TOPSAIL BEACH, NORTH CAROLINA: MARINE SAND SEARCH INVESTIGATIONS TO LOCATE SAND SOURCES FOR BEACH NOURISHMENT

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Town of Topsail Beach

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Abstract

To meet the needs of the Interim (Emergency) Beach Nourishment Project, the Town of Topsail Beach authorized Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC) to conduct a marine sand search investigation. Due to the urgent need for fill material, the goal of this investigation was to identify and develop a suitable borrow area as quickly and cost effectively as possible.

The classic CPE-NC three (3) phased approach to sand search investigations was modified for this investigation. During Phase I, borrow areas previously identified by the USACE were reviewed. Historic data indicated that the most promising area was located within USACE Borrow Area A. In order to maintain cost effectiveness and efficiency, the portion of the borrow area located landward of the State/Federal boundary was identified for further investigation. Phase II investigations consisted of a geophysical survey of the area identified during Phase I. In May 2006, joint seismic reflection profiling, sidescan sonar, magnetometer and bathymetric survey were conducted. Phase III investigations consisted of a vibracore survey of a further refined area that was developed using geophysical data collected during Phase II. In October 2006, twenty (20) vibracores were collected. The results of the geophysical and vibracore surveys indicated that the material within Borrow Area A1 had percent silt values in excess of those allowed by the State of North Carolina and in general was too fine to meet the Town's performance goals. A second three phase sand search investigation was initiated by the Town in January 2007.

Vibracore data collected by the USACE was re-examined to determine if the data indicated any additional potential sand resource areas. Based on this review, an area outside of New Topsail Inlet was identified for Phase II investigations. In February 2007, joint seismic reflection profiling, sidescan sonar, magnetometer, and bathymetric surveys of the New Topsail Inlet ebb tidal delta were conducted. Twenty-three (23) vibracores were collected in June/July 2007, from the areas with the highest probability of containing beach quality sand based on the geophysical data. These investigations resulted in the identification of a sand source that was coarse enough to meet the performance goals of the project and to satisfy all State requirements. A Phase III investigation of this area was conducted between October and December 2007. Seismic reflection profiling, sidescan sonar, bathymetric and magnetometer survey data was collected for this survey. The Phase III results were used to refine and further develop the New Topsail Inlet sand source into Borrow Area X.

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INTRODUCTION

To meet the needs of the Interim (Emergency) Beach Nourishment Project, the Town of Topsail Beach authorized Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC) to conduct a marine sand search investigation. Due to the urgent need for fill material, the goal of this investigation was to identify and develop a suitable borrow area as quickly and cost effectively as possible.

The classic CPE-NC three (3) phased approach to sand search investigations was modified for this investigation. Phase I (Historical Data Analysis) consisted of a comprehensive review of the sediment resources located offshore of the Town of Topsail Beach. CPE-NC researched literature stored in public and private archives, focusing on the USACE Draft Integrated General Reevaluation Report (GRR) and Environmental Impact Statement (EIS). This extensive collection of geotechnical and geophysical data was incorporated into a Geographic Information Systems (GIS) geodatabase created for the project area. Historic data indicated that the most promising area was located within USACE Borrow Area A (Figure 1). In order to maintain cost effectiveness and efficiency, the portion of the borrow area located landward of the State/Federal boundary was identified for further investigation (Figure 2). A geophysical survey (sidescan sonar, subbottom profile, magnetometer, and bathymetry) was planned to fill in data gaps between the historic geophysical survey lines and vibracores to identify the area with Borrow Area A with the greatest potential for containing beach compatible sand.

Phase II investigations consisted of geophysical surveys of the area identified during Phase I. In May 2006, a joint seismic reflection profiling, sidescan sonar and bathymetric survey was conducted. Phase III investigations consisted of a vibracore survey of a further refined area that was developed using geophysical data collected during Phase II. In October 2006, twenty (20) vibracores were collected. The results of the geophysical and vibracore surveys were used to refine the investigation area into CPE Borrow Area A1 (Figure 1). No cultural resource survey was required for this Borrow Area because the USACE had already conducted a cultural resource study for Borrow Area A. Grain size statistics were calculated for the material within the borrow area. Results of this analysis indicated that the sand had percent silt values in excess of those allowed by the State of North Carolina and in general was too fine to meet the Town's performance goals. A second three phase sand search investigation was initiated by the Town in January 2007.

Vibracore data collected by the USACE were re-examined during Phase I of the second sand search, in order to locate any additional potential sand resource areas. Based on this review, an area outside of New Topsail Inlet measuring 2.1 miles from the mouth of the Inlet seaward, and 2.2 miles wide (Figure 3) was identified for Phase II investigations. In February 2007, joint seismic reflection profiling, sidescan sonar, magnetometer and bathymetric surveys of this area were conducted (Figure 3). Results of the geophysical investigation were used to delineate the boundary of the CPE sand source area shown in Figure 3.

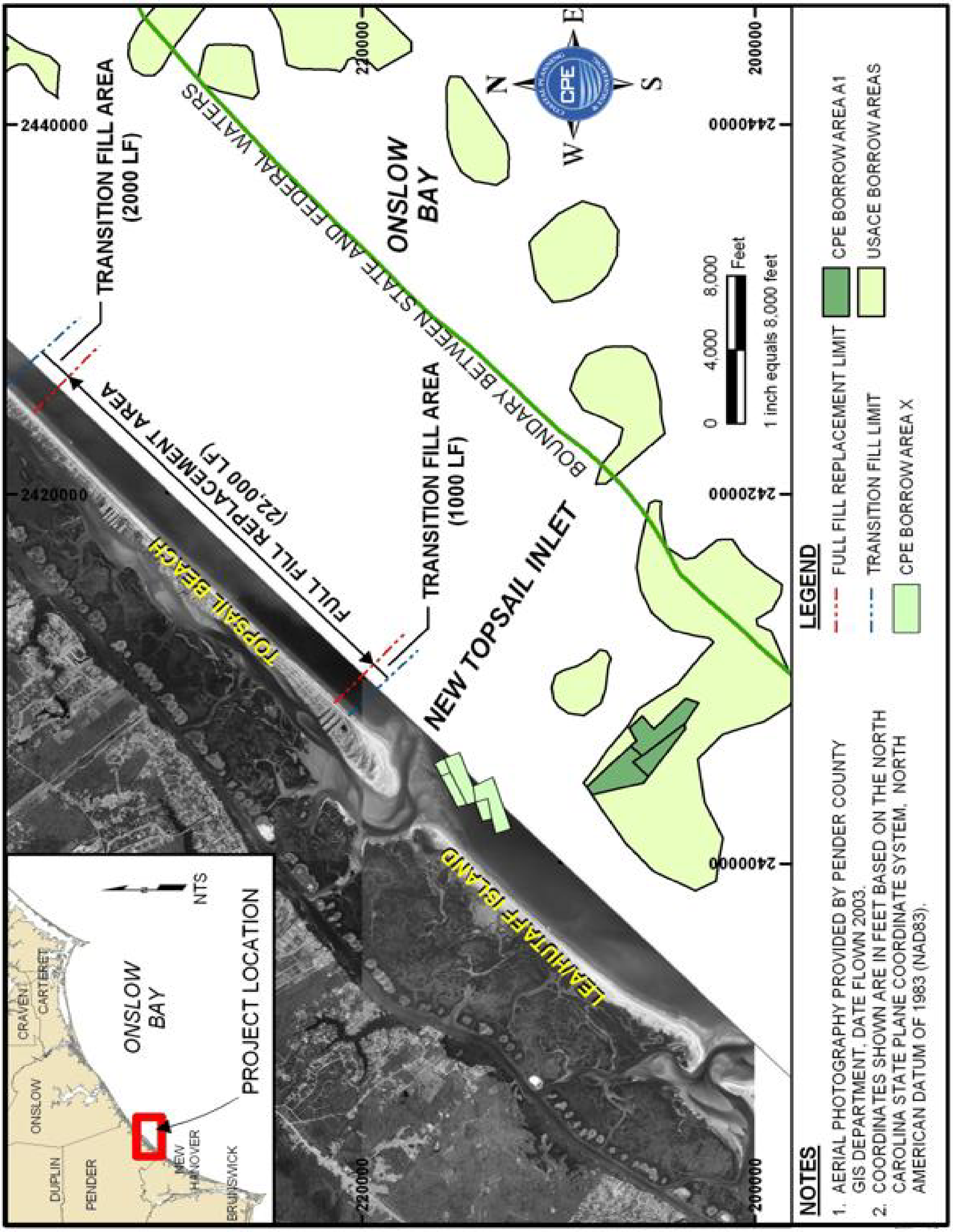

Figure 1. Location map showing the locations of the previously mapped USACE borrow areas in relation to CPE Borrow Areas A1 and X. Note the location of fill placement along Topsail Beach.

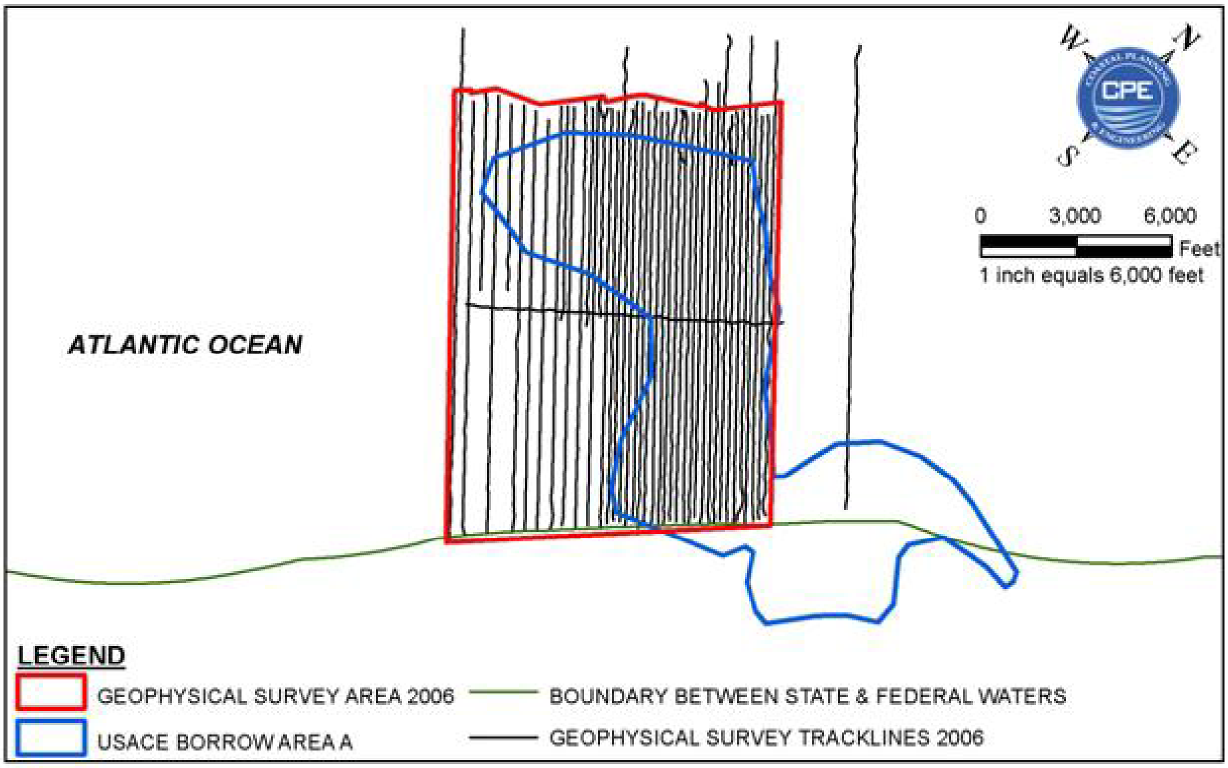

Figure 2. Map showing the area surveyed by CPE-NC within USACE Borrow Area A. Note geophysical tracklines stop at the boundary between State and Federal water. Areas of higher density line spacing indicate of areas with the highest potential for containing beach quality sand.

The Phase III investigations began with a vibracore survey in June/July 2007 during which twenty-three (23) vibracores were collected. The results of the vibracore survey identified a sand source that was coarse enough to meet the performance goals of the project and satisfy all State requirements. The second portion of Phase III was a detailed geophysical and cultural resource survey which was conducted between October and December 2007. Seismic reflection profiling, sidescan sonar, bathymetric and magnetometer survey data was collected for this survey. The Phase III results were used to refine and further develop the New Topsail Inlet sand source into Borrow Area X (Figure 1).

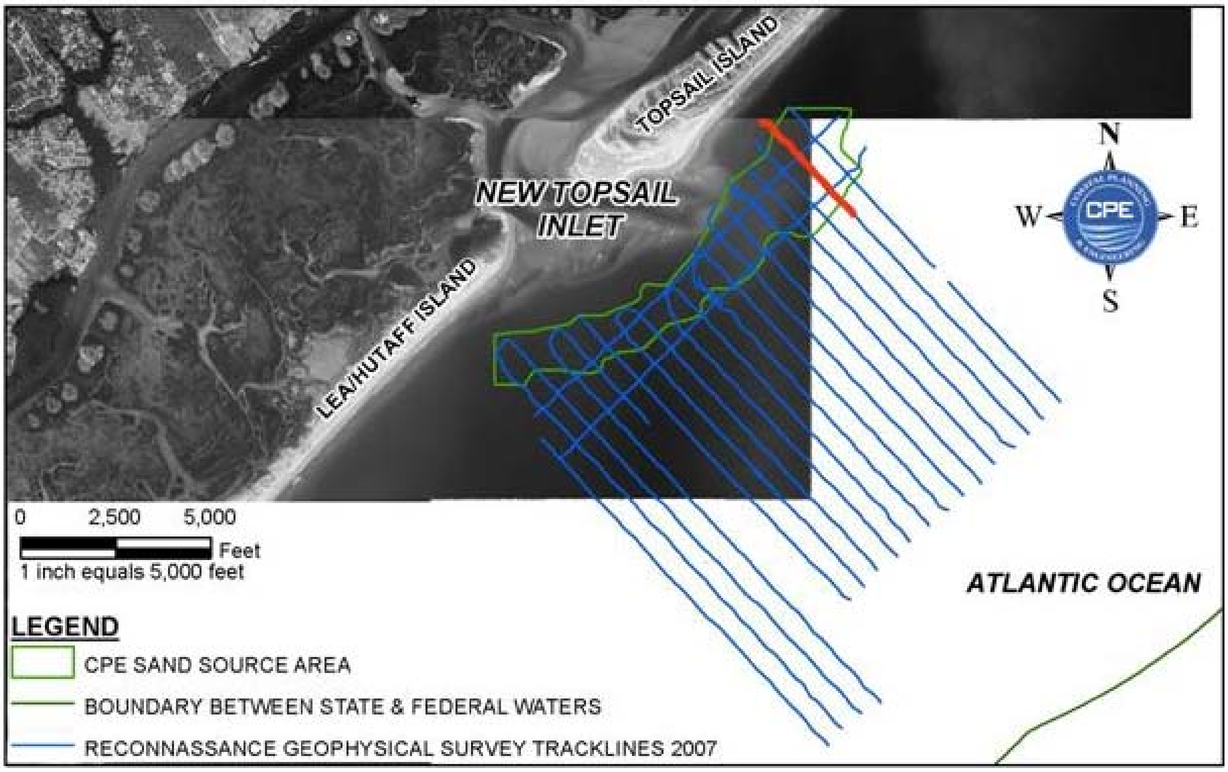

Figure 3. Map showing reconnaissance survey tracklines from the February 2007 geophysical survey. Note highlighted (RED) line showing the location of the seismograph shown in Figure 18.

