zone.

All sediments in the Ft. Pierce shelf area that have a brown coloration and which are devoid of silt or clay are classified as Type A. The group is variable but in most places is medium to very coarse, poorly sorted calcareous sand. Quartz is variably present, ranging from a few percent to over 40 percent. Type A sediment usually overlies Types B and C, but it also occurs in direct contact with Types D and E.

Type A Sediments

This group of sediments generally does not occur on the outer shelf area. Over the inner shelf flats, Type A sediments occur as a relatively thin blanket deposit less than 5 ft thick. Over shoals, Type A sediments thicken appreciably (to 30 ft or more) and seismic data indicates that some smaller shoals are entirely composed of this material. Thickness of Type A sediments is related to shelf topography, being thick under shoals and thin in the flats and swales.

Type B Sediments

According to Meisburger and Field (1971), these sediments are probably a facies of the Type A group, the main difference being the color of Type B constituent particles that range from white through gray to black (in contrast to the brownish and reddish colors of Type A). Type B sediment is a gray-colored calcareous sand that is usually fairly well sorted, but may be poorly sorted in some places.

Type C Sediments

This sediment group is normally gray, silty, very coarse skeletal sand to sandy shell gravel. It tends to be slightly cohesive when wet but dries to friable lumps of silt, sand, and shells. Quartz particles, present in small quantity, range from silt-size to very coarse, irregular, but well-rounded grains. Type C sediment is probably nearly continuous throughout the inner shelf area. Surface exposures of Type C sediment are uncommon, the layer being overlain by Types A and B.

Type D Sediments

These sediments are light gray or pale brownish gray, fine-to-medium, well sorted calcareous sand, probably of organic origin. Locally, Type D sediments contain shells and shell fragments in sufficient quantity to constitute a second size mode but most often the sediment has few inclusions. Constituent particles are generally rounded and sometimes polished. The ‘salt and pepper’ aspect of this sediment is due to contrasting light and dark colors.

Type E Sediments

This material on the inner shelf is quite variable, occurring as indurated rocks and calcareous clays to coarse sands. Re-deposition of calcium carbonate in grain interstices appears to have accounted for greater density although grain size and sorting may be equally important (Meisburger and Field, 1971).

Provenance

The source of most sediment particles on the inner shelf off of Ft. Pierce is the benthic biota (Meisburger and Field, 1971). Organisms contributing to the material are indigenous. Quartz, the only noncarbonat element present in significant quantity, must have been derived from the Piedmont Province because no quartz-bearing rocks outcrop on the Florida Peninsula (*e.g*. Puri and Vernon, 1964; Pilkey *et al*., 1969). The dominant carbonate suite may have been created in recent times by organisms inhabiting the area of accumulation or may have originated outside of the area and subsequently entered as detrital sediments. It is also possible that the skeletal fragments were reworked from older underlying formations. All three processes probably played a part in sedimentation of the inner shelf area off of Ft. Pierce. It is also likely that through time, the dominant depositional processes may have differed for different sediment types.

Native Beach Sands

According to Meisburger and Field (1971), sand from beaches in the Ft. Pierce area are not closely similar to any sediment found in offshore surface or subsurface deposits. Type A sediment is the closest in character to beach deposits. As a general rule, beach sands are better sorted and more quartzose than those found offshore. Quartz content from several midtide samples in the area is around 65% compared to 20% or 30% or less in offshore surficial sediments. Shell fragments, which are important but not dominant constituents of beach sediment, are mostly finely broken, well rounded, and polished. Beach drift shells near the Ft. Pierce Inlet contain many thick-walled pelecypods such as *Arca zebra*, *Noetia ponderosa*, and *Glycymeris*.

Even though offshore sands contain significantly more shell material than adjacent beaches, Meisburger and Field (1971) report that it is likely to break up into fine fragments under wave attack on the beachface. For Type A sediment, the only well-suited fill material, most of the shell fraction will probably withstand wave action on the beach as well as do the shell fragments in the existing beach material. The major shell constituent of Type A sediment is the barnacle plate, which appears to be resistant to mechanical degradation, especially in comparison to algal material such as *Halimeda* found in abundance in the Miami area. Type A sediment should not initially lose more than a small fraction of its sand sized material due to abrasion. The remaining material should not degrade at a greater rate than the existing beach sand.

Potential Borrow Sites

According to Meisburger and Field (1971), shoal areas off of Ft. Pierce contain the best materials for beach restoration and nourishment. Capron Shoal and the Indian River Shoal lie close inshore. Capron shoal contains about 64 x 10^6 cubic yards of Type A sediment that occurs above a Type D strata of poorer quality. The Indian River shoal contains at least 10 x 10^6 cubic yards of usable material. Other shoals in the Ft. Pierce area all contain Type A sediment.

MATERIALS AND METHODS

CPE conducted geophysical (bathymetric, magnetometer, sidescan sonar, and sub-bottom profiling) surveys offshore of St. Lucie County on November 5 and 6, 2005, January 5 and 6, 2006, and April 2 through April 6, 2006. CPE conducted a subsequent geotechnical (vibracore, jet-probe, and bottom sampling) survey along and offshore of St. Lucie from January 31 to February 2, 2006, February 18, 2006, May 20 through May 23, 2006, and May 26, 2006.

Geophysical/geotechnical equipment and techniques used during these investigations included:

- Real Time Kinematics (RTK) Global Positioning System (GPS).
- Differential Global Positioning System (DGPS) – Trimble GPS and U.S. Coast Guard Navigation Beacon (Provides accurate positioning of the survey vessel).
- Navigation/Survey Integration System – Hypack Inc.'s "HYPACK MAX®" (Integrates RTK GPS data with data collected during the survey).
- Bathymetric Survey – Odom Hydrographic Systems, Inc.'s "Hydrotrac" Hydrographic Echo Sounder.
- Geometrics G-882 Digital Cesium Marine Magnetometer.
- Subsurface Seismic System – EdgeTech's X-STAR CHIRP 512i Sub-bottom Profiler (state-of-the-art for shallow seismic surveying equipment).
- EdgeTech's "4200 FS" Sidescan Sonar System.
- Jet-Probe Survey.
- Vibracore Survey.
- Nearshore Sediment Samples.
- Sediment-Size Analysis.

The technical methods, analysis tools, and equipment used in this sand search investigation are described below.

Navigation Systems

Real Time Kinematics Global Positioning System

In order to achieve centimeter scale accuracy on our vertical and horizontal navigation control for the offshore geophysical investigation (sub-bottom, sidescan, bathymetric, and magnetometer surveys), CPE geologists employed a Trimble Real Time Kinematics (RTK) Global Positioning System (GPS). RTK GPS relies on a base station/transmitter placed on a survey point of known elevation and horizontal position. The base station at the known point transmits carrier phase and Doppler shift corrections via radio link to a receiver onboard the survey vessel. The receiver on the survey vessel can then apply the carrier phase and Doppler shift corrections to the position of the vessel as measured by GPS satellites, resulting in the determination of the vessel's position within several centimeters, both vertically and horizontally. The Trimble RTK GPS base station transmits data once per second to a receiver up to 10 kilometers away.

An initial reconnaissance of Hutchinson Island found three established vertical and horizontal survey control points; the “R-102” monument near Dollman Beach Park, the “A05” monument along the west right-of-way of highway A1A, and the “A06” monument located further north along the west right-of-way of highway A1A. The “R-102” monument was visually inspected and appeared to be in place and undisturbed. An RTK GPS Base Station was then setup on the “R-102” monument. Once the RTK GPS system was operational, an iron rod and cap monument (“Ginger Base”) was placed on private property belonging to the Island Club Condominium to be used as an initial base station setup and transmitter point. Once “Ginger Base” was established, the RTK GPS base station was moved to that point. At that time, the “A05” and “A06” monuments were visited to check the accuracy of the new “Ginger Base” survey point. Once the RTK GPS system at “Ginger Base” was operational and determined to be accurate, a cap monument (“Island Club Base”) was surveyed and fixed to the roof of the Island Club Condominium to be used as an elevated base station setup and transmitter point for the survey. Once “Island Club Base” was established, the RTK GPS base station was moved to that point (Figure 2). At that time, the “A05” and “A06” monuments were revisited to check the accuracy of the new “Island Club Base” survey point. The horizontal and vertical accuracy of this survey was found to be within an acceptable tolerance of 0.4 feet for geotechnical and geophysical surveys. Horizontal positioning checks were conducted before and after the survey at existing monuments located in the project area to confirm survey accuracy.

Figure 2. RTK GPS base station “Island Club Base” on the roof of the Island Club Condominiums.

Differential Global Positioning System

The navigation and positioning system used for the remaining geophysical and geotechnical surveys (nearshore sidescan, reconnaissance bathymetry, nearshore sediment samples, jet-probes, and vibracores) was a Trimble Differential Global Positioning System (DGPS) that was interfaced to Hypack Inc.’s HYPACK MAX®. A Pro

Beacon receiver provided differential GPS correction from the U.S. Coast Guard Navigational Beacon located at Cape Canaveral, Florida. The DGPS initially receives the civilian signal from the global positioning system (GPS) NAVSTAR satellites. The locator automatically acquires and simultaneously tracks the NAVSTAR satellites, while receiving precisely measured code phase and Doppler phase shifts, which enables the receiver to compute the position and velocity of the vessel. The receiver then determines the time, latitude, longitude, height, and velocity ten times per second. The GPS accuracy, with differential correction used in this study, provides for a position accuracy of one (1) to four (4) feet, which is within the accuracy needed for geotechnical investigations. The U.S. Army Corps of Engineers (USACE) test of the U.S. Coast Guard beacons found an accuracy of at least five (5) feet approximately 94% of the time.

Survey Integration via Hypack Inc.'s HYPACK MAX®

Navigational, magnetometer, and depth sounder systems were interfaced with an onboard computer, and the data integrated in real time using Hypack Inc.'s HYPACK MAX®. HYPACK MAX® is a state-of-the-art navigation and hydrographic surveying system. Online screen graphic displays include the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix, and line bearing. All data are recorded on the computer's hard disk and transferred to a USB memory stick each day during the survey to back-up raw survey data. After post-processing, the navigation data (locational) stored in the HYPACK MAX® system was then exported to a *.dxf* file and imported into ESRI® ArcMap™ 9.1 in order to create a GIS shapefile for analysis and report preparation.

Bathymetric Survey

The Odom Hydrographic Systems, Inc.'s Hydrotrac, a single frequency portable hydrographic echo sounder, was used to perform the bathymetric survey. The Hydrotrac operates at frequencies of 24, 33, 40, 200, 210, or 340 kHz and is a digital, survey-grade sounder. Prior to use, the sounder was calibrated and checked periodically throughout the survey. The sounder was calibrated by using an Odom Hydrographic Systems, Inc.'s DIGITAL PRO® speed-of-sound velocity meter. Speed of sound through water and other selected parameters are adjusted to accurately reflect physical water conditions in the survey area.

Magnetometer Survey

A Geometrics G-882 Digital Cesium Marine Magnetometer was used to perform a cursory investigation of magnetic anomalies within the potential sand sources. The purpose of the magnetometer survey was to establish the presence, and subsequent exclusion zones around any underwater wrecks, submerged hazards, or any other features that would affect sand source delineation and dredging activities. The HYPACK MAX® software recorded magnetic anomalies directly from the Geometrics magnetometer.

Sidescan Sonar Survey

CPE geologists collected sidescan sonar data in both the nearshore project area (from South Hutchinson Island beaches out to ~1,400 feet offshore) as well as the potential sand sources. The sidescan data was used to verify the unconsolidated sediment surface and to map ocean bottom features such as exposed pipelines, cables, underwater wrecks, potential cultural resources or other manmade features that may affect sand source delineation or introduce hazards to dredging. Hardbottom features were classified as high or low relief, isolated rock outcrops or by an equivalent descriptor. Manmade debris was classified based on apparent physical characteristics such as shipwreck remains, cables, or artificial reef structures. The sidescan sonar system utilized for this survey was the EdgeTech 4200-FS sidescan sonar system. The 4200 FS uses full-spectrum chirp technology to deliver wide-band, high-energy pulses coupled with high resolution and superb signal to noise ratio echo data. The sonar package included the portable configuration with laptop computer running the Discover® acquisition software and a 120/410 kHz dual frequency towfish running in high definition mode.

The sidescan was towed from the *M/V Aqua Quest* (offshore surveys) and a CPE survey vessel (nearshore survey) at an optimum position and depth to ensure isolation from sources of interference and for optimum record quality (Figure 3). The digital sidescan data was merged with positioning data (DGPS via HYPACK MAX®), video displayed, and recorded to the acquisition computer's hard disk for post processing and/or replay. At the end of the survey day all data was transferred to a USB memory stick and/or portable hard drive to back-up raw survey data. Hardcopy records were produced later during editing. The position of the sensor relative to the RTK GPS or DGPS antenna was documented to ensure proper positioning of the data. The survey was conducted in such a manner to achieve total bottom coverage (200%) within the survey area. Dual frequency provided a differential aid to interpretation.

The Chesapeake Technology, Inc. SonarWiz.MAP® software program was used to post-process the sidescan sonar data in a geographical framework for target interpretation and delineation. The geo-encoded sonar imagery data was collected as a **.jsf* file. The **.jsf* files were then converted to *.xtf* files for post processing using the EdgeTech Discover® software. The **.xtf* file was then imported into SonarWiz.MAP® to be processed, merged, and exported in the form of geo-referenced sidescan mosaics (geo-tiff files). Morphological features and potential artifacts observed in the sonar displays and records were digitized in SonarWiz.MAP®, edited in ESRI® ArcMap™ 9.1, and saved as **.shp* files.