This report presents the results of the offshore geophysical and geotechnical investigations that led to the identification of two (2) borrow areas designated Borrow Area A1 and Borrow Area X. Geological background is discussed first, followed by a description of field activities, analysis of results from field measurements, and finally definition of the characteristics of the sand resources.

Geographic Location

Topsail Beach is the southernmost of three (3) communities located on Topsail Island in southeastern North Carolina. North Topsail Beach occupies the northernmost end of the island and Surf City occupies the center of the island. The 26-mile long island fronts Onslow Bay and is flanked by two tidal inlets. New River Inlet is located north of the island and New Topsail Inlet is located to the south (Figure 4). New Topsail Inlet separates Topsail Island and Lea/Hutaff Island, an undeveloped barrier island located to the southwest.

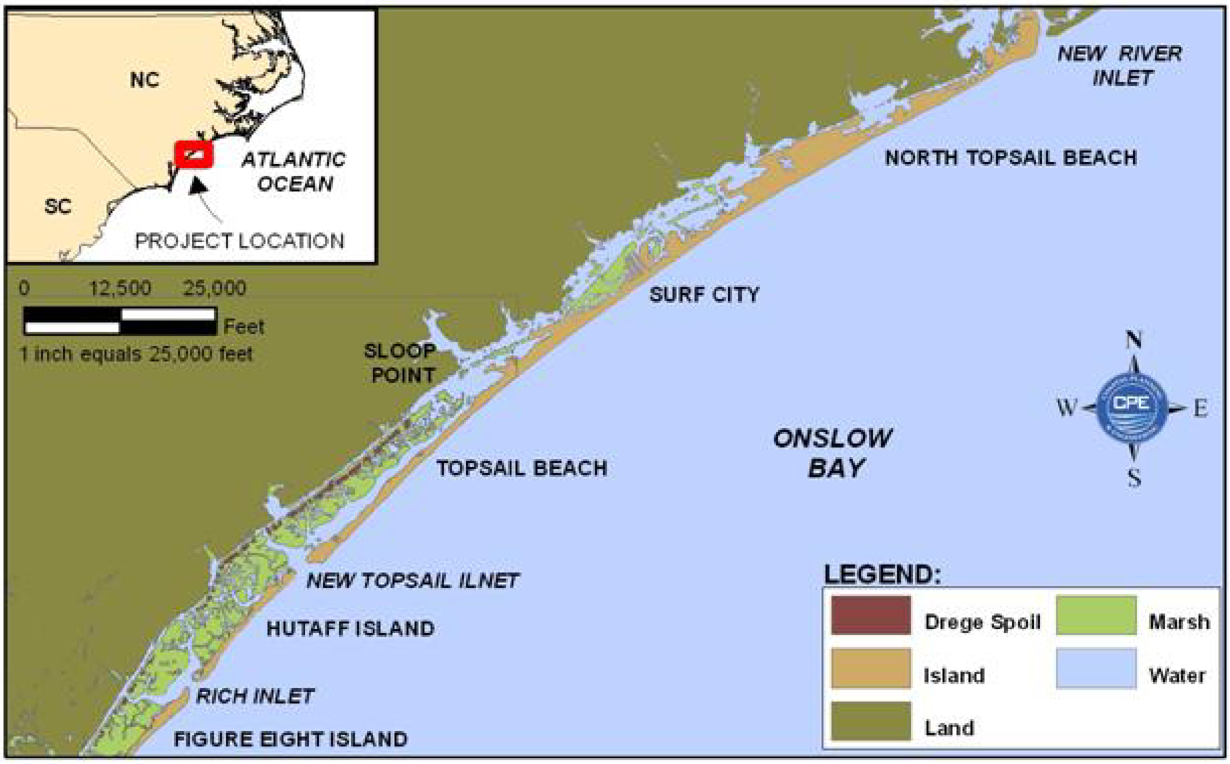

Figure 4. Map showing the location of Topsail Beach.

GEOLOGICAL BACKGROUND

Sidescan sonar data indicates that several distinct zones of seafloor morphology exist within the study area. The northeastern portion of the area is characterized by a patchy distribution of low-relief, sandy limestone hardbottom mantled by a thin veneer of sand and gravel. A large contiguous platform with scattered rock exposures occurs offshore from the southern 2.2 miles of Topsail Beach. A series of linear channel-like depressions, characterized by high acoustic reflectance, occurs across areas flanking the hardbottom. The largest of these features are generally filled with very coarse shell and lithic gravels while the smaller features are more sand rich. The Lea/Hutaff Island portion of the shoreface is underlain by flat lying Oligocene siltstone that crops out intermittingly offshore Rich Inlet. A thin veneer of fine quartz sand and silt caps portions of the hardbottom. The shoreface of Lea/Hutaff Island is dominated by sorted bedforms.

Previous studies indicate that there is a lack of sedimentary deposits along the Lea/Hutaff Island coastal segment. Therefore, there is little potential for the onshore movement of sediment (*e.g.* WRIGHT, 1987). This lack of significant sand resources precludes the use of much of the shoreface as a viable sediment source (*e.g.* CLEARY and RIGGS, 1999; CLEARY *et al*., 2001; BACKSTROM *et al*., 2001). The indurated Oligocene limestone of the Belgrade Formation is exposed on the seafloor as a highly irregular shoreface with a series of high and low relief hardbottom (rock outcrops) with intervening flat areas (WILLSON and CLEARY, 2003). Many hardbottom scarps are aligned in a shore parallel (NNE) direction (CROWSON, 1980; JOHNSTON, 1998; and CLEARY and

RIGGS, 1999). Vibracores and seafloor mapping by diver surveys indicate the presence of a thin sedimentary cover on the shoreface (WILLSON and CLEARY, 2003). The occurrence of relatively thick unconsolidated sedimentary deposits on the shoreface is rare due to surface exposure of lithified Oligocene siltstones and limestones (SNYDER *et al*., 1994; WILLSON and CLEARY, 2003). Although the shelf is primarily composed of Oligocene bedrock, sedimentary layers infill relict stream channels which form potential sand resources for beach nourishment projects.

Inlet and Barrier Island Morphodynamics

The southeastern coast of North Carolina is characterized by short barrier islands with an average length of 5 miles. The islands are separated by wave-dominated, mixed tidal inlets (HAYES, 1979) that have moderately well-developed ebb-tidal deltas. The barrier islands are migrating landward in response to rising sea level and a limited sediment supply. Barrier extremities typically exhibit pronounced shoreline changes (repositioning of shorelines) that are associated with tidal inlet processes (migration, channel switching, sediment bypassing and opening/closing) (*cf*. FITZGERALD, 1984). Morphosedimentary patterns and geographic location of coastal barriers and inlets, along the North Carolina coast are influenced by the inherited geologic framework (*e.g*. MACINTYRE and PILKEY, 1969; RIGGS *et al*., 1995). Underlying rock structure tends to influence the geomorphology of coastal barriers as does composition of the bedrock in relation to offshore sediment sources.

Nineteen (19) inlets occur along the North Carolina coast. Four (4) of these are located north of Cape Lookout. Ten (10) are located in Onslow bay. The remaining five (5), including the mouth of the Cape Fear River are found further south in Long Bay. The northern inlets are wave-dominated and have large flood tidal deltas. The tidal range is microtidal (0-7 ft). The inlets south of Cape Lookout tend to be smaller and are dominated by a mix of tidal and wave processes. Many of these inlets are migratory in nature and may move at rates ranging from 33-328 ft/yr. The U.S. Army Corps of Engineers maintains many of the inlets in southeastern North Carolina for navigational purposes. Others remain in a natural state and are controlled by natural processes like sediment supply to the inlet system, tidal prism, wave action, and longshore currents. Inlets exert an influence on the areas immediately adjacent to them in different ways. They generally cause shoreline change. Areas where a link between shoreline change and inlet process can be identified, are termed “inlet hazard zones”. These areas are designated by the North Carolina Coastal Area Management Act (CAMA) and are important areas of environmental concern (AEC).

New Topsail Inlet, located immediately south of Topsail Beach, has influenced the morphology and sedimentology of this coastal segment through a long history of migration (Figure 5). After opening at Sloop Point in the late 1720’s, the inlet has migrated over 6 miles in a southwesterly direction (CLEARY, 1994); two historic inlet locations are displayed in Figure 5. Recent migration has occurred at rates as high as 98 ft/yr, migrating approximately 1 mile between 1938 and 2002 (Figure 6). Previous inlet migration is evidenced within the backbarrier by a long (6 miles) channel (Banks Channel) that parallels the landward side of the island. Accompanying this feature are a series of narrow marsh islands, built from previous flood tidal deltas as storm waves and flood currents reworked the sediments (CLEARY *et al*., 1976). The hydrographic regime of the inlet was modified in the 1930's as a result of the dredging of the Atlantic Intracoastal Waterway (AIWW) and the associated channel that connects the estuary and the inlet (WILLSON and CLEARY, 2003).

Figure 5. Figure showing recent and historic locations of New Topsail Inlet. The red shoreline indicates the inlets location between 1849 and 1873, and the yellow shoreline indicates inlet location in 1938.

Maps and charts from the 1880's show three inlets occupying areas of what is now Lea/Hutaff Island. The inlets responsible for modifying the shoreface of this area were Old Inlet, Old Topsail Inlet and Sidbury Inlet. An 1880 T-sheet survey map (Figure 7) placed Old Inlet 0.6 miles northeast of Old Topsail Inlet's location at that time. Old Inlet has not been recorded on any maps or viewed in any aerials since the 1880's; its previous location is now an area that is being modified by New Topsail Inlet's southwestern shoulder.

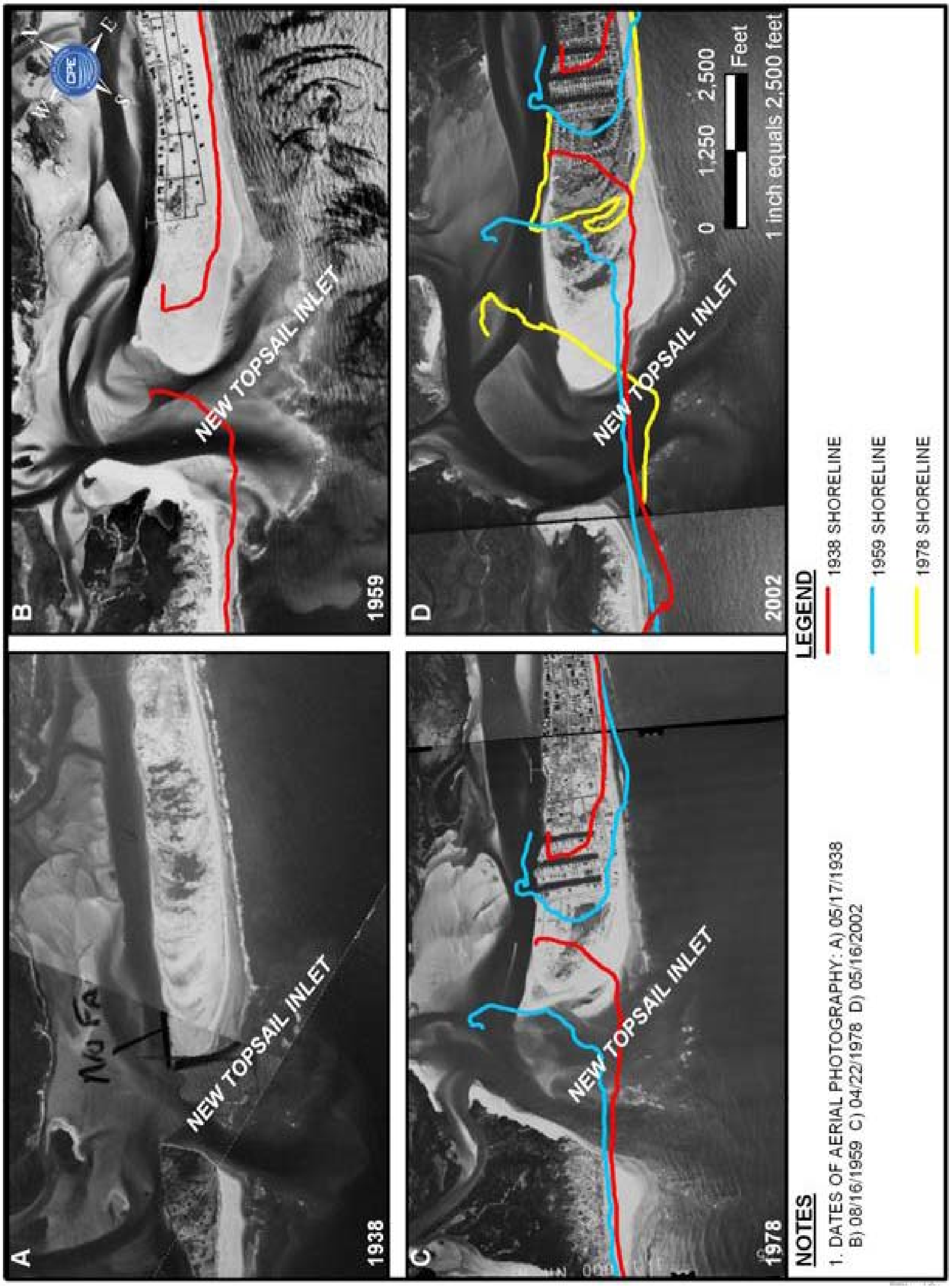

Figure 6. Migration of New Topsail Inlet shown by a series of historic aerial photographs. The average migration rate for this time period was 28 ft/yr over a distance of 1.0 mile.