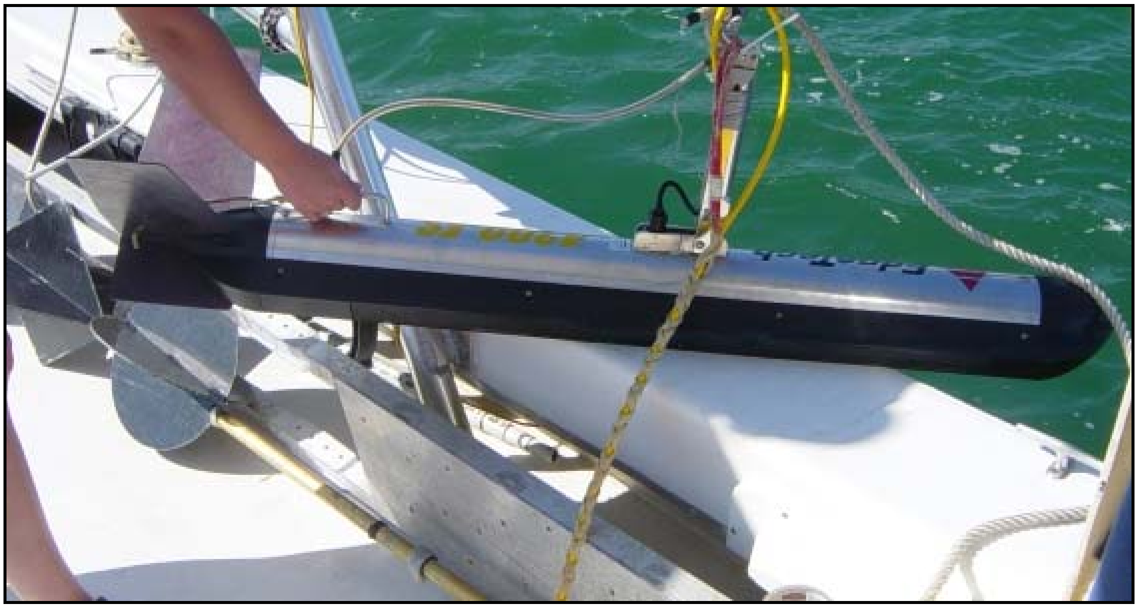


Figure 3. Deployment of the EdgeTech 4200-FS sidescan sonar system.

Sub-bottom Profile Survey

CPE used the EdgeTech SB-512i seismic instrumentation to acquire shallow sub-bottom data. This technology has been successfully utilized by CPE for several years viz. sand searches including Siasconset Beach (Nantucket Island, Massachusetts) (April/May 2006), Lido Key (Florida) (December 2005), Alligator Point (Florida) (September 2005), Mississippi River (Louisiana) (August 2005), South Shoal (Louisiana) (August 2005), Siesta Key (Florida) (July 2005), North Topsail Beach (North Carolina) (March 2005), and Anna Maria Island (Florida) (February 2005). The system often shows a distinct reflector at the boundary of sand deposits and accumulations of silts, clays, gravels, and peat.

The X-STAR Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross-sectional images of the seabed (to an approximate depth of 40 feet in this survey). X-STAR transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called a “chirp pulse”). The tapered waveform spectrum results in images that have virtually constant resolution with depth.

The SB-512i, the latest model of the EdgeTech suite of Chirp Full-Spectrum sub-bottom towfish has one 13” diameter low-frequency transducer and one 6.5” diameter high-frequency transducer. This low-frequency transducer provides more low-frequency energy at all pulse settings, which allows deeper penetration of seafloor sediments while at the same time maintaining the high resolution of the original configuration.

The Chirp systems have an advantage over 3.5 kHz and boomer systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise. The full wave rectified reflection horizons are cleaner and more distinct than the half wave rectified reflections produced by the older analog systems.

Because the model SB-512i tow vehicle weighs over 400 pounds, deployment must be accompanied by a sufficiently large vessel equipped with a davit or crane. For this survey, the SB-512i was winch-deployed from the *M/V Aqua Quest* (Figure 4). It has been our experience, however, that SB-512i transducers achieve deeper penetration through sands than do smaller (and lighter) higher frequency towfish that are easier to deploy. The SB-512i frequency range thus generates a very high-resolution image of the sub-bottom stratigraphy in sand to a depth of 20-50 feet below the sediment/water column interface, which are the typical depths of interest for sand searches.

All sub-bottom data were recorded on the acquisition computer's hard disk and transferred to a USB memory stick and/or portable hard drive at the end of each survey day to back-up raw survey data.

Figure 4. Deployment of the EdgeTech SB-512i sub-bottom profiling system.

Jet-Probe Survey

Jet probes were used to ascertain sediment thickness and other selected parameters (*e.g.* grain size, composition, layers of fine materials, coarse rock fragments, shells) relevant to the determination of the potential of sand deposits for use in beach nourishment. Jet probes are also used to confirm historical vibracore information, such as depth, grain size, composition, and salient morphological properties. Information obtained from jet probes and surface sand samples collectively provide an indication of deposit architecture (presence of fine- or coarse-grained layers, cementation lenses), thickness and general sedimentology of unconsolidated layers.

Jet probe locations were recorded using the Trimble DGPS interfaced with the HYPACK MAX® navigation system. Water depths for each site were determined using an Odom Hydrographic Systems, Inc.'s Hydrotrac precision echo sounder. The jet probes determined the thickness of unconsolidated sedimentary bodies to a maximum of twenty (20) feet.

The jet probing procedure involves jetting a 20-foot long PVC pipe into the seafloor using a water pump mounted on the deck of either the *M/V Aqua Quest* or a CPE survey vessel. As the probe penetrates sediment on the seafloor, a CPE geologist/diver (Figure 5) observes the depth of the probe and the characteristics of the sub-surface sediment. The geologist/diver estimates sub-surface sediment characteristics from probe resistance ("feel" of the probe as it penetrates the sub-surface) and from observation of sediments flushed out of the hole. A second diver records turbidity levels by observing relative suspended sediment concentrations in the dispersal plume, created during the jet probing process, which in turn is used to estimate levels of silt plus clay in the deposit.

A small deposit mound is formed around the jet probe site as the jetted water flushes sediment to the surface. Three samples are obtained from each jet probe site: (1) an undisturbed surface sample, (2) a composite sample from the annular sediment mound that builds up around the hole and which represents bottom-of-hole materials (basal 20 foot sample or shallow refusal on a hard substrate), and (3) a mid-depth composite sample from a second jet probe (a few feet away from the first hole) that is driven to half the depth of the first probe. Twenty-six (26) jet probes (seventy-eight samples) were obtained in this way. Twenty-two (22) samples were selected for sieve analysis; textural characteristics of the remaining samples were visually estimated.

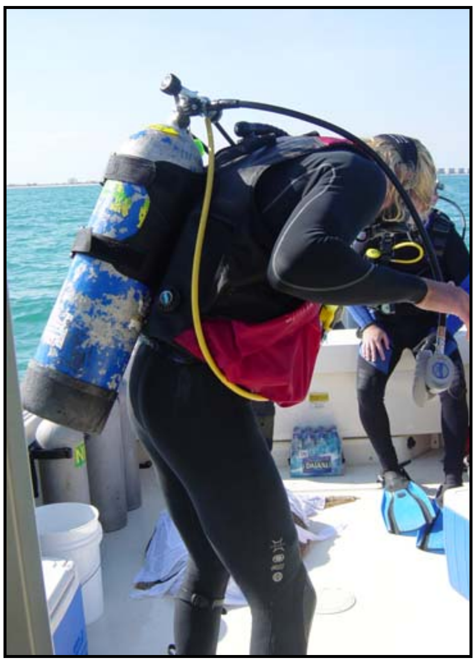


Figure 5. Jet probe operations. CPE survey vessel (above), diver preparing to enter water (bottom left), and water-jet pump in operation (bottom right).

Vibracore Survey

A 271B Alpine Pneumatic Vibracore, configured to collect undisturbed sediment cores 20 feet in length, was used for this project (Figures 6 and 7). This self-contained, freestanding pneumatic vibracore unit contains an air-driven vibratory hammer assembly, an aluminum H-beam which acts as the vertical beam upright on the seafloor, a steel coring pipe (with a plastic core liner), and a drilling bit with a cutting edge. An air hose array provided compressed air from the compressor on deck to drive the vibracore. If penetration refusal occurred at less than 80% of expected penetration, the sampled portion was removed from the pipe, a new liner inserted, and a jet pump hose was attached just below the vibracore head. After lowering the rig to the bottom and jetting to one (1) or two (2) feet above the refusal depth, the jet was turned off and the vibrator turned on in order to collect the remaining core. The vibracore unit was truck-crane deployed from a barge. The barge was maneuvered by the Tug Boat the *M/V Regina T*.

Figure 6. The 271B Alpine Pneumatic Vibracore unit.

Figure 7. Core extraction from (top) and truck-crane deployment of (bottom left and bottom right) the 271B vibracore unit.

After the retrieval of each core, the core was split in half, logged, and sampled aboard the work barge (Figure 8). Splitting the vibracores during field investigations provides an opportunity for immediate inspection of the core and assessment of environmental conditions and real-time optimization of the vibracoring plan (the sampling program can be modified on the basis of what is observed in the recovered materials). This flexibility in the field is important due to the significant costs associated with deployment and setup of vibracore investigations. Other advantages from core splitting and logging in the field are realized when it can be immediately determined whether shorter than expected cores are due to loss of sediment or compaction, or whether there are other abnormalities such as coarse materials plugging the core causing gaps in sediment retrieval, *etc.* Upon completion of field operations, the vibracores were retuned to the CPE laboratory in Boca Raton, Florida, where they were re-examined and photographed.

Nearshore Sediment Samples

CPE collected native beach and nearshore sediment samples from two transects at monuments R-93 and R-96 in St. Lucie County. On these two (2) transects, samples were collected at Top of Dune, +9 feet, Midberm, +6 feet, +3 feet, Mean High Water (MHW), Mean Tide Level (MTL), and Mean Low Water (MLW) by a CPE geologist physically removing a representative sample. At elevations of -3, -6, -9, -12, -15, -18, -21, -24, -27, and -30 feet, CPE geologists collected boat-based sediment samples utilizing a Ponar bottom grab sampler off a CPE survey vessel.

Sediment-Size (Mechanical) Analysis

Sieve analyses were conducted for all samples obtained by vibracoring, native beach, and nearshore sediment sampling (described above) in accordance with American Society for Testing and Materials Standard Materials Designation D422-63 for particle size analysis of soils (ASTM, 1987). This method covered the quantitative determination of the distribution of sand size particles. Mechanical sieving was accomplished using calibrated sieves, with a gradation of half phi intervals. Additional sieves representing key ASTM sediment classification boundaries were also used, per Florida Department of Environmental Protections standards.

Figure 8. Vibracore splitting, description, sampling, and wrapping being conducted aboard the work barge during the vibracore operations.

Grain size results were entered into the gINT® software program, which computes the mean and median grain size, sorting, and silt/clay percentages for each sample using the moment method (Folk, 1974). A grain-size distribution curve for each sample as well as composites for each vibracore, the native beach, and subsequent sand sources were compiled.

Investigation Sequencing

A methodological approach to marine sand searches, developed over the years by the CPE Coastal Geology and Geomatics team (*e.g.* Finkl, Khalil and Andrews, 1997; Finkl, Andrews and Benedet, 2003; Finkl *et al.*, 2005; Finkl and Khalil, 2005), was adapted to the St. Lucie offshore conditions and applied throughout this sand search investigation. In comprehensive marine sand searches such as the St. Lucie project, CPE typically employs sequential survey procedures that maximize resources to effectively characterize offshore sand deposits. These sequential surveys collect preliminary data over relatively large expanses of seafloor in the form of surface grab samples, jet probes, and reconnaissance bathymetry prior to the collection of remotely sensed data (*i.e.* seismic reflection profiles, sidescan characterization of the seafloor and magnetometer surveys) and vibracores in smaller target areas. Reconnaissance-level surveys that cover large areas of the seafloor provide useful information that helps define smaller targets (areas with higher potential for containing materials that are suitable for beach nourishment) where more intensive (and more expensive) sand and cultural resource investigations are conducted.

The investigative sequence, shown in Figure 9, describes logical progressions and interactions between different data sources and indicates appropriate steps that were used during the St. Lucie sand search by CPE geologists and geophysicists. The method draws together local geological information and data to generate the final sand search deliverables in an efficient and cost effective way.

During Phase I (review of historical data), CPE researchers conducted archival literature studies of the St. Lucie inner continental shelf area and analyzed data that was input to a GIS database. These collective analyses indicated that offshore sand ridges were the most promising geomorphological features on the inner continental shelf off of St. Lucie that contained beach compatible sediments. With this new model envisioned (compared to traditional extraction from nearshore sheet deposits, shoals, and ebb-tidal deltas), reconnaissance bathymetric surveys and surface sampling were used to confirm sand ridges on the inner continental shelf (Phase II). After reconnaissance bathymetry and sand sampling, prospective ridges were jet probed to determine sediment thickness and grain size. Before field investigations of Phase II and Phase III were conducted permits from the State (FDEP) and Federal (MMS) agencies were obtained to perform offshore activities.

Phase III investigations, together with cultural resource assessments, comprised the last phase of this comprehensive sand search by incorporating final identification and characterization of beach-compatible sand sources. The principal tools used in this phase are vibracore and seismic surveys, complemented by interpretation of side scan (for seabed surface morphology) combined with prior bathymetry and jet probe surveys. Beach sand samples were also collected in this phase.

This report presents the results of these multi-phased investigations with emphasis on definition of final sand sources that is supported by textural and stratigraphic properties of the borrow site.

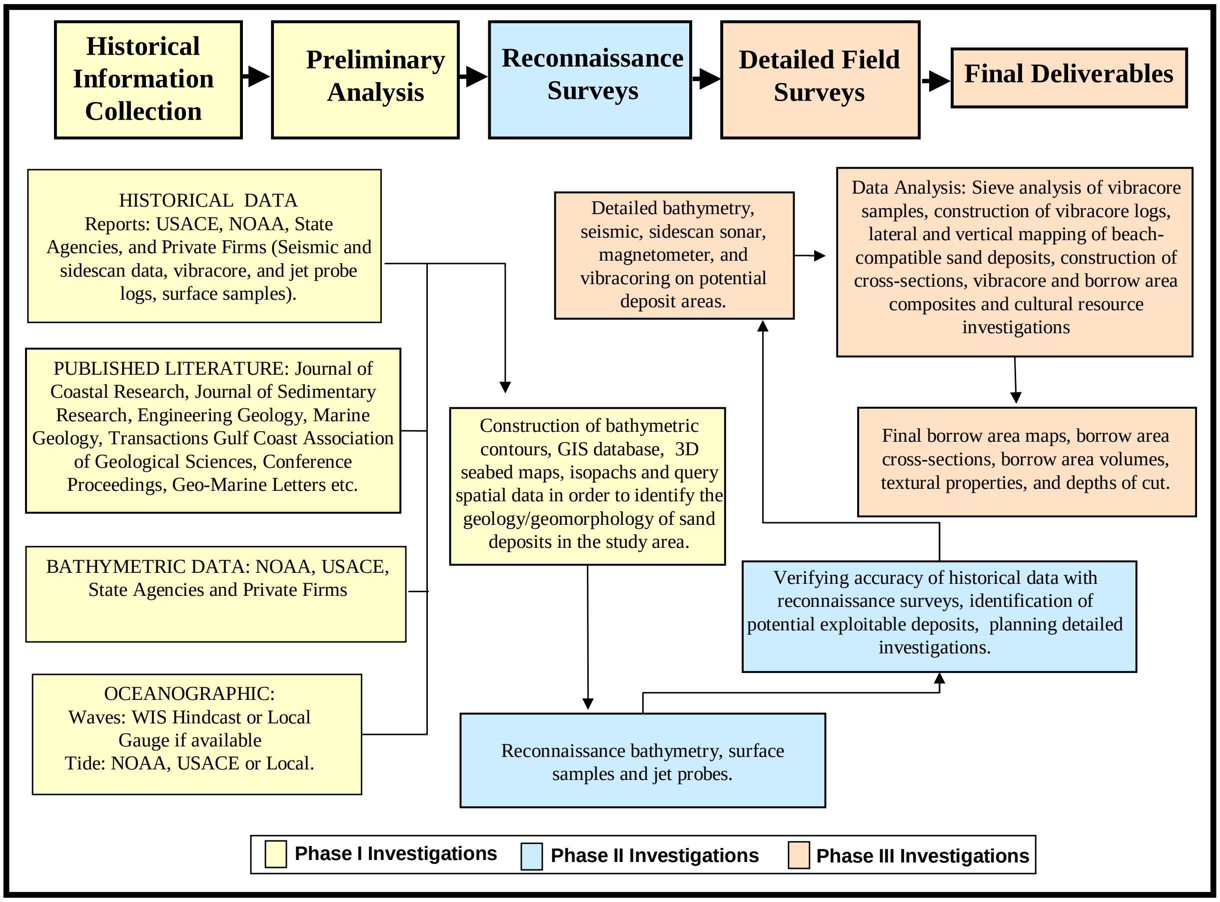


Figure 9. This flow diagram summarizes the main phases of sand searches that are comprised by strategic geotechnical and geophysical studies.

RESULTS AND DISCUSSION

Historical Data Analysis

CPE geologists reviewed historical geotechnical data and created a geo-referenced 3D image of the seabed along the project area using NOAA-GEODAS Hydrographic data (Figure 10) to select target areas for the offshore surveys. Based on the analysis of historical data and experience from past projects near St. Lucie County, it was concluded that nearshore sand ridges had the most potential for storing beach-quality sand.

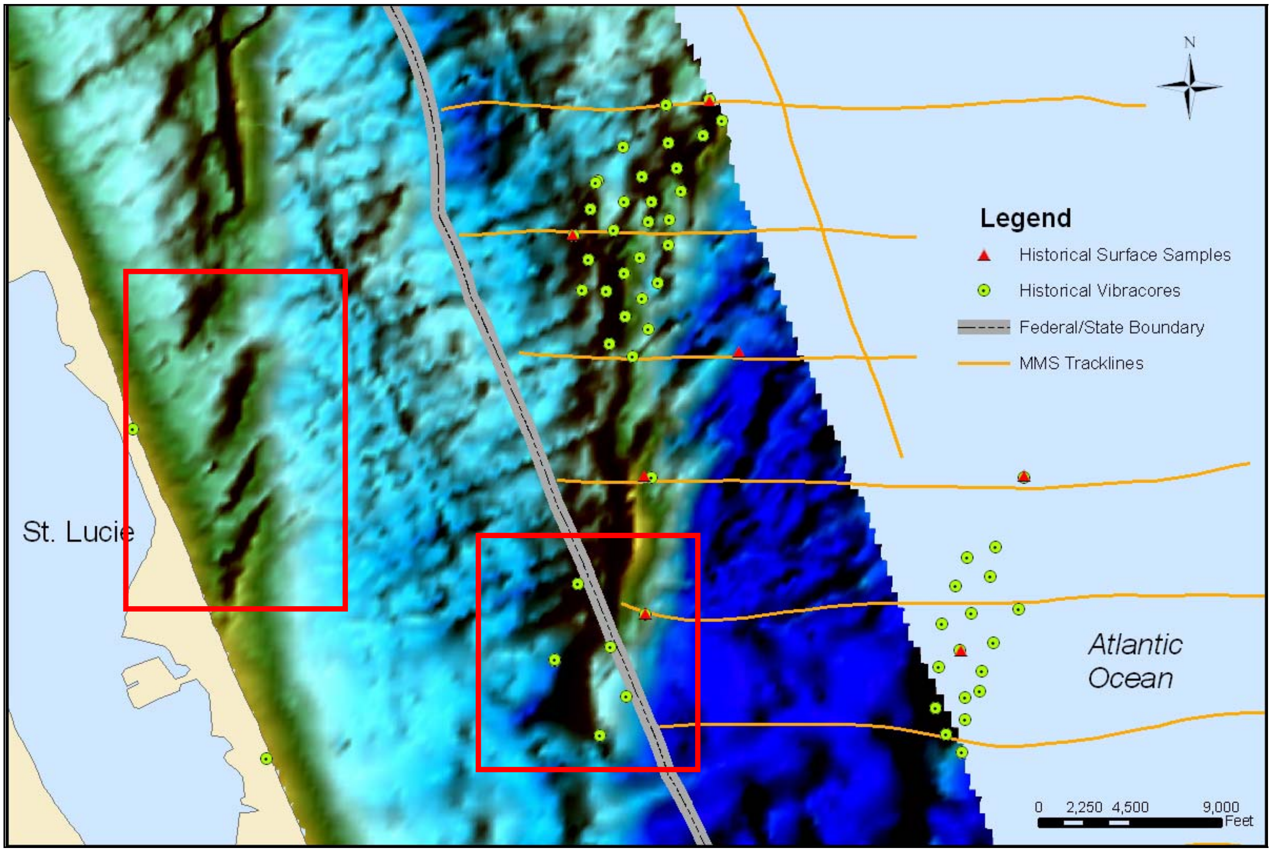


Figure 10. Location of historic geotechnical and geophysical data overlaid on top of a 3D bathymetric model created using NOAA-GEODAS bathymetry data. Sand ridge features identified offshore of the project area (see red rectangles) were selected for reconnaissance investigations.

The most prominent sand ridges near the proposed project limits and located within State waters were identified on the seabed map and a reconnaissance survey plan was prepared to investigate these ridges. The seabed image, constructed using the historical bathymetric data overlaid by existing geotechnical historical data, is shown in Figure 10. This data was used to select target locations for reconnaissance surveys. The two target locations are indicated by the red rectangles in Figure 10.

Reconnaissance Bathymetry and Surface Samples

As discussed before, reconnaissance investigations followed a sand search protocol outlined by Finkl, Benedet and Andrews (2003) and others. The protocol suggests that, in areas where bathymetrically positive features (sand ridges) occur, reconnaissance investigations should concentrate on obtained recent bathymetry data and reconnaissance sand samples (Phase I), followed by jet probes (Phase II) and finally seismic and vibracores (Phase III). Because the NOAA bathymetric data used in the historical data analysis is at least a decade old, it is necessary to obtain current bathymetry data to accurately map the sand ridge boundaries and relief. To supplement the bathymetric survey, reconnaissance samples were obtained using surface ponar grabs. These samples are an inexpensive method to confirm historical data in surficial layers before further investigations are conducted. Results from this reconnaissance bathymetry and sand sampling survey were analyzed to provide further up-to-date information regarding sand ridge geomorphology and quality of surface sands within the target sand ridges.

The bathymetric data obtained by CPE (November 2005) was gridded at high resolution and proved essential in providing better definition of the sand ridges previously identified based on scattered historical data. The new bathymetric data showed prominent ridges in both study areas and emphasized well-defined series of shore-oblique ridges mapped in the nearshore survey area (Figure 11). Substantial sand ridges are also located in the survey area located further offshore. The location and shape of the ridges in the updated bathymetry differed slightly from that identified from interpretation of the NOAA-NOS data. The surface sediment samples confirmed that these ridges contained beach quality sand in surface layers and that future survey efforts in these areas are warranted.

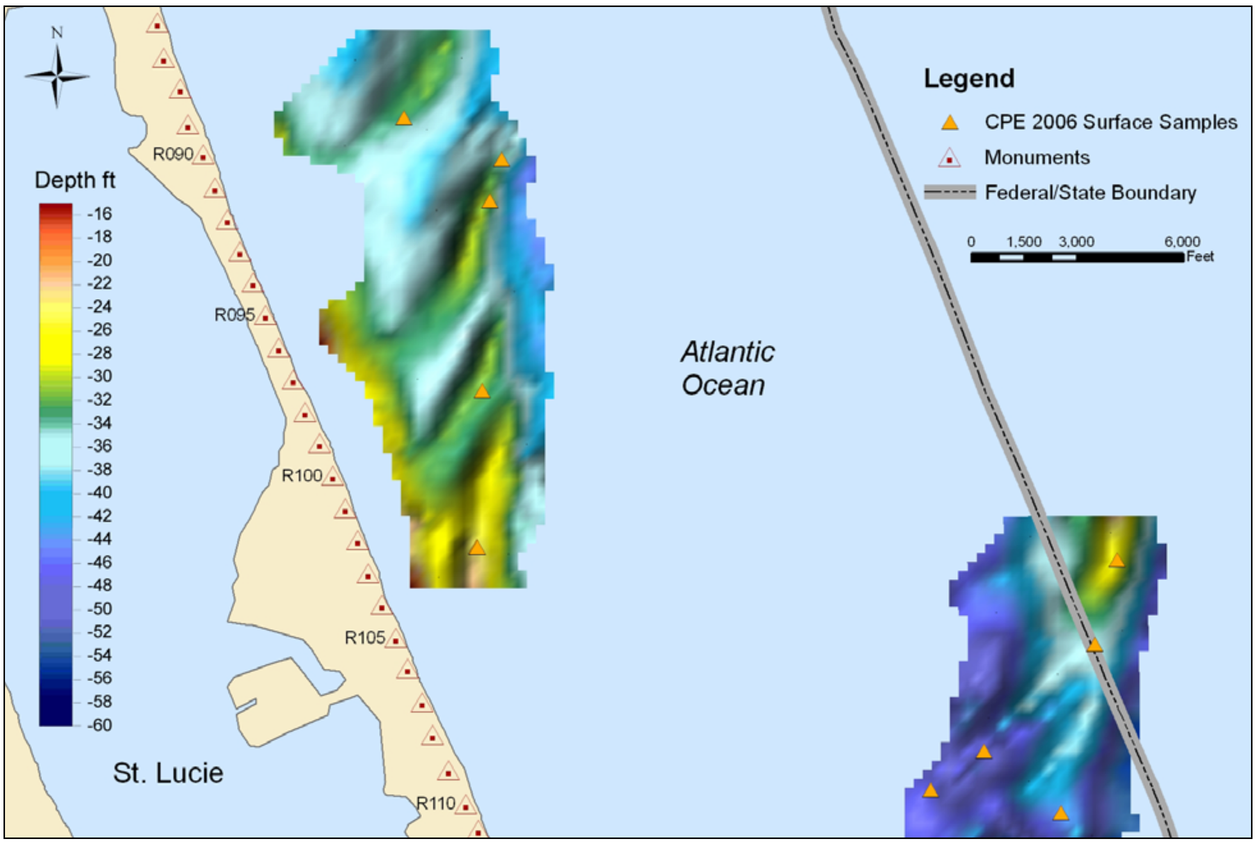


Figure 11. Three-dimensional bathymetric model created from updated bathymetry obtained by CPE and location of surface sand samples.

Jet Probes

Jet probes were obtained from January 31 to February 18, 2006 (high waves occurred in the middle of the survey and prohibited offshore work for about 10 days). Twenty-six jet probes were acquired in the two selected areas to investigate sediment thickness on the selected ridges and subsurface sediment texture. Three samples were analyzed per jet probe (bottom, mid, top) and the diver also noted bed resistance to penetration and turbidity generated by probing (as an indication of percent of fines). Most jet probes penetrated more than 15 ft into the sediment layers and contained grain sizes generally ranging from 0.3 mm to 0.7 mm (most commonly occurring grain size class) with little fines and some shell fragments. Some jet probes obtained on the base of lower relief ridges contained coarser grains (> 0.7 mm) and generally showed less sediment thickness (see Figure 12 for location of jet probes with coarser grained sand). The jet probes overlaid on the CPE high-resolution bathymetry are shown in Figure 12. Jet probes in Figure 12 were classified exclusively on grain size ranges (green indicates grain size from 0.3 mm to 0.7 mm and red indicates grain sizes > 0. 7 mm).