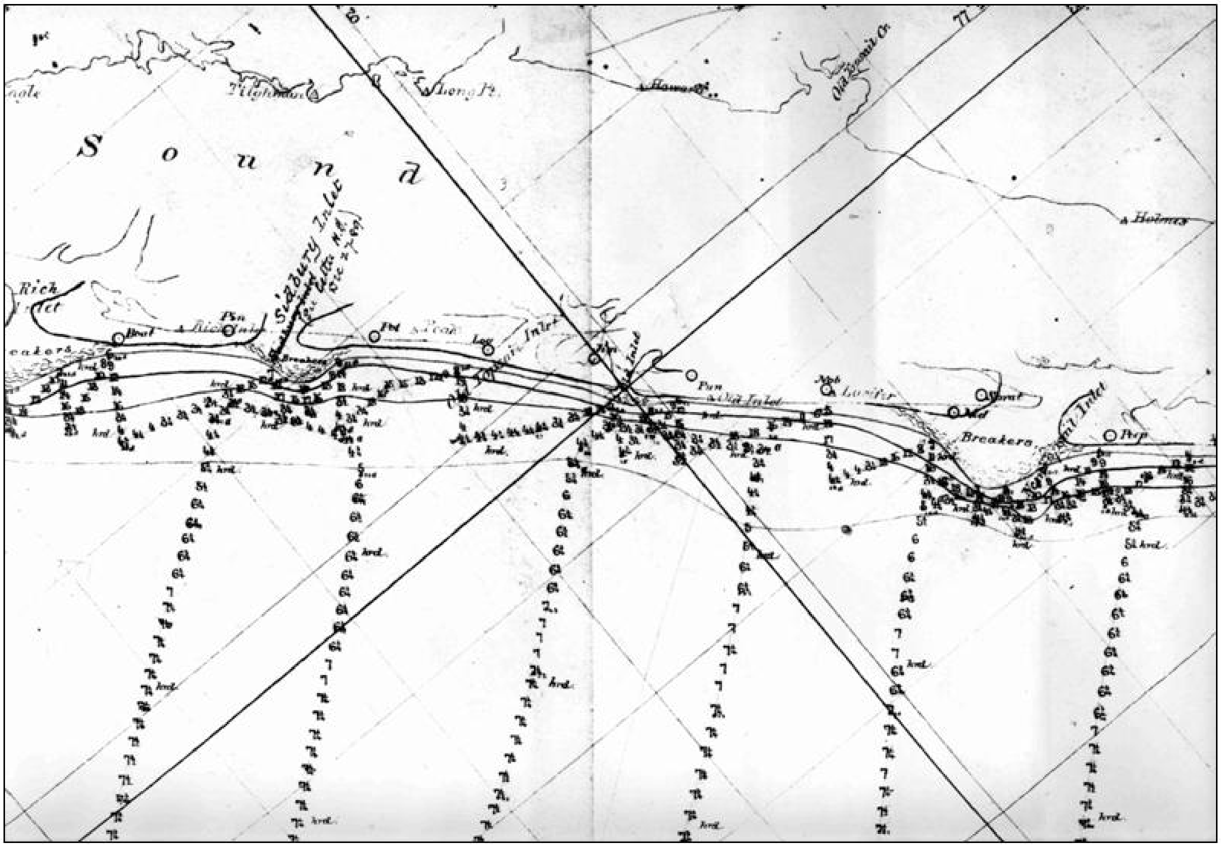

Figure 7. Historic map of the study area, showing three (3) inlets open along Lea/Hutaff Island.

Old Topsail Inlet, the most prominent of the three historic inlets, previously separated Lea/Hutaff Island into two smaller islands, Lea Island to the northeast and Coke Island to the southwest. Similar to many inlets in the region, Old Topsail inlet has migrated, moving 0.8 miles to the southwest between 1938 and 1998 (McGinnis, 2004). The inlet continually reduced in size during this time, eventually closing between September 1997 and June 1998. Sidbury Inlet has migrated throughout its history. The small inlet was located 1.3 miles northeast of Rich Inlet and has been recorded four (4) times. The inlet is shown on T- sheets from 1857 and 1880, and has also been recorded more recently opening from 1909 - 1925 and from 1959 – 1962 (Gammill, 1990). A study by McGinnis (2004) showed that between 1938 and 2002, variations in inlet position at Rich and Sidbury Inlets, and the migration of Old Topsail Inlet suggested that 35% of Lea/Hutaff Island, in 2002, would have been underlain by inlet fill. In addition to this data, identification of previous inlet features, such as marsh islands, coupled with recorded locations on T-sheets suggest that the entire Lea/Hutaff Island shoreline, in 2002, was underlain by inlet fill.

EQUIPMENT AND METHODS

The technical procedures, operational methodologies, analytical tools, and equipment used in this investigation are described below. Due to the scope and precision required by modern sand search protocols, a wide range of geotechnical and geophysical survey methodologies are required. These include bathymetric surveys, seismic reflection profiling and magnetometer surveys, cultural resource assessment prior to vibracore collection and determination of sediment composition and thickness via vibracoring. Three (3) separate geophysical surveys (simultaneously collecting sidescan sonar, subbottom profile, magnetometer, and bathymetric data) and two (2) vibracore investigations were conducted throughout the course of the sand search investigation for the Town of Topsail Beach, North Carolina. In May 2006 a geophysical survey of the previously mapped USACE Borrow Area A was conducted (Figure 2). Twenty (20) vibracores were collected in October 2006 from locations within Borrow Area A. In February 2007, a geophysical survey was conducted within an area offshore of the New Topsail Inlet. In June/July 2007, twenty-three (23) vibracores were collected from this area. In December 2007, a submerged cultural resource investigation of the New Topsail Inlet ebb tidal delta was conducted. Table 1 lists the geophysical and geotechnical equipment used during these investigations.

Table 1. *Equipment used during the sand search investigation.*

Equipment Type	Description
Navigation	Trimble 5700 Real Time Kinematic (RTK) Global Positioning System (GPS) interfaced with Hypack Inc.'s
Sounder (Bathymetry)	Odom Hydrographic Systems, Inc. "Hydrotrac" Hydrographic Echo Sounder
Sub-bottom Profiler (seismic reflection)	EdgeTech X-STAR SB-512i and SB-216s Sub-bottom Profilers
Sidescan Sonar	Edgetech 4200-FS sidescan sonar
Vibracores	271B Alpine Pneumatic Vibracore Athena Cabled Mechanical Vibracore and Generator System
Magnetometer	Geometrics G-882 Digital Cesium Marine Magnetometer interfaced with Hypack Max® software

Navigation Systems

The navigation and positioning system deployed for this survey was a real-time kinematic (RTK) global positioning system (GPS) with dual frequency receivers. RTK GPS relies on a base station and transmitter placed on a survey point with a known elevation and horizontal position. The base station for the survey was set on a known survey point on the Jolly Roger Pier in Topsail Beach (Figure 8) because this location provided a clear horizon to minimize phase-measurement effects caused by multi-pathing. The base station position for the RTK GPS system was surveyed and established before survey operations. Horizontal positioning checks were conducted before and after each survey at existing monuments located within the project area to confirm survey accuracy (see Table 2 for a list of survey monuments used). The base station 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

Figure 8. RTK GPS base station set up on the Jolly Roger fishing pier.

Table 2. *Information regarding the location of survey monuments used as horizontal and vertical control points.*

Designation	Northing	Easting	Elevation (ft)	Horizontal RMS error (survey ft)	Vertical RMS error (survey ft)
BORYK	221687.637	2408051.703	5.273	0.09	-0.05
CROCKER	224875.030	2411447.18	4.351	0.06	0.04
TOPSAIL 2	222837.226	2409348.446	2.980	0.07	-0.03
JOLLY ROGER	226818.857	2414031.148	15.637	N/A	N/A

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. GPS data was collected at 1 Hz or faster to minimize position interpolation when assigning the position to the various geophysical data. Baselines between the base station and vessel were less than 6 miles to ensure clear communication and minimize phase differences between the two antennas.

Hypack Inc.'s HYPACK MAX ® Data Collection and Processing Program

Navigational, magnetometer, and depth sounder systems were interfaced with an onboard computer, and the data was integrated in real time using Hypack Inc.'s Hypack Max®. Hypack Max® is a state-of-the-art navigation and hydrographic surveying system. The location of the fish towfish tow-point on the vessel in relation to the RTK GPS was measured, recorded and entered into the Hypack Max survey program. The length of cable deployed between the tow-point and each towfish was also measured and entered into Hypack Max. Hypack Max can then take these values and monitor the actual position of each towfish in real time. 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 measured by Position Dilution of Precision (PDOP), and line bearing. The digital data is merged with positioning data (RTK GPS), video displayed and recorded to the acquisition computers hard disk for post processing and/or replay. All data were 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 exported to AutoCAD and converted to ArcView shapefiles 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 a frequency of 210 kHz and is a digital, survey-grade sounder. Prior to use, the sounder was calibrated and checked periodically throughout the survey. Calibration was performed using an Odom Hydrographic Systems, Inc.'s Digital Pro® speed-of-sound velocity meter. Speed of sound through water and other selected parameters were 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 sediment sources. The purpose of the magnetometer survey was to establish the presence, and subsequent exclusion zones around any potential underwater wrecks, submerged hazards, or any other features that would affect borrow area delineation and dredging activities. The Hypack Max® software recorded magnetic anomalies directly from the Geometrics magnetometer.

Seismic Reflection Profile Surveys

An EdgeTech X-STAR SB-512i and the X-STAR SB-216s were used to conduct the seismic reflection profile surveys. The X-STAR series full spectrum sonar systems are versatile wideband FM sub-bottom profilers that collect digital normal incidence reflection data over many frequency ranges. This instrumentation generates cross-sectional images of the seabed (to a depth of up to 50 ft in this survey). The X-STAR SB-512i and X-STAR SB216s transmit 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. This technology has been utilized by CPE in several previous North Carolina and other sand searches including North Topsail Beach, NC (2005); Bay County, FL (2006); Lido Key, FL (2005); East Marsh Island, LA (2007) and Nantucket, MA (2006).

The X-STAR system is configurable with multiple towfish options. The different towfish have different frequencies for different survey goals, and can be limited by logistical issues depending on the target marine environment and the type of survey vessel used. CPE-NC utilized the X-STAR SB-512i towfish for the first two sub-bottom profile surveys to acquire offshore, shallow sub-bottom data for the project. During the second survey, which was partially conducted on the outer margin of the New Topsail Inlet ebb tidal delta, CPE-NC had difficulty using the X-STAR SB-512i because of the shallow water depths. Therefore, an X-STAR SB-216s towfish was used in the final survey on and around the outer margin of the New Topsail Inlet ebb tidal delta. The model X-STAR SB-216s towfish weighs approximately 100 lbs, which is manageable for small vessel and shallow water deployment, whereas the X-STAR SB-512i towfish weighs over 420 pounds and deployment must be accompanied by a sufficiently large vessel equipped with a davit or crane. The X-STAR SB-512i (0.5 – 12.0 kHz) and the X-STAR SB-216s (2.0 – 16.0 kHz) frequency ranges generate a high-resolution image of the sub-bottom stratigraphy in sand to a depth of 10-30 ft (X-STAR SB-216s towfish) and 20-50 ft (X-STAR SB-512i towfish) below the sediment/water column interface, which are typical depths of interest for sand searches.

The "chirp sonar" 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.

Throughout the seismic reflection surveys, selection of the chirp pulse was modified in real time to obtain the best possible resolution of geological features and the seismo-stratigraphy (*i.e.* vertical sequence and lateral distribution of sediment bodies comprised by different sediment types) that in turn optimizes data quality and enhances subsequent interpretation. High frequency and or short duration pulses are, for example, used to obtain highest resolution (clearest reflector image) in near surface situations; low frequency or longer duration pulses are used where deeper penetration is required.

All sub-bottom data was 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. Processing of the seismic data was done using Chesapeake Technology, Inc's SonarWiz.MAP +SBP® software. In addition to processing and interpretation, this software also produces georeferenced HTML's exportable for incorporation into a GIS database.

Sidescan Sonar Survey

The sidescan sonar system utilized for this survey was an EdgeTech 4200-FS sidescan sonar system (Figure 9). The system was interfaced to the RTK GPS along with navigational input provided by the Hypack Max® system.

The 4200-FS instrumentation 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 includes a portable configuration with laptop computer running the DISCOVER acquisition software and a 300/600 kHz dual frequency towfish running in high definition mode.

The sidescan sonar was towed at an optimum position and depth to ensure isolation from interference and optimum record quality. The digital sidescan data was merged with positioning data (RTK GPS via Hypack Max®), video displayed and logged to disk for post processing and/or replay. The position of the sensor relative to the RTK GPS antenna was thoroughly documented to ensure proper positioning of the data. The surveys were conducted to achieve total bottom coverage within the investigation area.

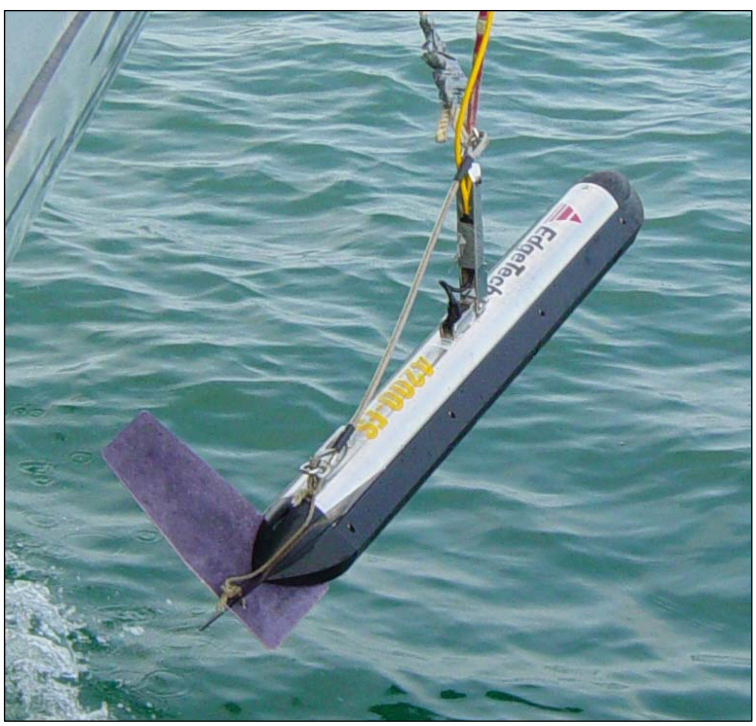

Figure 9. Deployment of the EdgeTech 4200-FS sidescan sonar towfish.

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 shapefiles.

Potential (probable and possible) hardbottom areas that were identified based on the sidescan sonar data were diver verified. Target transects were designed based on sidescan interpretations. Transects were generally set up across transitions interpreted as sandy bottom and potential rock outcrops (Figure 10).

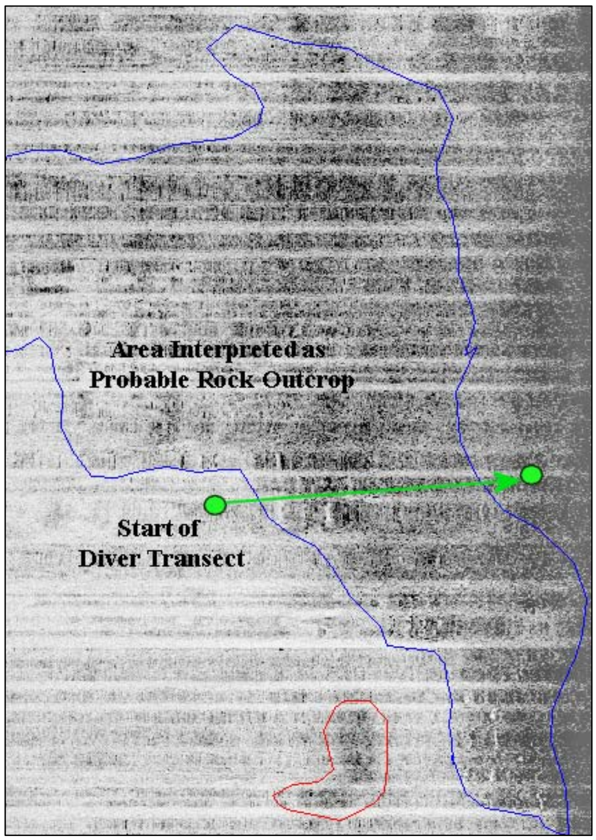

Figure 10. Sidescan sonograph depicting a ground truthing transect used to investigate presence / absence of rock outcrops.

Using a properly equipped vessel integrated with the Hypack Max® software, a weighted buoy was dropped at one end of each transect. The divers used the buoy as a starting position and swam along a pre-determined compass heading a sufficient distance to inspect the bottom transition. When divers encountered changes in bottom type along transects they would signal to the boat operator onboard the surface vessel who would record the position of the transition along the transect. Upon completion of the dive, the divers recorded the observed bottom types.

Vibracore Survey

Historic as well as the recently collected geophysical data was used to identify potential vibracore targets within USACE Borrow Area A. A plan was developed for a vibracore program that followed a logical sequence that optimized personnel, corporate resources, and time. A total of twenty (20) vibracores were collected using a 271B Alpine Pneumatic Vibracore, configured to collect undisturbed sediment cores up to 20 ft in length (Figure 11). 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, 20-ft long steel tubes measuring 4” in diameter (with a plastic core liner), and a drilling bit with a cutting edge. An air hose array provides compressed air from the compressor on deck to drive the vibracore. The vibracore unit was truck-crane deployed from a barge. The vibracore unit was crane deployed from a work barge (Figure 11) which in turn was towed to the deployment site by a towing vessel.

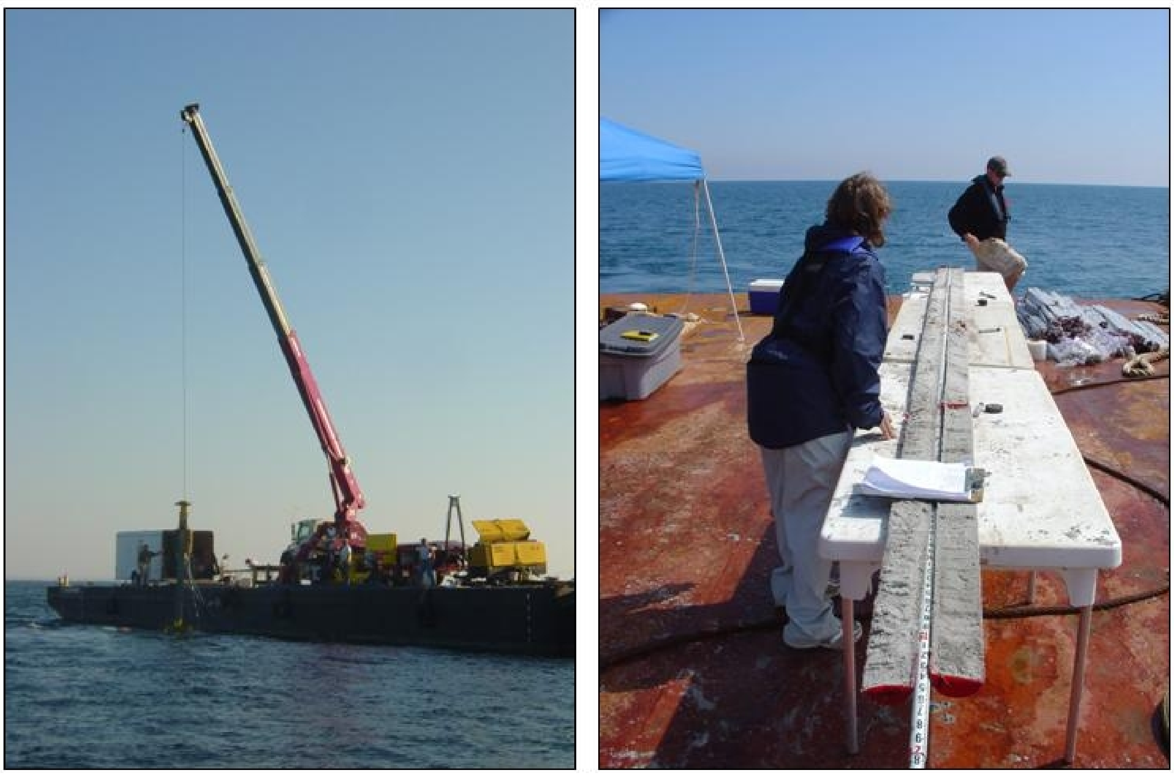

Figure 11. Crane deployment of the 271B Alpine Pneumatic vibracore system (left). Vibracore logging being conducted aboard the work barge during the vibracore operations (right).

Between 26 June and 24 July 2007, twenty-three (23) additional vibracores were collected from an area offshore of New Topsail Inlet. The vibracores were collected by

Athena Technologies of Columbia, South Carolina under the direction of a CPE-NC geologist. Vibracores were collected using a 3-inch galvanized steel tube that was vibrated to a pre-determined depth below the sediment-water interface or until refusal was experienced. This system consisted of a generator and mechanical vibracore head connected via cable (Figure 12). Several vibracores, required a two to three phase approach to retrieve sufficient material. In the first phase, a 3-inch galvanized steel tube was vibrated into the sediment to the depth of refusal. This was followed by jetting (with water pressure) a 3-inch galvanized steel tube to the depth of 2 feet above recovery and then vibrating the 3-inch galvanized steel tube into the sediment to the pre-determined depth for that particular vibracore or until the vibracore encountered refusal. If this second attempt did not recover a core of sufficient length, a third attempt was made to recover material to a sufficient depth.

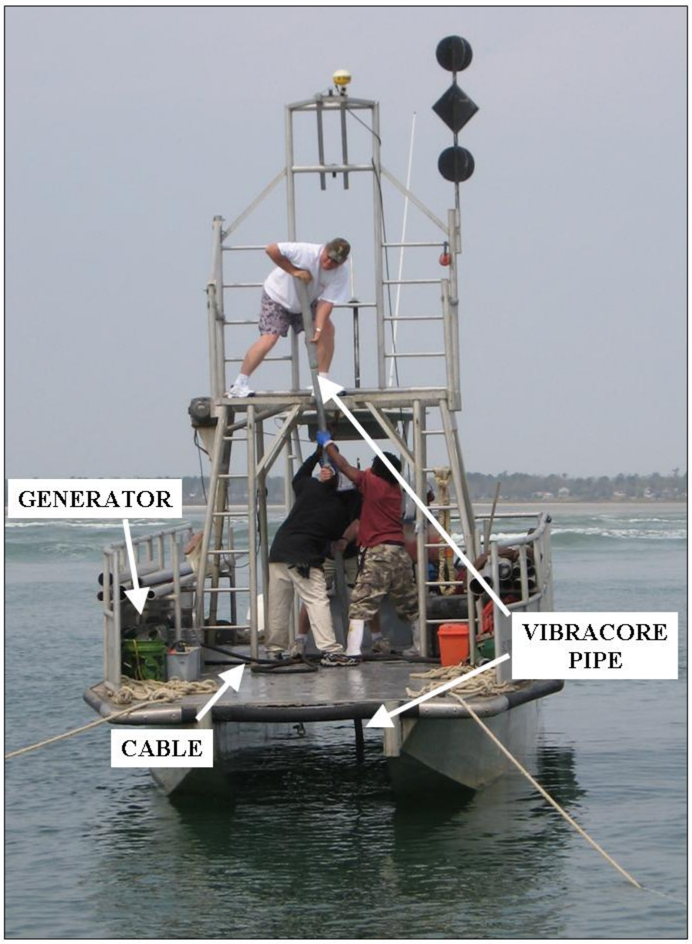

Figure 12. The Athena Technologies vibracore system showing the components of the Cabled Mechanical Vibracore and Generator system.

After core retrieval, the barrel was split in half (lengthwise) and each core was field logged (Figure 11). The cores were then wrapped in plastic, labeled, and transported to CPE-NC's office in Wilmington, North Carolina. There, the vibracores were re-logged in greater detail by describing sedimentary properties by layer in terms of layer thickness, color, texture (grain size), composition and presence of clay, silt, gravel, or shell and any other identifying features. The vibracores were digitally photographed against an 18% gray background in 2 ft intervals. Sediment samples were obtained from irregular intervals based on distinct layers in the sediment sequence. The cores were then re-wrapped in plastic. The sediment samples extracted from the vibracores, with the exception of samples that were analyzed onsite to direct survey efforts, were sent to the CPE Boca Raton, Florida office for grain-size analysis.

Beach and Nearshore Sediment Sampling

In 2003, USACE collected beach samples and nearshore sediment samples from six (6) transects spaced 5000 feet apart along the length of Topsail Beach. This was done as part of the Federal General Re-evaluation Report (GRR) and Environmental Impact Statement (EIS) Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach), North Carolina. The USACE collected four (4) samples landward of Mean Low Water (MLW) at the Toe of the Dune, Berm (+7 feet NGVD), Mean High Water (MHW), and Mean Tide Level (MTL). Twelve (12) samples were collected seaward of the MLW. The State Technical Standards require that six (6) samples be collected landward of MLW and six (6) be collected seaward. To meet this requirement, CPE-NC collected two (2) additional samples landward of the MLW along each of the six (6) USACE profiles. The two (2) additional samples were collected from the dune and midway between the MHW and the berm samples.

Sediment-Size (Mechanical) Analysis

Sieve analyses were conducted on all sediment samples in accordance with American Society for Testing and Materials Standard Materials Designation D422-63 for particle size analysis of soils (ASTM, 2007). This method covered the quantitative determination of the distribution of sand size particles. For sediment finer than the No. 230 sieve (4.0 phi) the ASTM Standard Test Method, Designation D1140-00 was followed (ASTM, 2006). Mechanical sieving was accomplished using calibrated sieves.

Grain size data was 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). Grain size distribution curves and gradation analysis reports were compiled for each sample.

Quantification of Clasts > 3"

To meet the North Carolina Technical Standards for Beach Fill Projects (15A NCAC 07H.0312(1)(h)), a survey of a 50,000 square foot portion of Topsail Beach in the vicinity of station TI-12 and TI-13 of the USACE baseline (approximately 300 ft north of the Jolly Roger Pier) was conducted. The four (4) corners of a rectangular section of the beach measuring approximately 320 ft along the beach from the toe of dune to the MLW Line (distance of approximately 160 ft) were identified and marked. The area was then sub-divided into approximately 10 ft x 10 ft blocks (Figure 13). The number of clasts exceeding 3 inches within each area were then counted.

Figure 13. Layout of survey area to quantify the amount of clasts > 3” in diameter within a 50,000 ft^2 area of Topsail Beach. Wooden stakes around the perimeter of the survey area and utility flags mark the corners of 10 ft x 10 ft blocks.

INVESTIGATION SEQUENCING

A methodological approach to marine sand searches, developed by the CPE Coastal Geology and Geomatics team (FINKL, KHALIL and ANDREWS, 1997; FINKL, ANDREWS and BENEDET, 2003; FINKL, BENEDET and ANDREWS., 2005; FINKL and KHALIL, 2005), was applied to this sand search investigation. In comprehensive marine sand searches, 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 sonar 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 14, describes the logical progressions and interactions between different data sources and indicates the steps that were followed by CPE-NC geologists and geophysicists during the Town of Topsail Beach sand search.