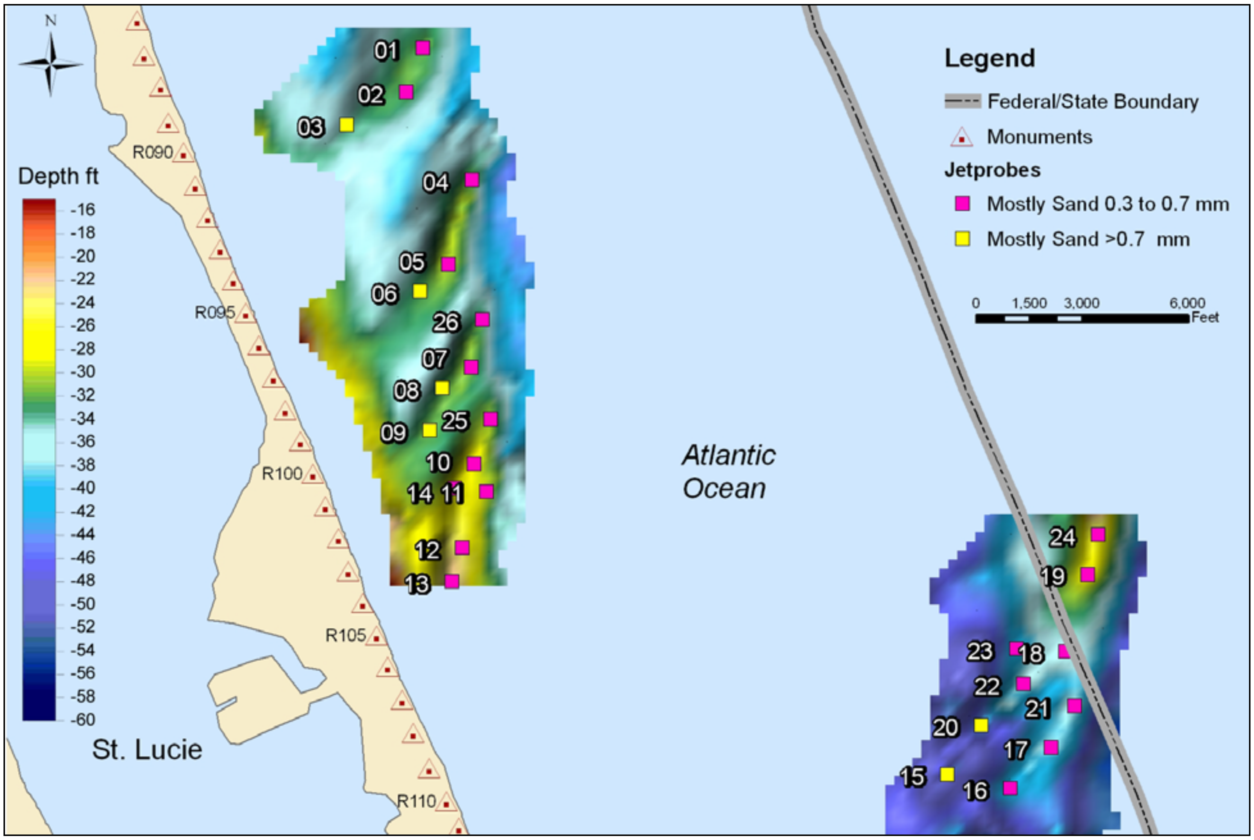


Figure 12. Location of CPE jet probes on top of bathymetric image. Jet probes are classified based on grain size intervals indicated in the legend.

Detailed Geotechnical and Geophysical Investigations

Geophysical surveys were conducted in April 2006 and consisted of seismic, sidescan and magnetometer investigations (see Figure 13 for geophysical tracklines). Vibracores were obtained in June 2006 after processing and analysis of seismic data. Vibracores followed the preliminary analysis of seismic results because the interpretation of seismic records allowed for optimized selection of vibracore locations. After the vibracores were selected and analyzed, the seismic records were re-interpreted and the different seismic reflectors were correlated with vibracore layer boundaries. High-resolution seismic data, calibrated to vibracores, was then used to interpolate sediment thickness between wider spaced cores. Examples of seismic cross-sections for one selected location in the nearshore and offshore areas are shown in Figure 14. Locations of the seismic cross-sections shown are indicated in Figure 13.

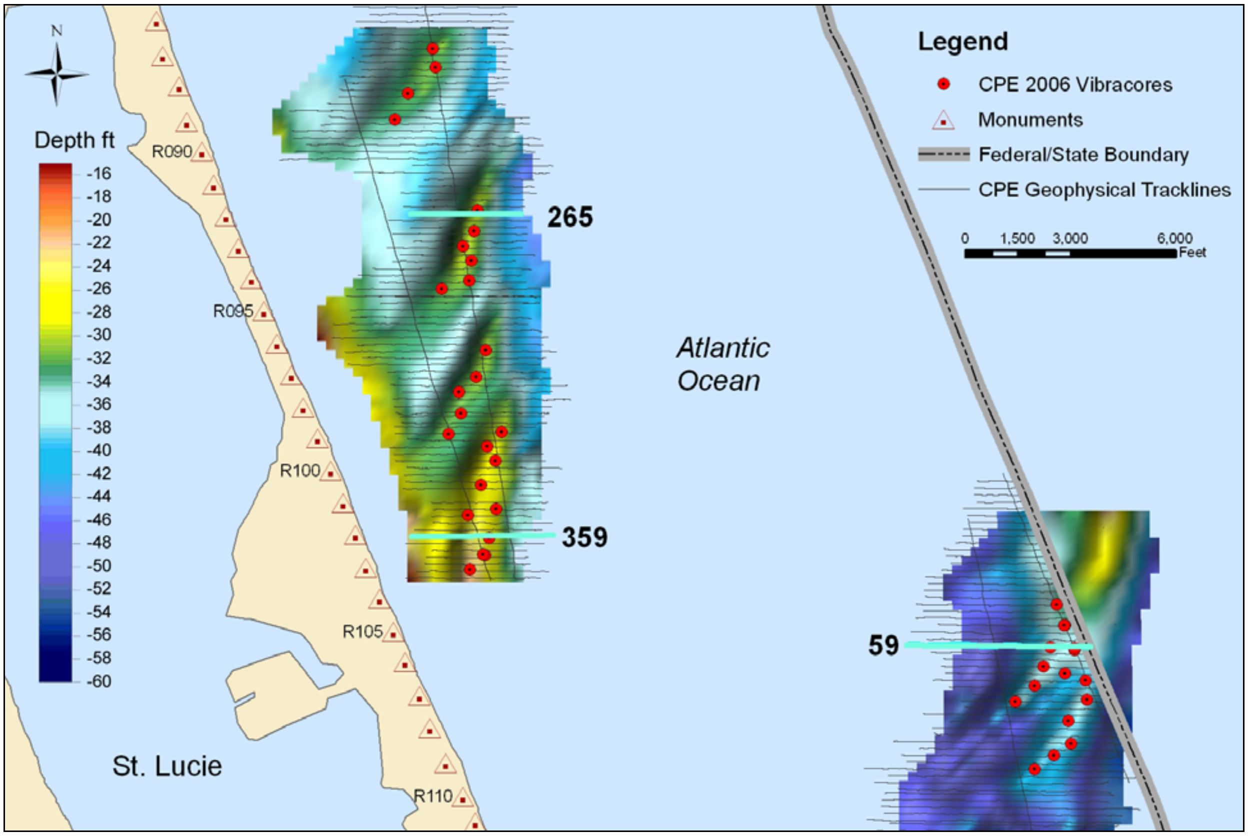


Figure 13. Location of seismic tracklines, vibracores and selected seismic cross-sections shown in Figures 9 and 10. Cross-sectional seismic profiles for the highlighted blue tracklines are shown in Figure 14.

Forty vibracores were obtained from the two study areas, 24 in the nearshore area and 16 in the offshore location (Figure 13). In the nearshore area, the vibracores indicate that the upper 6 to 12 ft of the sand ridge thickest segments contain clean (moderately to moderately well sorted) fine to medium sand generally ranging from 0.3 mm to 0.6 mm (most commonly occurring grain size classes) with low silt percentage (less than 5%) and shell content ranging from 1% to 5%. Bottom sediment layers become gradually poorly to very poorly sorted and contain mixtures of sandy-silty-clayey sediments with high shell content (shell hash, shell fragment, whole shells and some rock fragments). The location of the vibracores in the nearshore area is shown in Figure 15. A cross-section of the thickest sand ridge (second one from north to south) showing vertical sequencing of sediment layers is shown in Figure 16.

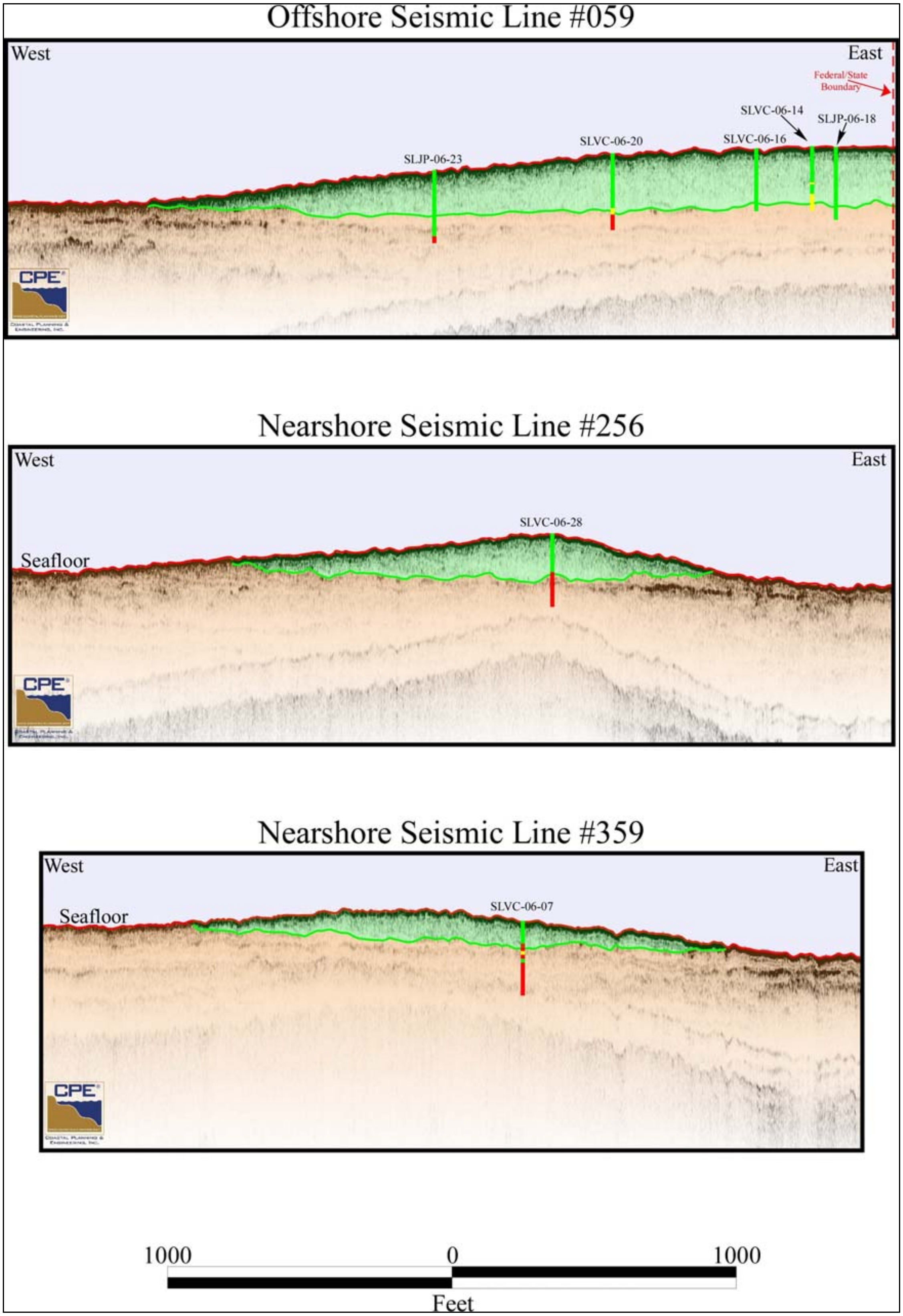


Figure 14. Seismic images showing correlation between seismic reflectors and vibracores layers. The thickness of the clean sand deposits correlate with sand ridge relief, but deposit thickness decreases away from ridge crests. The location of the seismic lines in plan view is shown in Figure 13.