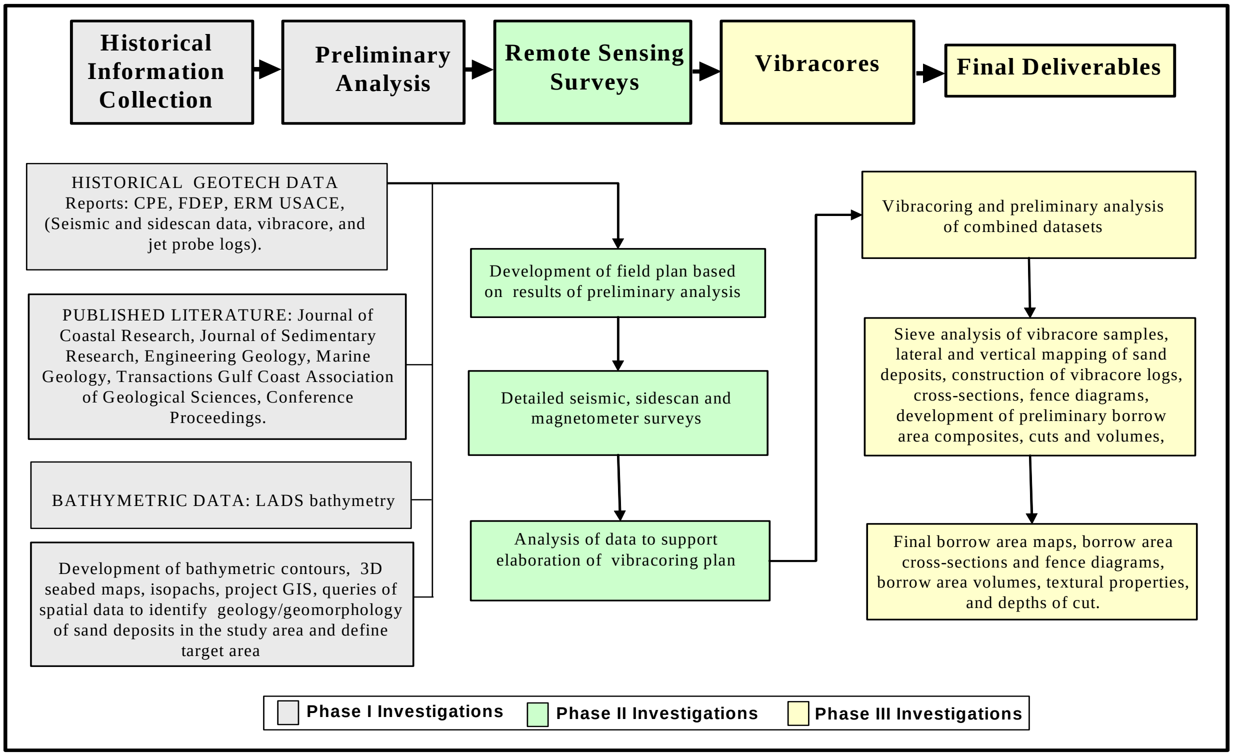

Figure 14. Flow diagram showing the main phases of sand search investigations for the Town of Topsail Beach sand search.

RESULTS

Four primary factors were considered by CPE-NC in the development of borrow areas for the Topsail Beach Interim (Emergency) Beach Nourishment Project. These factors include defining a borrow area with a minimum of 2 million cy of sand, maintaining a minimum thickness of 3 ft, optimizing grain size, and minimizing silt content. The initial proposal for the project required 1.3 million cy of sand; however, it is common practice for CPE-NC and an industry standard to design borrow areas with a minimum of 50% more material than required to allow dredgers latitude within the borrow site in the case that pockets of less suitable material are encountered during construction. This is also done to account for dredging inefficiencies and losses that typically occur within the project site between the time the project is designed and actual construction. It has been the intention of the Town of Topsail Beach to formulate this project to incur zero turtle takes. In attempting to design the project in a way that would minimize the risk of turtle takes the borrow site was designed to be dredged with a pipeline dredge. In order to design a borrow site that could be dredged using a pipeline dredge a minimum cut thickness of 3 ft was established. In order to maximize beach fill performance fill material should have a comparable mean grain size to the native beach. The mean grain size for Topsail Beach has been calculated to be 0.24 mm therefore the closer the mean grain size of fill material is to 0.24 mm the better the fill will perform. If the percentage of silt (< 0.0625 mm) contained in the borrow area exceeds the State allowance of native beach + 5% (5.94%), the borrow site can not be permitted; therefore it is important to minimize the percentage of silt contained in the borrow site.

Borrow Area A1

Historical Data Collection and Preliminary Analysis The investigation into finding a suitable sand source for an interim (emergency) beach nourishment project for the Town of Topsail Beach began in June, 2006 when CPE-NC was contracted. The plan for this investigation was to use data collected by the USACE and incorporated into the USACE Draft Integrated General Reevaluation Report (GRR) and Environmental Impact Statement (EIS), develop a survey plan. The investigative sequence for Topsail Beach was modified to incorporate the large amount of offshore data available for the historical data analysis phase. During Phase I (review of historical data), CPE supplemented data collected by the USACE for the GRR/EIS with literature in public and private archives. This extensive geotechnical (vibracores) and geophysical data (sidescan and seismic) was incorporated into a GIS geodatabase for the project area. This analysis led to the development of a survey plan that would target the USACE Borrow Area A. Based on previous correspondence with representatives of the Minerals Management Services (MMS) it was determined that to include the portion of Borrow Area A that was seaward of the State / Federal boundary (3 mi offshore) would not be feasible based on the time and uncertainty involved with obtaining a permit to survey the area and a lease to dredge material from the area. For this reason, only the portion of Borrow Area A that is landward of the State / Federal boundary was included in the survey area (Figure 2). A geophysical survey (sidescan sonar, subbottom profile, magnetometer, and bathymetry) was thus planned to fill in data gaps between existing geophysical survey lines and vibracores to identify the area with greatest potential for containing high quality sand within the USACE Borrow Area A.

Geophysical Survey CPE-NC collected geophysical data along 93 nautical-miles of survey trackline in July, 2007 (Figure 2). Correlation of seismic reflectors with existing vibracore data in real time during the geophysical survey allowed the team to refine the survey area. This real time analysis enabled the team to determine the most promising sections of the survey area and collect data at a dense enough spacing to allow for final borrow area design (60 m).

North Carolina State standards (15A NCAC 07H. 0208(b) (12) (A) (iv)) have established a 500 meter (1,640 feet) buffer zone between dredging activities and "significant biological communities (15A NCAC 07H. 0208(b)(12)(A)(iv)). Sidescan sonar mapping of the seafloor identified scattered areas of probable and possible rock outcrops. The designation of "probable" hardbottom was based on an acoustic signature that was indicative of exposed rock on the seafloor. The designation of "possible" hardbottom was given to acoustic signatures that were more indicative of coarse shell material or rock rubble that warranted ground truthing. It was determined not to be necessary to conduct ground truthing surveys prior to the vibracore survey because sufficient areas for further investigation existed beyond tentative buffers placed around probable and possible hardbottom areas (Figure 15). In the initial phase of the Borrow Area A investigation, an arbitrary boundary of 305 m (1000 ft) was established around areas designated as probable or possible hardbottom. Based on CPE-NC's past experience with the North Topsail Beach Shoreline Protection Project (non-federal) where a 122 m (400 ft) buffer was approved by the Project Delivery Team and the existing State standards, a 305 m (1000 ft) buffer was developed as a reasonable area around probable and possible hardbottom to establish a vibracore survey area. A vibracore survey area was then identified by incorporating seismic reflection data, existing USACE vibracore data, and buffer areas around the probable and possible hardbottom identified through analysis of sidescan sonar data.

A subsequent ground truthing survey conducted in an area between USACE Borrow A, B, and CPE Borrow Areas A1 and X determined that features with similar acoustic signatures classified as probable hardbottoms were in fact rock outcrops. The extrapolation of this ground truthing data supports the conclusion that these areas designated as probable hardbottoms are rock outcrops. No biological hardbottom characterization of these rock outcrops was conducted.

Vibracore Survey Twenty (20) vibracores were collected within the vibracore survey area in October, 2006 (Figure 16). The first five vibracores (Primary) were widely spaced throughout the survey area to allow geologists to determine which portion of the survey area held the greatest potential for beach quality sand. Vibracore TBVC-06-01 contained 16 ft of fine sand with trace shell hash and 8% to 10% silt with a mean grain size ranging from 0.13 mm to 0.16 mm. Vibracore TBVC-06-02 contained 4.2 ft of shelly sand over 16.0 ft of clay. Vibracores TBVC-06-03 through TBVC-06-05 contained 10.0 to 13.8 ft of fine sand with mean grain size ranges from 0.14 mm – 0.22 mm and percent fine (< 0.0625 mm) ranges from 4% to 10%. The decision was made in the field upon initial analysis of these vibracores to take the rest of the samples in the vicinity of TBVC-06-03, TBVC-06-04, and TBVC-06-05 on the basis of the high volume of clay material in vibracore TBVC-06-02 and the relatively finer mean grain size and high silt content in vibracore TBVC-06-01 (See Geotechnical Appendix 2 for complete vibracore logs).

The remaining sixteen (16) vibracore (Secondary) locations are shown in Figure 16. Vibracores TBVC-06-07, TBVC-06-08, TBVC-06-15, TBVC-06-17, and TBVC-06-18 were found to contain material that was determined unsuitable for inclusion in the final borrow area and thus was excluded from the final borrow area design. In total thirteen (13) of the twenty (20) vibracores collected were used in the final borrow area design.

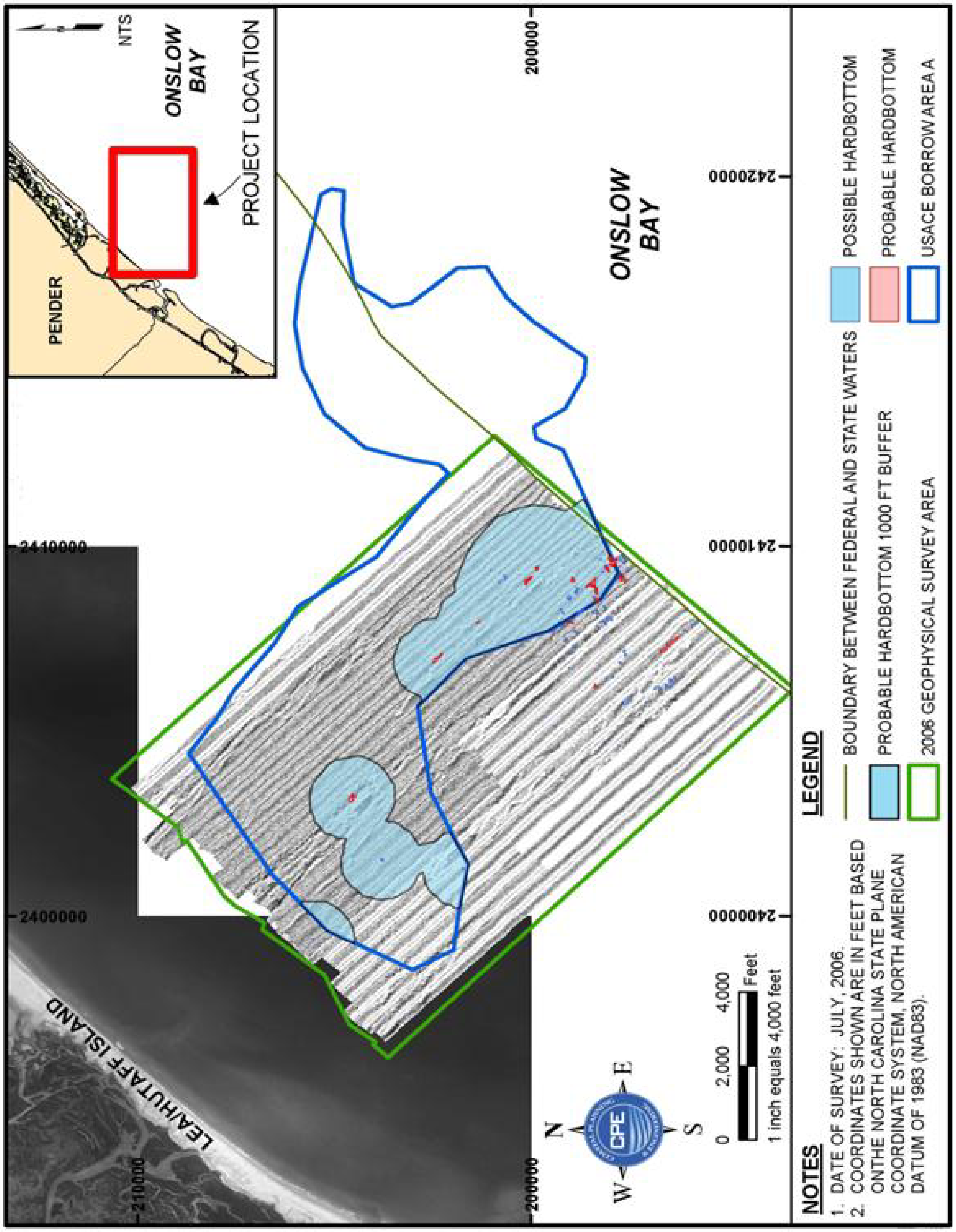

Figure 15. Map depicting sidescan sonar coverage of the portion of USACE Borrow Area A that was surveyed by CPE in 2006. Note the probable and possible hardbottom targets identified through analysis of the sidescan sonar data.

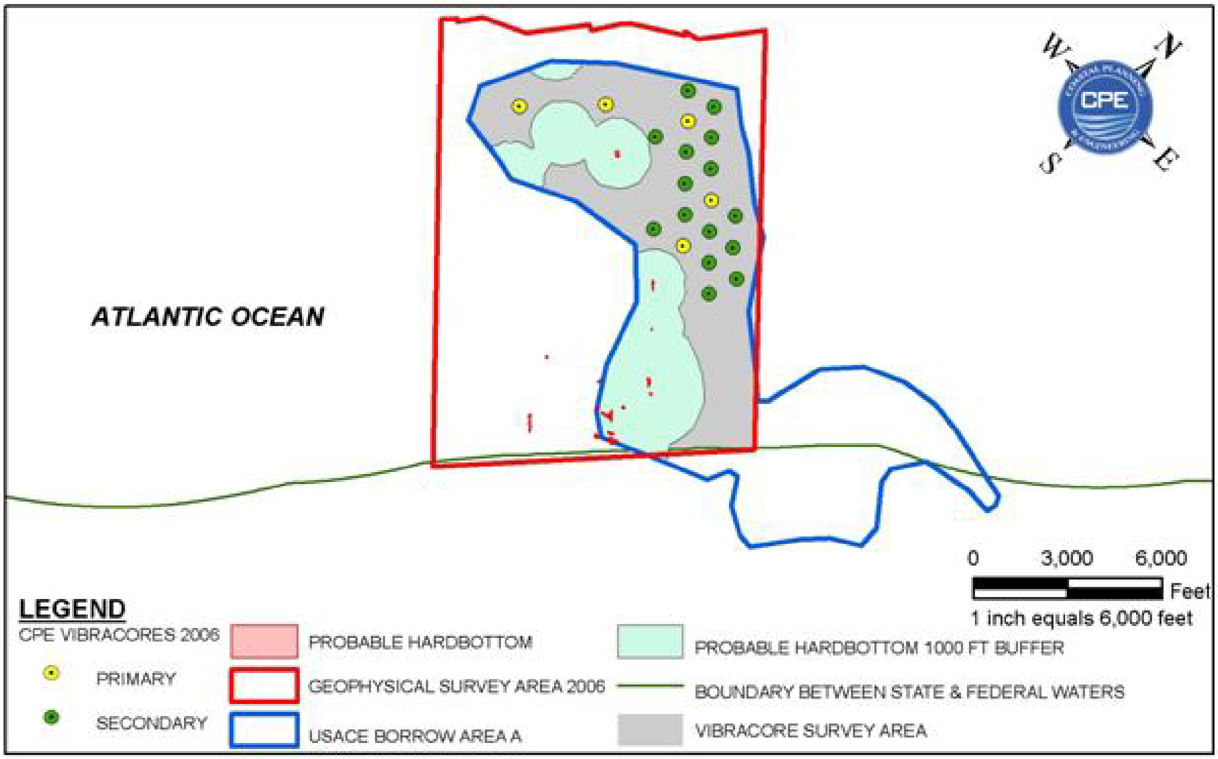

Figure 16. Map depicting 20 vibracores collected during the CPE investigation to design Borrow Area A1. Note the location of five primary vibracores. Note the 305 m (1000 ft) buffer around probable and possible hardbottoms.

Borrow Area Development and Textural Properties Borrow area shape, cuts, and locations of 13 vibracores used in the development of Borrow Area A1, are shown in Figure 17. The borrow area was split into three different sections with different cut depths (-47.0, -48.5, -51.0 NAVD) to maintain a minimum cut thickness of 3 ft, maximize composite mean grain size values, and minimize percent silt. Composite mean grain size, percent silt, and sorting were calculated for each vibracore by calculating the weighted average (average of each sample weighted by representative core length). The composite mean grain size, percent silt, and sorting for Borrow Area A were calculated by averaging the weighted results for the vibracores collected within the borrow area. Borrow Area A composite granularmetric reports and grain size distribution curves/histograms are provided in Appendices 6 and 7.

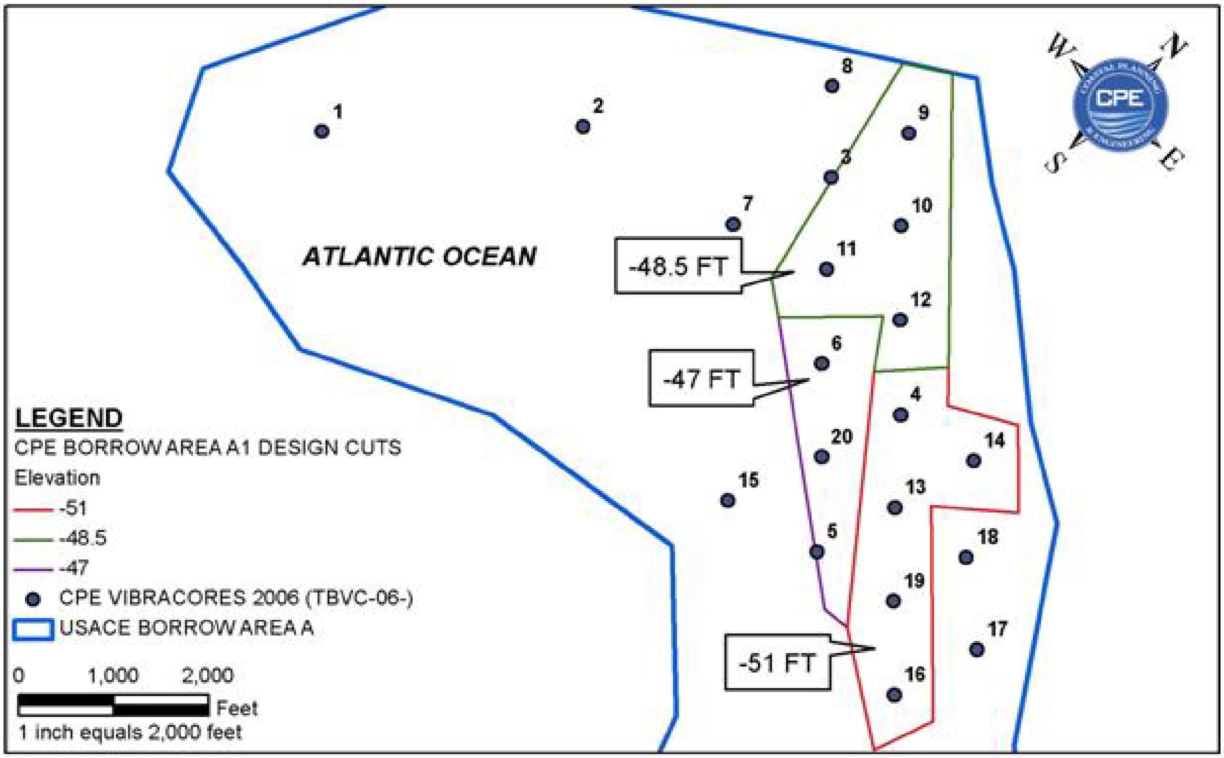

Figure 17. Map depicting the location of Borrow Area A1 as designed by CPE-NC. Note the three separate cuts and cut depths within the Borrow Area.

Summary results (composites) indicate that Borrow Area A1 contains a mean grain size of 0.17 mm (fine sand), with a phi sorting of 1.11 (poorly sorted), and 7.3% silt content and contain 2.14 million cy. The total acreage of Borrow Area A1 is 230 acres. Borrow Area A1 is 1.34 mi from Hutaff Island at its closest point and 2.71 mi at its most seaward point. The average pumping distance (center of borrow area to center of project) was measured to be 5.05 mi.

Based on the Town's desire not to move forward with Borrow Area A1 as a borrow source for the Interim (Emergency) Project, no further modifications were made to Borrow Area A1. Based on additional discussions with resource agencies, the development of Borrow Area X employed a 500 m (1,640 ft) buffer as opposed to the 305 m (1000 ft) buffer used in the development of Borrow Area A1. Analysis of the data indicated that had a 500 m buffer been applied in the development of Borrow Area A1, the size of the borrow area would decrease by 7% to 214 acres and 1.99 million cy. Composite characteristics would not differ significantly with the mean grain size of Borrow Area A1 remaining 0.17 mm and the percent silt decreasing from 7.30% to 7.27%.

Borrow Area X

Historical Data Collection and Preliminary Analysis A second investigation into finding a suitable sand source for an interim (emergency) beach nourishment project for the Town of Topsail Beach was initiated by the Town in January, 2007. This decision was made on the basis that the material in Borrow Area A1 would not meet the performance goals of the Town for the Interim (Emergency) Project. The plan for this investigation was to re-examine vibracore data collected by the USACE during Phase I, and determine if data indicated an additional potential sand resource area. This re-examination identified an area directly outside of New Topsail Inlet measuring 2.1 mi from the mouth of the Inlet seaward, and 2.2 miles wide. A reconnaissance geophysical survey (sidescan sonar, subbottom profile, magnetometer, and bathymetry) was thus planned to collect data within the survey area and identify the areas with the greatest potential for containing high quality sand (Figure 3).

Geophysical Survey The geophysical survey was conducted aboard the University of North Carolina at Wilmington's (UNCW), 65 ft, *R/V Capefear*. A grid spacing of 180 m (591 ft) was used to allow for 100% sidescan sonar coverage and acceptable bathymetric and subbottom reconnaissance level coverage of the survey area. CPE-NC collected geophysical data along 36.5 nautical miles survey trackline (Figure 3). Subbottom profile data revealed a wedge of sand, interpreted as a relict ebb-tide delta feature, at the landward edge of the survey lines. Figure 18 shows a seismograph of the wedge feature. By digitizing the areal extent of this wedge of sand based on the landward extent of the geophysical data and maintaining a minimum sand thickness of three feet a potential sand resource area was identified in which subsequent investigations were concentrated (Figure 3).

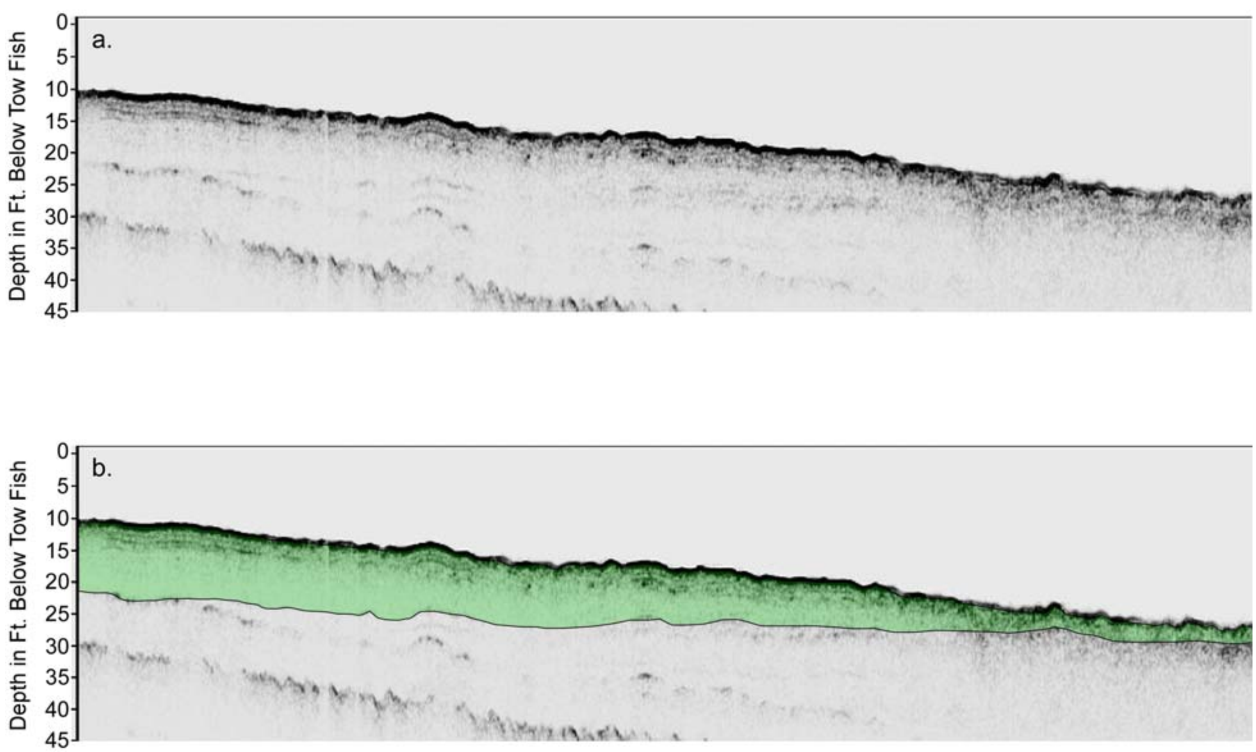

Figure 18. Seismograph showing wedge shaped sand deposit as seen along seismic track 5, a. blank seismograph with no reflectors digitized, b. seismograph with base of sand deposit shown as the black digitized reflector at the base of the shaded section interpreted as sand.

Ground Truthing Investigation Analysis of the sidescan sonar data collected during the February, 2007 reconnaissance geophysical survey identified a number of anomalies interpreted as possible and probable rock outcrops (Figure 19). The designation of "probable" hardbottom was based on an acoustic signature that was indicative of exposed rock on the seafloor. The designation of "possible" hardbottom was given to acoustic signatures that were more indicative of coarse shell material or rock rubble that warranted ground truthing. Upon the application of buffers to probable and possible hardbottom areas sufficient area for further development did not exist. This made ground truthing the sites necessary to determine the largest area in which additional investigation could occur. A ground truthing survey was conducted on May 29th and 30th, 2007 by a team of CPE-NC geologists to verify presence / absence of rock outcrops. A total of 17 ground truthing dives were conducted on sites both designated as possible and probable rock outcrops located east of Borrow Area A and between Borrow Areas B and X (Figure 20). These groundtruthing dives revealed 100% of the dives on possible hardbottom areas (14 of 14 dives) found the seafloor to be composed of shell hash (Figure 21a)and 100% of the dives on probable hardbottom areas (3 of 3 dives) proved to be low relief (< 1.0 m) exposed rock outcrops partially covered with fine sand and shell hash (Figure 21b).