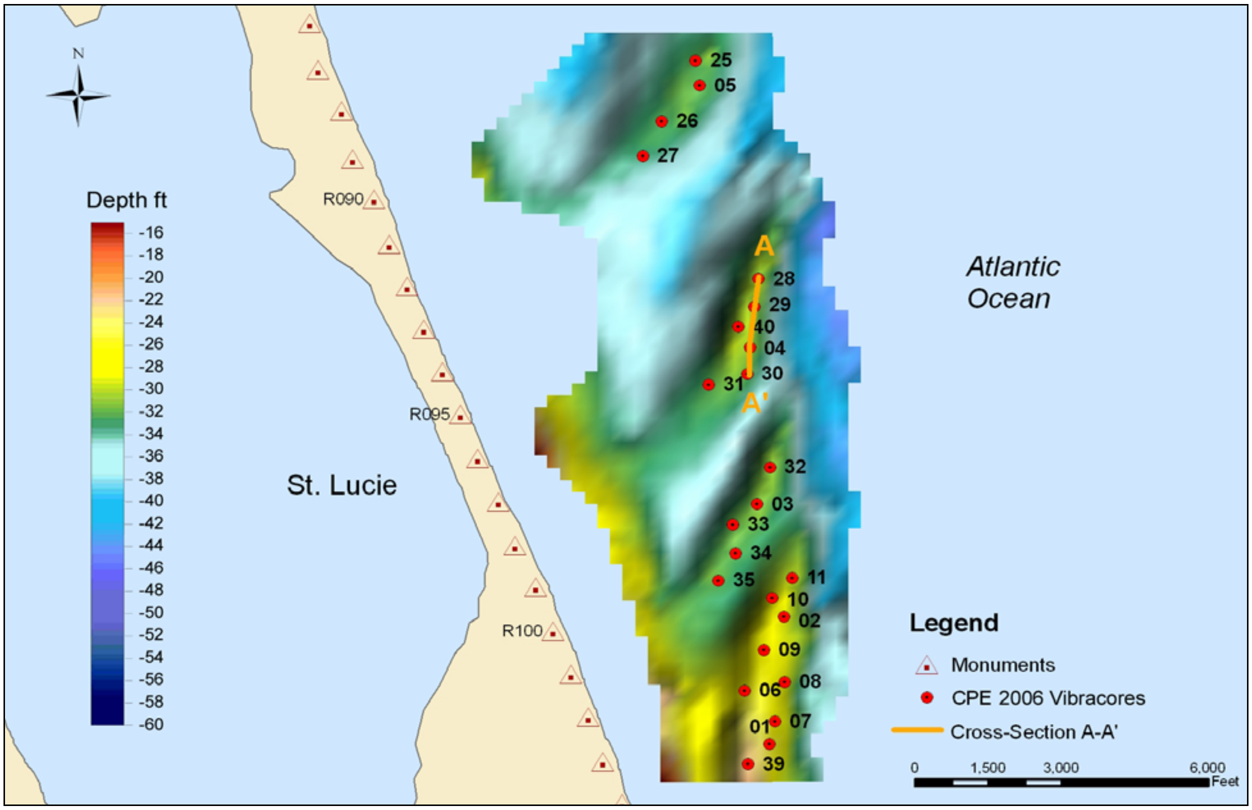


Figure 15. Zoom view of the nearshore study area showing vibracores and location of vibracore cross-section A-A' (Figure 16).

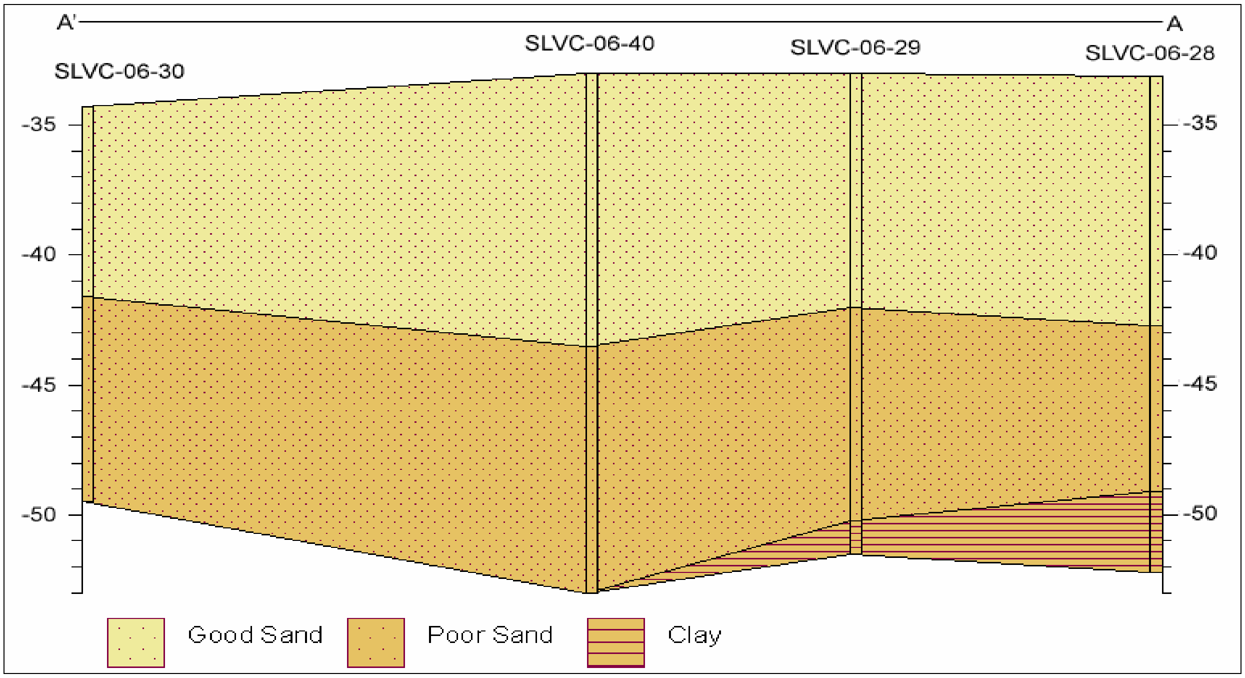


Figure 16. Schematic cross section based on interpretation of vibracore data (see Figure 15 for cross-section location). Sediments in the vibracores were divided into three main categories: (1) good sand, (2) poor sand and (3) clay. The "good sand" layer contains clean sandy sediments (fine to medium sand less than 5% silt, generally less than 5% shell, moderately to moderately well sorted). "Poor sands" are those sandy layers mixed with more than 5% fines (silt or clay) and shell/rock fragments. The clay contains clay-sized particles.

All sixteen (16) vibracores in the offshore study area penetrated at least 15 ft into the seabed. The offshore cores generally exhibit a fining downward (coarsening upward) sequence. Clean (moderately to moderately well sorted) sands occur in the upper 10 to 14 ft of the cores. Textural characteristics for most of the samples obtained within the clean sand layer include a mean grain size generally ranging from 0.3 mm to 0.7 mm (most commonly occurring grain size classes), low silt content (less than 5%) and low shell content. Similar to the nearshore area, bottom sediment layers (mostly between 15 ft and 20 ft deep into the vibracores) become gradually poorly to very poorly sorted and contain mixtures of sandy-silty-clayey sediments with shell fragments/shell hash and scattered rock fragments. The location of the vibracores on the offshore area is shown in Figure 17. A cross-section of the northern ridge in this study area (drawn in a NE-SW orientation), shows the vertical sequence of sediment layers (Figure 18).

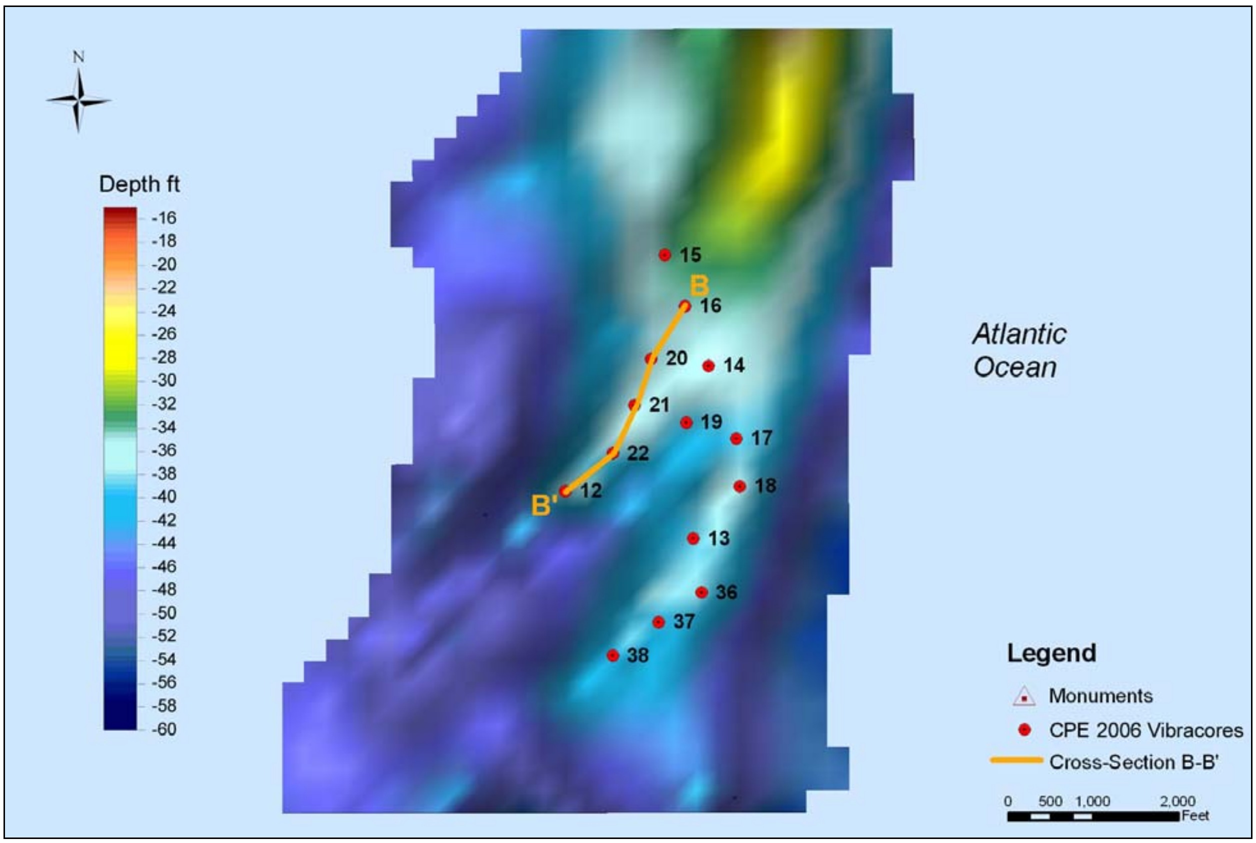


Figure 17. Zoom view of the offshore study area showing vibracores and location of vibracore cross-section B-B' (Figure 18).

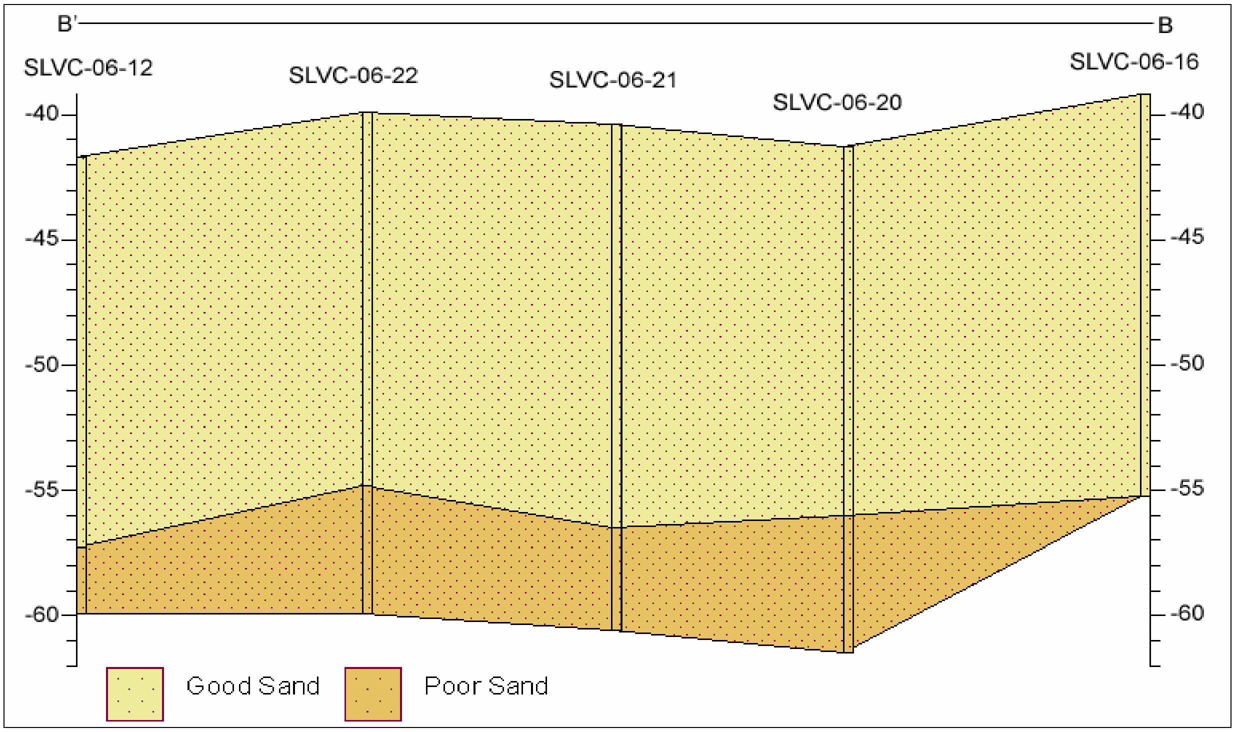


Figure 18. Schematic cross section based on interpretation of vibracore data (see Figure 17 for location). Sediments in the vibracores were divided into two main categories: (1) good sand, (2) poor sand, and (3) clay. The "good sand" layer contains clean sandy sediments (fine to medium sand less than 5% silt, generally less than 5% shell, moderately to moderately well sorted). "Poor sands" contain sandy layers mixed with more than 5% fines (silt or clay) and shell/rock fragments.

Sediment Thickness and Volumes

Sediment volumes and textural properties (composites) were calculated for each of the sand ridges investigated. An isopach map that shows sediment thickness in each ridge was created by calculating the difference between seabed elevations (bathymetry) and the base of the clean sand layer. The clean sand layer was defined as the upper sediment layer of the sand ridges that contained moderately to moderately well sorted quartz sand with grain sizes generally ranging from 0.3 mm to 0.7 mm and less than 5% silt. Elevations of the base of the clean sand layer were obtained from interpretation of the high-resolution seismic records calibrated to the vibracore data. Isopach maps of the nearshore and offshore study areas are shown in Figures 19, 20 and 21.

Thickness of the clean sand layer ranges from 4 to 16 ft in the nearshore sand ridges (Figures 19 and 20). Nearshore sand sources 1 and 3 contain the thickest clean sand layers with the ridge crest 8 to 16 ft thick and side slopes about 4 to 6 ft thick. Nearshore sand sources 2 and 4 contains ridge crests 6 to 8 ft thick and side slopes about 4 ft thick (Figures 19 and 20). Sand thickness, as expected, decreases towards side slopes and the ridge base.

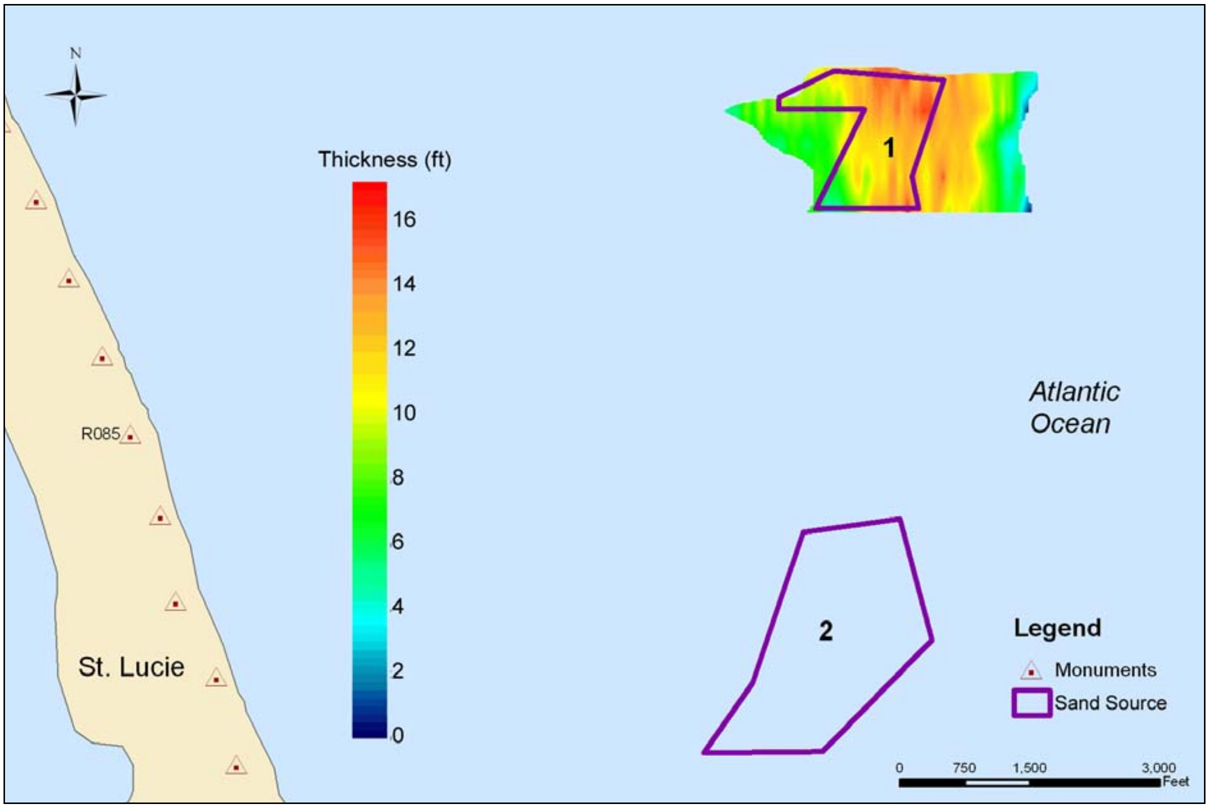


Figure 19. Isopach of nearshore Sand source 1 and sand source layout. Sediment thickness is greater at the ridge crest and diminishes with distance from the crest (to the east and west).

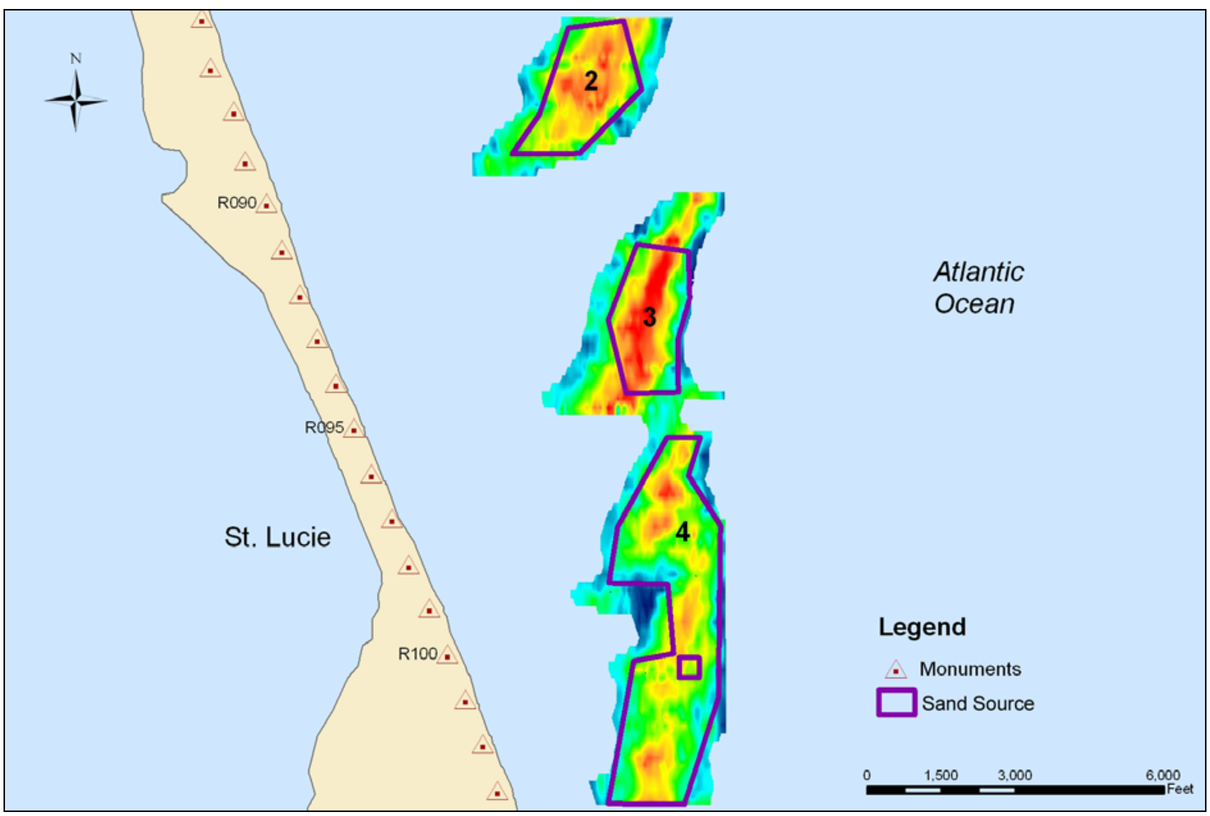


Figure 20. Sediment thickness (isopach map) for Sand sources 2, 3 and 4.

Orientation of the thicker sediment packages range from shore parallel (southern ridges) to shore-oblique (northern ridges). Four sand sources were defined in the nearshore study area (Figures 19 and 20). Sand volumes were computed based on sediment thicknesses shown in the isopachous maps, minus a 1 ft safety buffer between the clean sand layer and underlying poor sand layers (sand, silt, clay, shell and rock fragments). These nearshore sand sources combined contain an estimated 4.2 million cy of clean sandy sediments. A breakdown of the volume per sand source is shown in Table 1.

Thicker clean sand layers occur in the offshore study area (sand source 5) in relation to the nearshore area. In the offshore study area, clean sand thickness ranges from 4 to 20 ft, thicknesses generally increase to the E-NE and reach a maximum near State-Federal water boundaries (Figure 21). Sediment thickness increases seaward (to the east) because large high-relief ridges are located further offshore (seaward of the State-Federal boundary) and the seaward edge of the study area includes the tip of these large offshore ridge systems (see Figures 1 and 10 for regional view of the bathymetry). Thicker sands in offshore study areas occur in two segments, one shore-parallel zone near the State-Federal water boundary with clean sand thickness ranging from 16 to 20 ft and a shore-oblique ridge on the southern segment of the study area containing clean sands 6 to 16 ft thick.

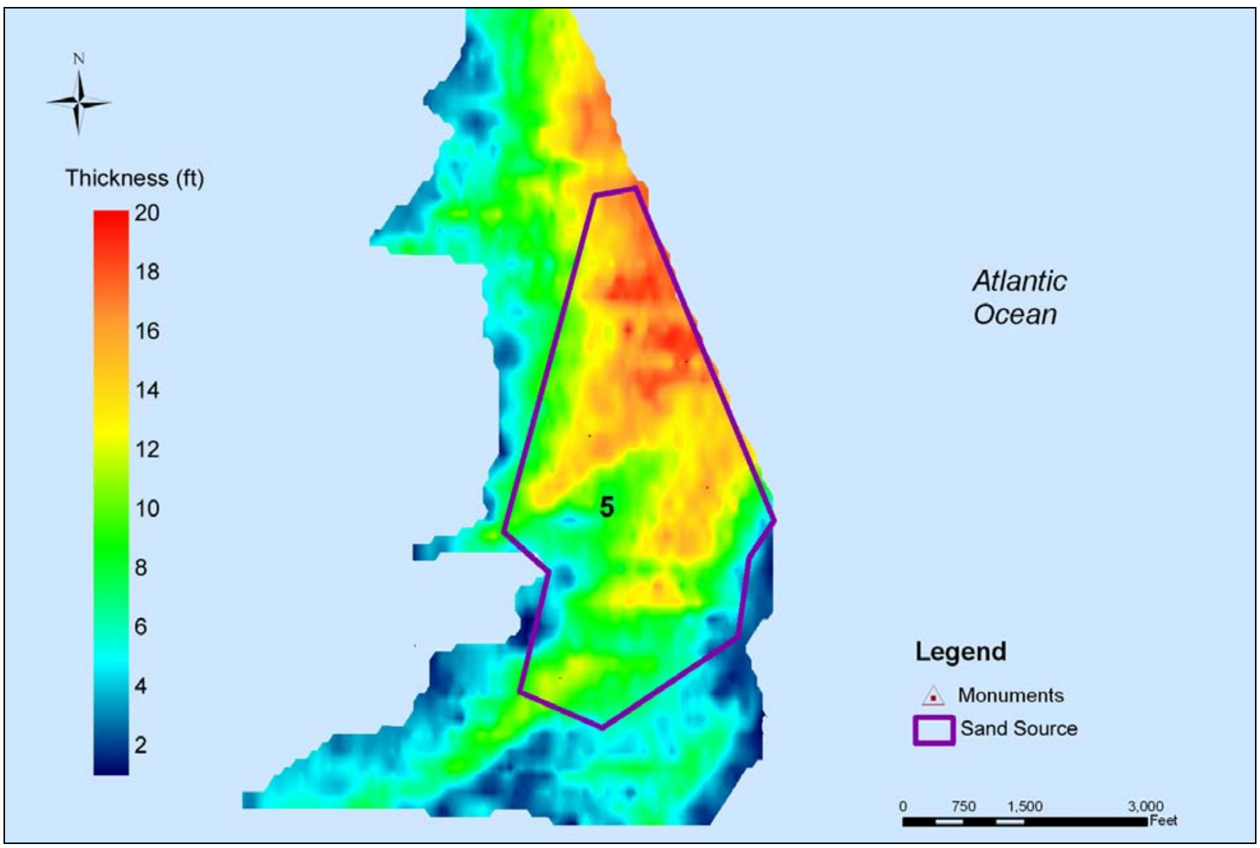


Figure 21. Sediment isopachs for the offshore sand source. Sediment thickness increases to the NE, towards the main ridge crest. This study area is the terminus (W-SW corner) of a very large sediment ridge that lies seaward of the study area (to the E-NE) (see Figure 10). Only the corner of the ridge was surveyed because the seaward section lies in Federal waters under MMS jurisdiction. It is anticipated, however, that the seaward continuation of this sand body represents a significant sand reserve for future renourishments in St. Lucie County.

One large sand source that combines these two segments was defined in the offshore study area (Figure 21). Sand volumes were computed using the sediment thickness shown in the isopach (Figure 21) minus a 1 ft buffer that was added between the clean sand layer and underlying poor sand layers (sand, silt, clay, shell, and rock fragments). Sand source 5 contains about 5.1 million cy of clean sandy sediments. A breakdown of the volume per sand source is shown in Table 1.

Sub-samples obtained from the 40 vibracores available for five sand sources were used to calculate sand source composite characteristics. Data from sieve analysis (see tables/gradation and curves/histograms analysis reports) and vibracore logs are presented in the report appendices. Composite mean grain size, percent silt, and sorting were computed for each vibracore by calculating the weighted average (average of each sample weighted by the length of core represented) (see the appendices for composite information). The composite mean grain size, percent silt and sorting for the entire sand source were computed by averaging the weighted results for all cores within the limits of the sand source. Sand source composite grain size ranged from 0.39 mm to 0.47 mm (nearshore sand sources) and 0.44 mm for the offshore sand source. Silt percentage was less than 3.5% in all sand sources. Summary of results (composites values), for each sand source, are summarized in Table 1.