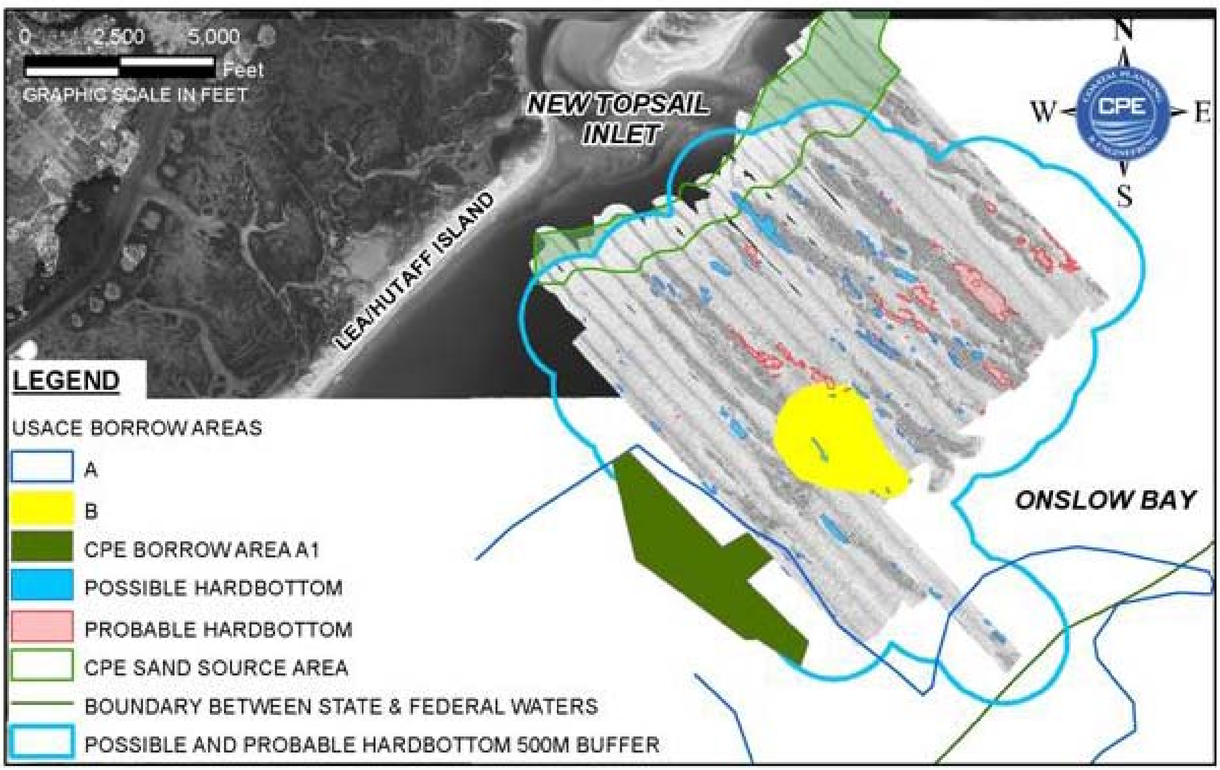

Figure 19. Map depicting the location of probable and possible hardbottom locations identified using sidescan sonar during the February, 2007 reconnaissance geophysical study. Note the majority of the Sand Source Area is eliminated using a 500 m buffer for all sidescan anomalies

Areas that were ground truthed and confirmed to be rock outcrops were digitized and designated as confirmed rock outcrops (Figure 22). These areas were assigned a 500 m buffer to determine the maximum extent of the previously designated potential sand source area in which vibracore investigations would be conducted. The ground truthing confirmation dives cleared a significant portion of the potential sand source area that would have been eliminated from the sand search based on sidescan interpretations only.

Vibracore Survey Twenty-three (23) vibracores were collected within the vibracore survey area between June 26 and July 24, 2007 (Figure 22). The Town of Topsail Beach wanted to target material that would perform better than the material in Borrow Area A1 (mean grain size = 0.17 mm) based on grain size. CPE-NC collected 6 primary vibracores that were widely spread throughout the potential sand source area to determine the areas with the coarsest sand (Figure 22). Preliminary grain size analysis performed on site indicated TBVC-07-01 and TBVC-07-02 contained sand with mean grain sizes finer than 0.17 mm whereas Vibracores TBVC-07-03 through TBVC-07-06 contained sandy sediments coarser than 0.17 mm (Figure 22).

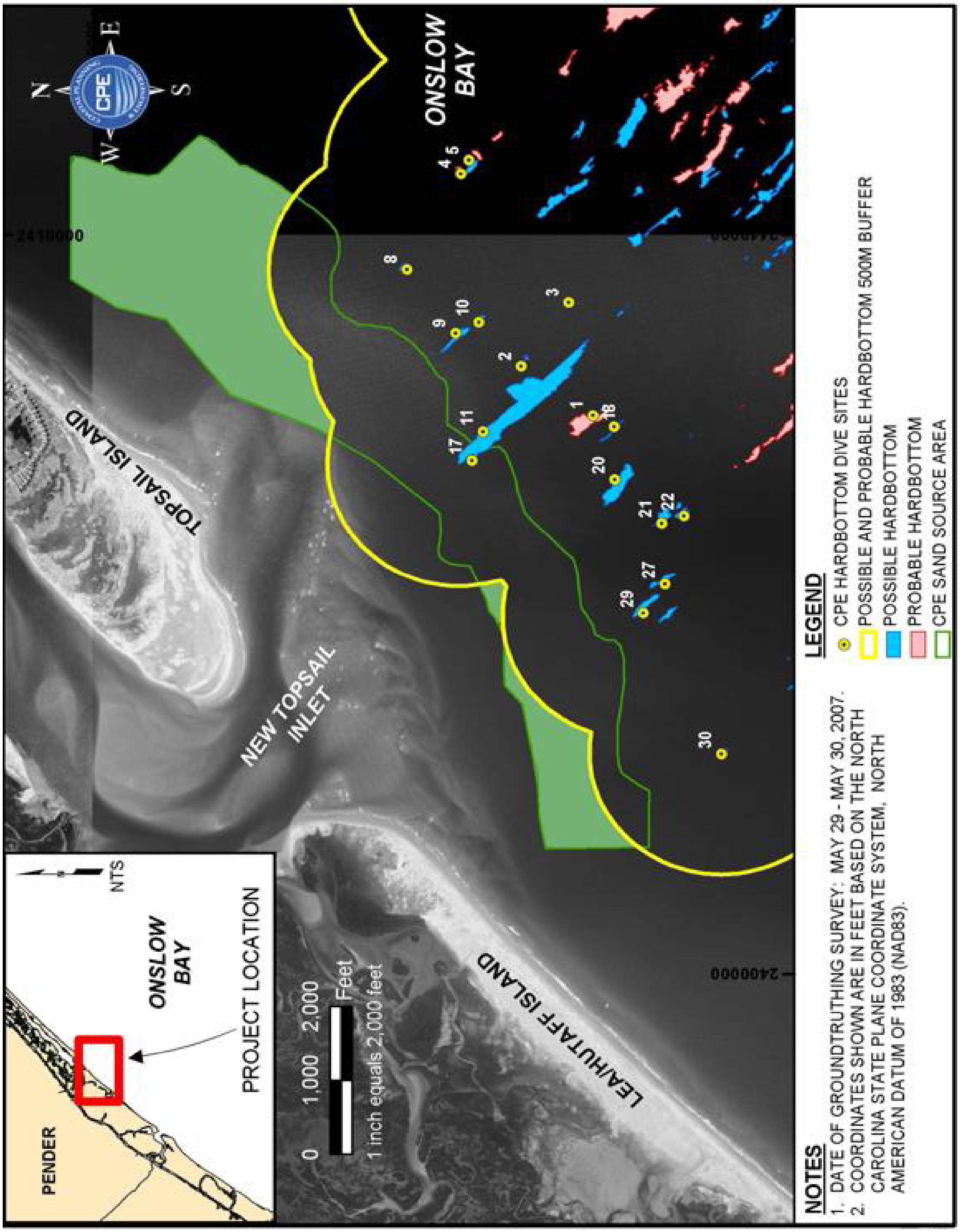

Figure 20. Map depicting the locations of the ground truthing dives conducted in May 2007 to determine presence / absence of rock outcrops.

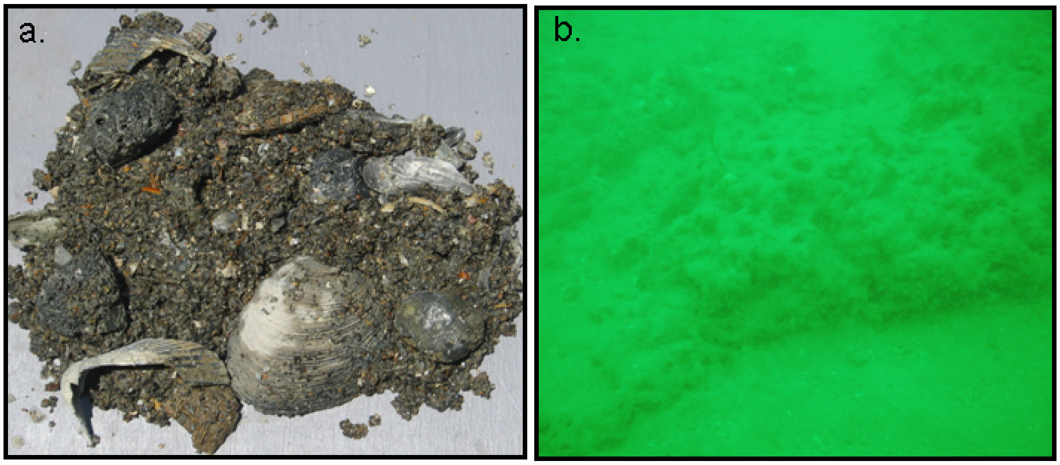

Figure 21. a) Material typically observed during the groundtruthing surveys (i.e. shell hash and shell fragments with large mercenaria shells). b) low relief (< 1.0 m) rock outcrops partially covered with fine grained sand and shell hash.

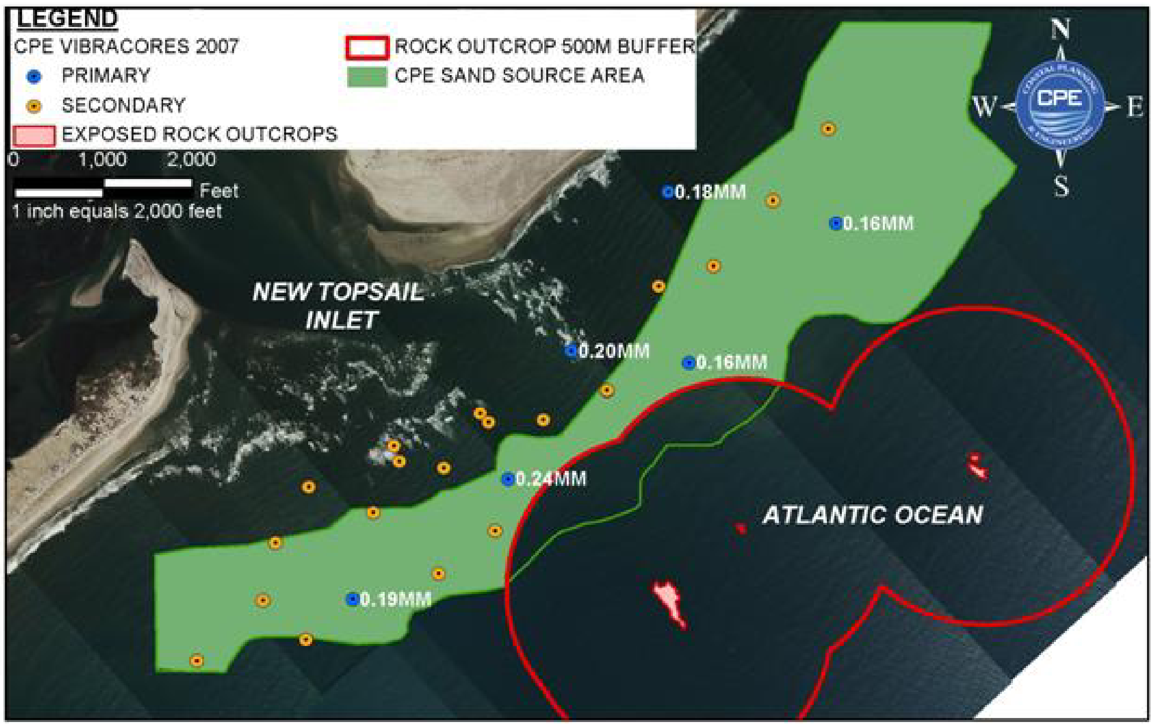

Figure 22. Map depicting areas confirmed to be rock outcrops with a 500 m buffer surrounding them and the location of 23 vibracores collected during the Borrow Area X investigation.

Subsequently, the seventeen (17) secondary vibracores were concentrated around primary vibracores containing material coarser than 0.17 mm (Figure 22) (See Geotechnical Appendix 9 for mean grain size composites for all vibracores taken in 2007). Of the 20 secondary vibracores, TBVC-07-11, TBVC-07-15, TBVC-07-19, and TBVC-07-20 were found to have composite mean grain sizes finer than 0.17 mm and thus were excluded from a maximum footprint for a potential borrow area.

Cultural Resource Survey Upon completion of the vibracore survey conducted in June and July, 2007, a preliminary borrow area was delineated. This preliminary borrow site was delineated as the maximum footprint of a borrow area that could be designed using the available vibracore and ground truthing data, that would contain a minimum of 2 million cy while maintaining a minimum cut thickness of 3 ft, maximizing grain size, and minimizing silt content. In order to fill in data gaps landward of the February 2006 geophysical survey, a seismic and bathymetric survey was conducted between October and December, 2007 in conjunction with the submerged cultural resource survey conducted by Tidewater Atlantic Research (TAR) in which 48 nautical miles of survey tracklines were surveyed (See Appendix C of the SEIS for complete Submerged Cultural Resource Survey results). Two seismic reflectors were identified and used to map areas containing beach quality material (Figure 23). The seismic data was used to develop an isopach which was incorporated into the final design of Borrow Area X.

Analysis of the data collected during the cultural resource survey between October and December 2007 revealed forty-six (46) magnetic and/or acoustic anomalies. Analysis of the magnetic data indicated that two (2) of the targets exhibit signature characteristics consistent with shipwreck material and/or other potentially significant submerged cultural resources. The remaining forty-four (44) anomalies appear to have been generated by modern material such as short lengths of wire rope, cable, pipe, small boat anchors, traps or other modern debris. Six (6) of these non-significant anomalies fell within the New Topsail Inlet ebb tidal delta investigation area. No buffering was recommended by the marine archaeologist.

Borrow Area Development and Textural Properties Along with the four primary factors considered in the design of Borrow Area X (minimum 2 million cy, minimum cut thickness of 3 ft, maximize grain size, and minimize silt percentage) a number of other factors were considered. These factors included data coverage, results of the cultural resource survey, State and Federal agency recommendations, and results of modeling efforts. Borrow Area X was divided into five (5) sections with cut elevations ranging from -16.0 to -34.0 ft NAVD88 (Figure 24). Composite mean grain size, percent silt, and sorting were computed for each vibracore by calculating the weighted average (average of each sample weighted by representative core length). The composite mean grain size, percent silt, and sorting for Borrow Area X were calculated by averaging the weighted results for vibracores collected from the borrow area. Borrow Area X composite granularmetric reports and grain size distribution curves/histograms are provided in Appendices 14 and 15. Composites indicate that Borrow Area X contains 2.02 million cy of sand with a mean grain size of 0.20 mm (fine sand), with a phi sorting of 1.04 (poorly sorted), and 1.86% silt.

Compatibility Analysis In March, 2008 the North Carolina Coastal Resource Commission (CRC) adopted an amended, comprehensive list of technical standards for beach fill projects (15A NCAC 07H.0312). These standards included methodology related to the assessment of compatibility between beach and borrow area sediments.

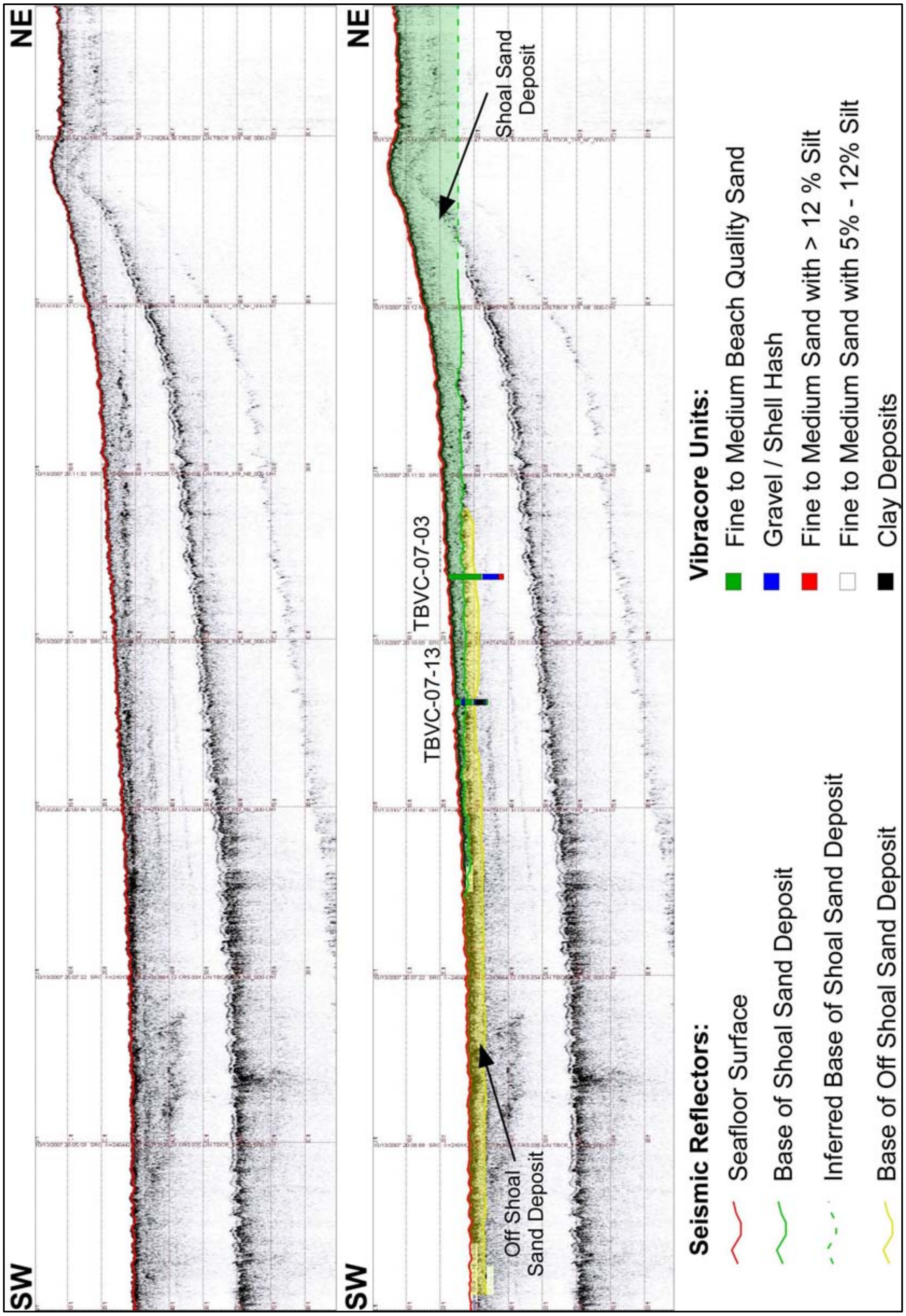

Figure 23. Example seismograph showing the shoal deposit and off shoal deposit, targeted for Borrow Area X.

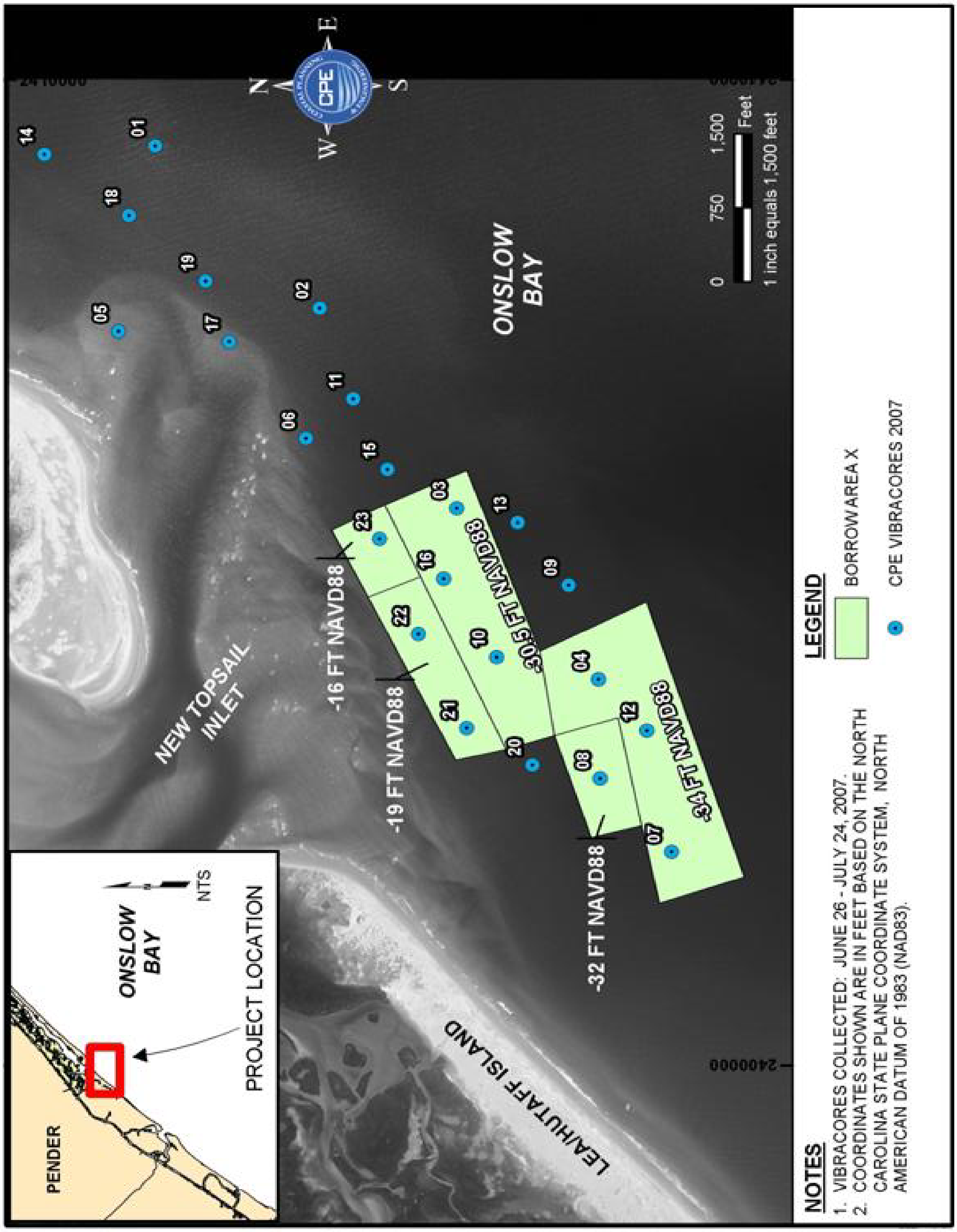

Figure 24. Map showing Borrow Area X design cuts.

The applicant is required to characterize the beach and borrow area(s) in terms of percentage silt, sand, granular sediment, gravel and carbonate, as well as amount of sediment and shell material greater than three (3) inches in diameter. A visual estimate of shell content can be used as a proxy for carbonate weight percent for samples collected prior to the effective date of rule 15A NCAC 07H .0312(1)(g). In addition to the requirements above, the current state standards require that percent silt, granular, and gravel in fill material not exceed the amount found in the native beach plus 5%. Likewise, the State standards require that the percent carbonate in fill not exceed the amount found on the native beach plus 15%.

The USACE native composites, which were developed prior to the adoption of the State sediment criteria, included one sample collected at MLW, 4 samples collected landward of MLW, and 12 samples collected seaward of MLW. These samples were collected at the following locations along transects in July, 2003: dune toe, mid-berm, MHW, MSL, MLW, -3', -4', -6', -8', -10', -12', -14', -16', -18', -20', -22', and -24'. The composite characteristics of the native material computed by CPE-NC differ slightly from the native characteristics determined by the Corps of Engineers due to the native beach sampling criteria adopted by the State.

Beach grain size data collected by the USACE and supplemented with samples collected by CPE-NC were used to generate composite grain size statistics for each of the grain size categories (silt, sand, granular, and gravel). For final composites six (6) of the twelve (12) samples collected by the USACE seaward of the MLW line (-6.0, -8.0, -12.0, -14.0, -18.0, and -20.0 ft NGVD), the four (4) samples landward of the MLW line collected by the USACE, the two (2) samples landward of the MLW collected by CPE-NC, and the sample collected by the USACE at MLW were used. The USACE visually estimated bulk shell content during sieve analysis. As such, CPE-NC recorded bulk shell values for the additional samples that were collected along each profile and incorporated them into the final profile composites. A comparison of the native composites computed by CPE-NC and the Corps of Engineers follows:

Characteristic	CPE-NC	Corps of Engineers
Mean (mm)	0.24	0.22
Sorting Coefficient (phi)	0.86	0.70
% silt	0.94	1.16
% shell	11	12

Composites for the beach are provided in Appendix 18. To determine the bulk shell content of the beach samples, CPE generated a mechanical composite of the thirteen (13) samples for each of the six (6) profiles. Beach composite granularmetric reports and grain size distribution curves/histograms are provided in Appendices 21 and 22. The calculated composites were then compared to those calculated for Borrow Area A1 and Borrow Area X to determine compatibility based on the State Technical Standards.

The results of the native beach composite analysis show that the beach has a silt content of 0.94%. The coarse components of the beach, granular content and gravel content, were determined to be 0.82% and 0.17%, respectively. The visual bulk shell estimate is 11%. Borrow Area A1 has a mean grain size of 0.17 mm. The borrow area has a silt content of 7.30% and granular and gravel contents of 2.13% and 1.22%, respectively. The visual bulk shell estimate is 6%. Composite summaries for Borrow Area A1 are provided in Appendix 1. Borrow Area X has a mean grain size of 0.20 mm. The borrow area has a silt content of 1.88% and granular and gravel contents of 1.55% and 1.56%, respectively. The visual bulk shell estimate is 4%. Composite summaries for Borrow Area X are provided in Appendix 9. Beach and borrow area characteristics are summarized in Table 3. Given the criteria set forth by the State of North Carolina, fill material found in Borrow Area X complies with the State standards. The silt content of the material in Borrow Area A1 exceeds the limits set by the State of North Carolina.

The results of the survey to quantify the amount of rocks and shells exceeding 3 inches in diameter are provided in Appendix 23. This survey was performed in the vicinity of USACE baseline stations TI-12 and TI-13 in March 2008 prior to construction to determine a background value for the amount of rock and shell > 3 inches in diameter on the recipient beach. The total number of clasts > 3 inches in diameter identified during the survey was seven hundred and forty-five (745).

Table 3. *Beach and borrow area characteristics.*

Location	**Mean Grain Size (mm)**	**Fine % (<0.0625mm)**	**Sand % (0.0625-2.00mm)**	**Granular % (2.00-4.76mm)**	**Gravel % (4.76-76.00mm)**	**Visual Bulk Shell Estimate (%)**
Beach	0.24	0.94	98.06	0.82	0.17	11
Borrow Area A1	0.17	7.30	89.36	2.13	1.22	6
Borrow Area X	0.20	1.88	95.2	1.55	1.56	4

CONCLUSIONS

Two (2) areas on the inner continental shelf near Topsail Beach, North Carolina were investigated in an effort to locate suitable sand sources for the Town of Topsail Beach Interim (Emergency) Beach Nourishment Project. A rational sequence of geotechnical and geophysical investigations, based on CPE strategic sand search protocols, was applied to this investigation. These protocols featured analysis of historical data, understanding of local coastal geological frameworks and regional morphodynamics, and performing geophysical and geotechnical surveys that included on-the-fly analysis of geophysical data and vibracores in the field. Application of these procedures resulted in the identification of beach-compatible sands. The sand mapped in the 2006 investigation is a thin veneer of Holocene age sand over an unconsolidated, sandy Oligocene age unit. The sand mapped in the 2007 investigation is part of a residual ebb tidal delta deposited at different times as several inlets have migrated through the region.

Sand located in Borrow Area A1 as designed by CPE-NC is generally suitable for placement on the beach. However, the silt content of this borrow area exceeds the limits set by the State of North Carolina. Sand located in Borrow Area X as designed by CPE-NC complies with all North Carolina State standards. Borrow Site A contains 2.14 million cy of sand within 230 acres. Borrow Site X contains 2.02 million cy of sand within 151 acres.

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