A native beach composite was calculated based on a weighted average of 16 samples collected in two profile lines (R-93 and R-96) above the mean low water line. The sample locations were intentionally selected to lie outside the area of influence of the South County Restoration Project constructed after the 2004 Hurricanes (Jeanne and Frances). This data indicated that the native beach above the mean low water line (subaerial beach) contains a mean grain size of 0.42 mm, 0.82% silt and 1.09 sorting (poorly sorted sediments). These values are similar with the sand source composite values suggesting a high level of compatibility between beach and sand source sediments.

Table 1. Sediment volumes on potential sand sources.

Area	**Location**	**Mean grain size (mm)**	**Percent silt (%)**	**Sorting**	**Volume (cy)**
SS 1	Nearshore	0.39	3.14	1.21	919,940
SS 2	Nearshore	0.47	2.43	1.26	915,550
SS 3	Nearshore	0.42	3.25	1.33	1,752,750
SS 4	Nearshore	0.43	2.27	1.30	620,970
SS 5	Offshore	0.44	1.97	1.09	5,118,750
Beach	Subaerial beach	0.42	0.82	1.09	-
Total	-	-	-	-	**9,327,950**

Sidescan and magnetometer investigations were conducted to map potential hardbottom habitats occurring near the sand sources and to investigate the presence of potential magnetic anomalies. The sidescan data showed that there are no hardbottom habitats occurring in the vicinity of the sand sources and no other prominent features that prohibited dredging (Figures 22 and 23). The magnetometer survey showed only one significant magnetometer anomaly occurring within the proposed sand sources (sand source 4). A 200 ft buffer was created around the magnetic anomaly and the buffered area was excluded from sand source volume calculations.

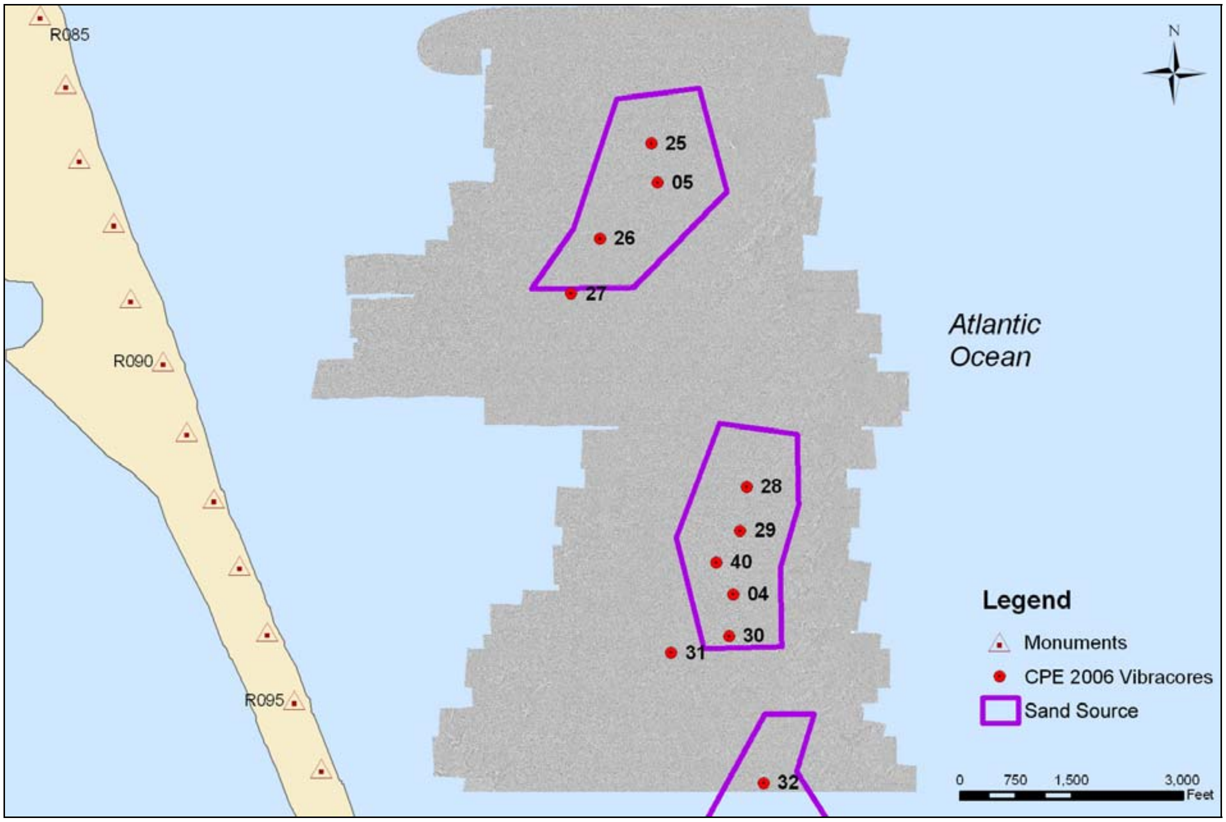


Figure 22. Geo-referenced sidescan mosaic, nearshore study area

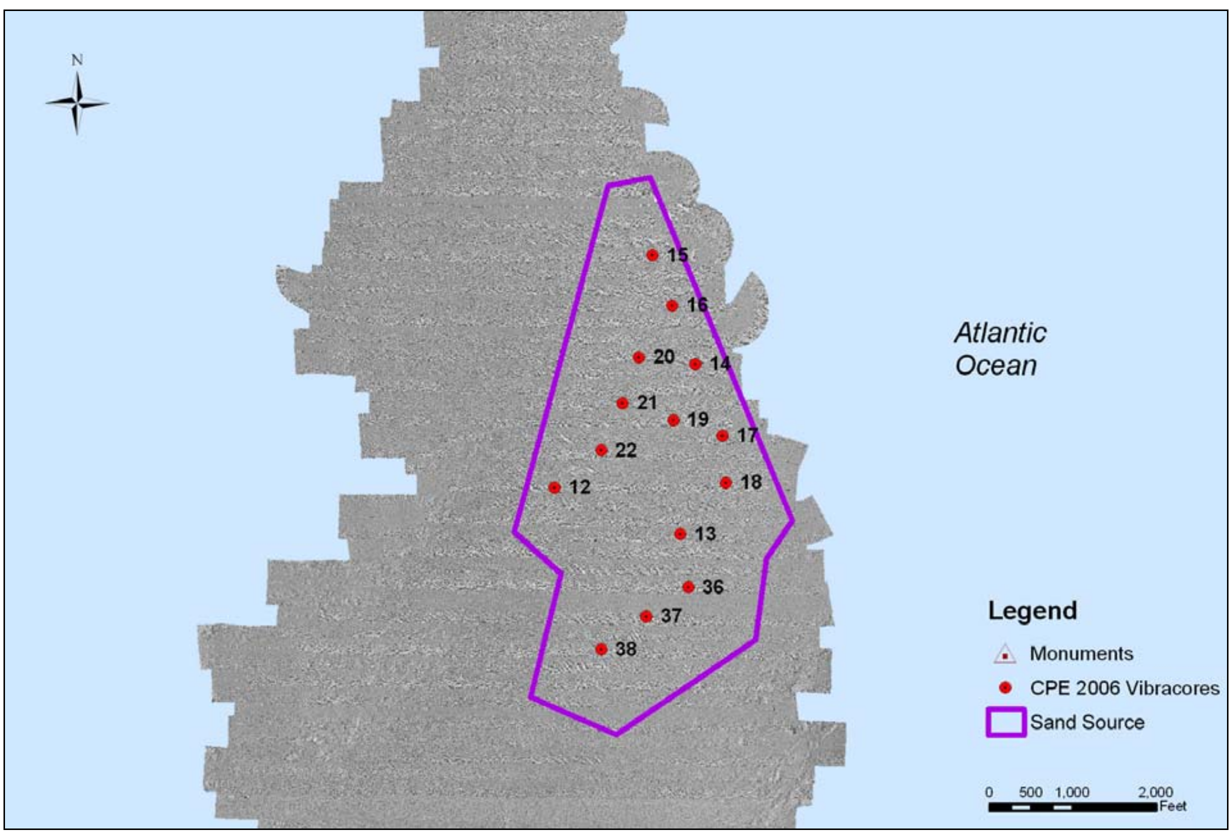


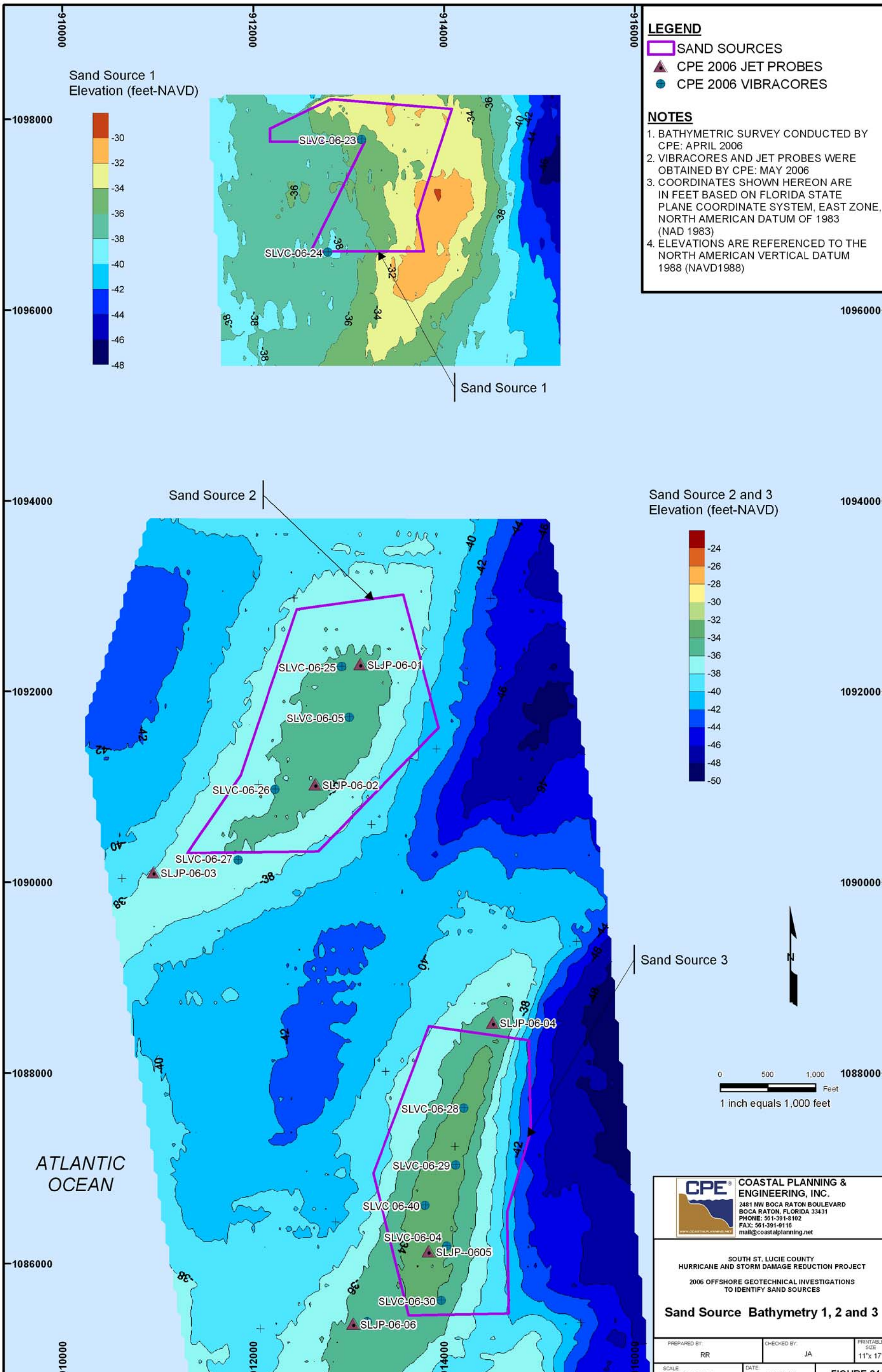
Figure 23. Geo-referenced sidescan mosaic of the offshore study area.

Detailed 11 by 17 plots of the sand source with location of vibracores, jet probes and tracklines are shown in Figures 24, 25 and 26.

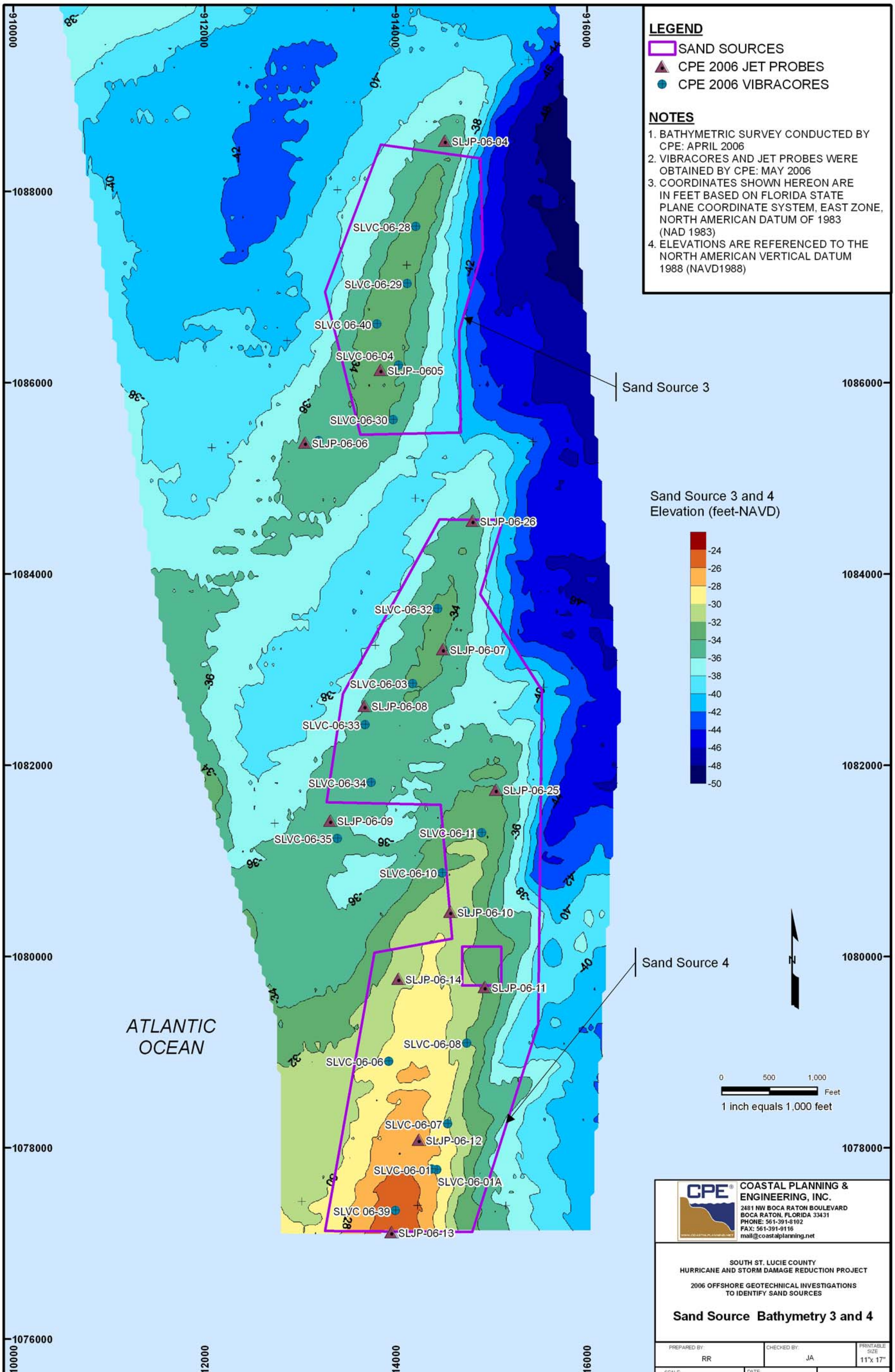
Dredging Feasibility

The five sand sources identified along southern St. Lucie County are located close to the coastline and contain sufficient quantity and quality to construct the proposed South County Beach Restoration Project. Based on sidescan sonar mapping, there are no sensitive environmental habitats adjacent to the sand source areas that would restrict dredging feasibility or permitability. Extensive nearshore hardbottom areas exist along most of the fill area. Pipeline corridors will need to be identified along gaps in the nearshore hardbottom to avoid environmental impacts during construction. This will require environmental field investigations and assessment when the final sand sources are designed.

Dredging cost is directly related to the pumping distance between the sand source and the beach fill location. Sand sources 1, 2, 3 and 4 are an average of 0.5 to 1.5 miles east of the shoreline. Sand from these sources could be dredged with a cutterhead dredge at an approximate cost of $4 to $6/CY. Sand source 5 is located between 2 and 3 miles offshore. This distance makes it impractical for smaller pipeline dredges, yet constructible for larger pipeline dredges or hopper dredges. If a hopper dredge is utilized for this sand source, the approximate cost would be $6 to $8/CY.



LEGEND
SAND SOURCES
CPE 2006 JET PROBES
CPE 2006 VIBRACORES
NOTES
1. BATHYMETRIC SURVEY CONDUCTED BY CPE: APRIL 2006
2. VIBRACORES AND JET PROBES WERE OBTAINED BY CPE: MAY 2006
3. COORDINATES SHOWN HEREON ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, EAST ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 1983)
4. ELEVATIONS ARE REFERENCED TO THE NORTH AMERICAN VERTICAL DATUM 1988 (NAVD1988)
Sand Source 1
Elevation (feet-NAVD)
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
Sand Source 2 and 3
Elevation (feet-NAVD)
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
910000
912000
914000
916000
1098000
1096000
1094000
1092000
1090000
1088000
1086000
SLVC-06-23
SLVC-06-24
Sand Source 1
Sand Source 2
SLVC-06-25
SLJP-06-01
SLVC-06-05
SLVC-06-26
SLJP-06-02
SLVC-06-27
SLJP-06-03
Sand Source 3
SLJP-06-04
SLVC-06-28
SLVC-06-29
SLVC 06-40
SLVC-06-04
SLJP--0605
SLVC-06-30
SLJP-06-06
ATLANTIC OCEAN
N
0
500
1,000
Feet
1 inch equals 1,000 feet
CPE
COASTAL PLANNING & ENGINEERING, INC.
2481 NW BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
PHONE: 561-391-8102
FAX: 561-391-9116
mail@coastalplanning.net
SOUTH ST. LUCIE COUNTY
HURRICANE AND STORM DAMAGE REDUCTION PROJECT
2006 OFFSHORE GEOTECHNICAL INVESTIGATIONS
TO IDENTIFY SAND SOURCES
Sand Source Bathymetry 1, 2 and 3
PREPARED BY:
RR
CHECKED BY:
JA
PRINTABLE SIZE
11"x 17"
SCALE:
AS SHOWN
DATE:
09/28/06
FIGURE 24



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SAND SOURCES
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4. ELEVATIONS ARE REFERENCED TO THE NORTH AMERICAN VERTICAL DATUM 1988 (NAVD1988)
Sand Source 3
Sand Source 4
Sand Source 3 and 4
Elevation (feet-NAVD)
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
ATLANTIC
OCEAN
SLJP-06-04
SLVC-06-28
SLVC-06-29
SLVC 06-40
SLVC-06-04
SLJP--0605
SLVC-06-30
SLJP-06-06
SLJP-06-26
SLVC-06-32
SLJP-06-07
SLVC-06-03
SLJP-06-08
SLVC-06-33
SLVC-06-34
SLJP-06-25
SLJP-06-09
SLVC-06-35
SLVC-06-11
SLVC-06-10
SLJP-06-10
SLJP-06-14
SLJP-06-11
SLVC-06-08
SLVC-06-06
SLVC-06-07
SLJP-06-12
SLVC-06-01
SLVC-06-01A
SLVC 06-39
SLJP-06-13
910000
912000
914000
916000
1088000
1086000
1084000
1082000
1080000
1078000
1076000
N
0
500
1,000
Feet
1 inch equals 1,000 feet
CPE
COASTAL PLANNING & ENGINEERING, INC.
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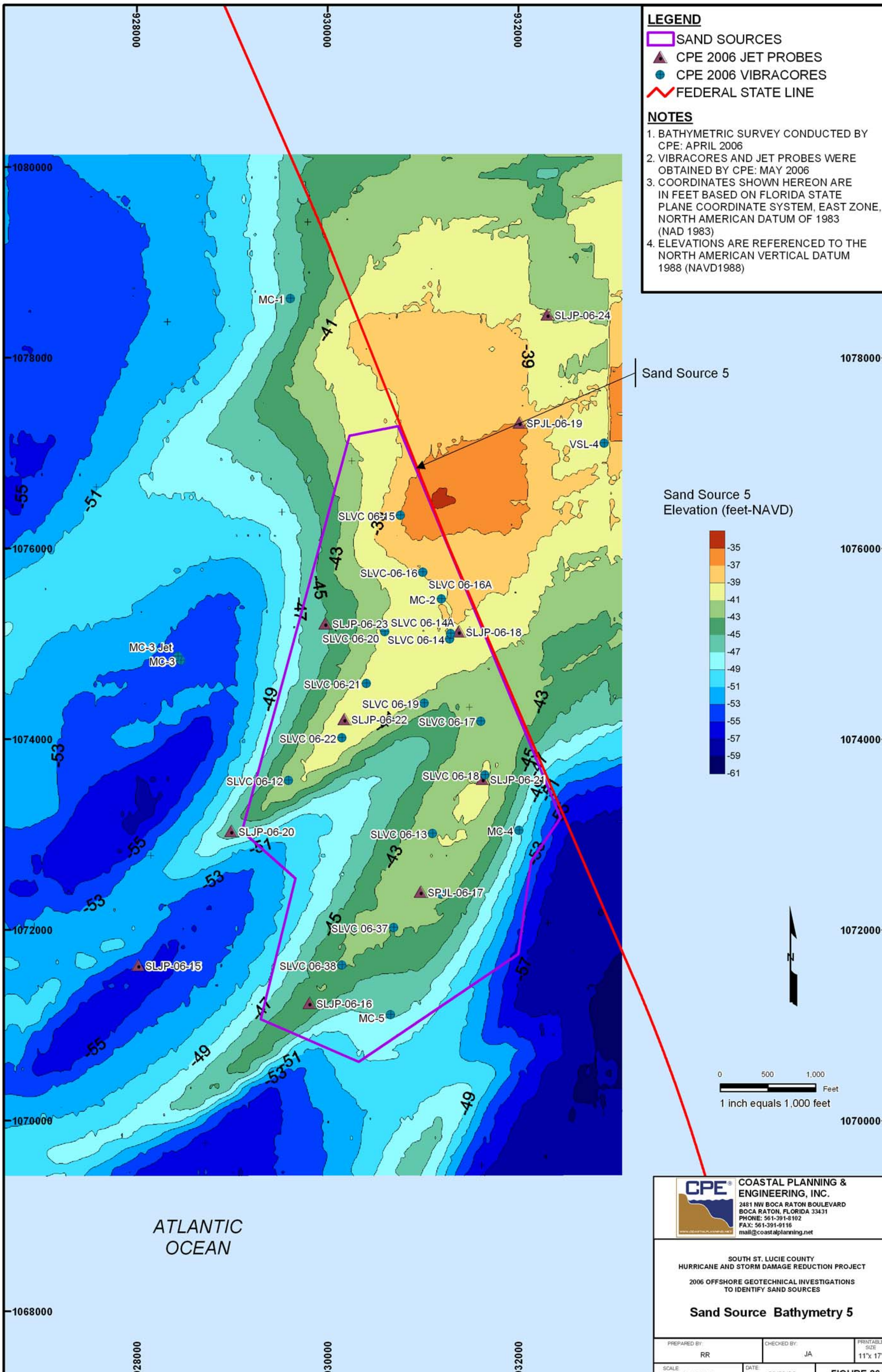
SOUTH ST. LUCIE COUNTY
HURRICANE AND STORM DAMAGE REDUCTION PROJECT
2006 OFFSHORE GEOTECHNICAL INVESTIGATIONS
TO IDENTIFY SAND SOURCES
Sand Source Bathymetry 3 and 4
PREPARED BY: RR
CHECKED BY: JA
PRINTABLE SIZE 11"x 17"
SCALE: AS SHOWN
DATE: 09/28/06
FIGURE 25


LEGEND
SAND SOURCES
CPE 2006 JET PROBES
CPE 2006 VIBRACORES
FEDERAL STATE LINE
NOTES
1. BATHYMETRIC SURVEY CONDUCTED BY CPE: APRIL 2006
2. VIBRACORES AND JET PROBES WERE OBTAINED BY CPE: MAY 2006
3. COORDINATES SHOWN HEREON ARE IN FEET BASED ON FLORIDA STATE PLANE COORDINATE SYSTEM, EAST ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 1983)
4. ELEVATIONS ARE REFERENCED TO THE NORTH AMERICAN VERTICAL DATUM 1988 (NAVD1988)
928000
930000
932000
1080000
1078000
1076000
1074000
1072000
1070000
1068000
Sand Source 5
Sand Source 5 Elevation (feet-NAVD)
-35
-37
-39
-41
-43
-45
-47
-49
-51
-53
-55
-57
-59
-61
MC-1
SLJP-06-24
SPJL-06-19
VSL-4
SLVC 06-15
SLVC-06-16
SLVC 06-16A
MC-2
SLJP-06-23
SLVC 06-14A
SLJP-06-18
SLVC 06-20
SLVC 06-14
MC-3 Jet
MC-3
SLVC 06-21
SLVC 06-19
SLJP-06-22
SLVC 06-17
SLVC 06-22
SLVC 06-12
SLVC 06-18
SLJP-06-21
SLJP-06-20
SLVC 06-13
MC-4
SPJL-06-17
SLVC 06-37
SLJP-06-15
SLVC 06-38
SLJP-06-16
MC-5
ATLANTIC OCEAN
N
0 500 1,000 Feet
1 inch equals 1,000 feet
CPE
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HURRICANE AND STORM DAMAGE REDUCTION PROJECT
2006 OFFSHORE GEOTECHNICAL INVESTIGATIONS TO IDENTIFY SAND SOURCES
Sand Source Bathymetry 5
PREPARED BY: RR
CHECKED BY: JA
PRINTABLE SIZE 11"x 17"
SCALE: AS SHOWN
DATE: 09/28/06
FIGURE 26

CONCLUSIONS AND RECOMMENDATIONS

A comprehensive multi-phased marine sand search was conducted offshore of southern St. Lucie County to locate sand resources for a beach restoration project. The marine sand search utilized legacy data and knowledge, reconnaissance field surveys, and detailed geotechnical and high-resolution geophysical investigations to define five potential sand sources. The five sand sources defined in this study contain an estimated 9.3 million cy of clean sandy sediments (less than 5% silt, little shell content and grain size range from 0.3 to 0.7 mm). The total sand volume identified in these investigations is enough to meet the needs of the initial restoration project and several future renourishments. The data suggests that a similar volume of sand exists in the area immediately north of Sand source 5 in Federal waters. The five sand sources need to be further refined during future final design phases (definition of dredging cuts) in order to provide sands that meet engineering design specifications for desired project performance. Sidescan and preliminary magnetometer investigations indicated that there are no features that prohibit dredging within the proposed sand sources.

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