

## **Appendix E- Geotechnical Investigation Report**

**GEOTECHNICAL INVESTIGATION OF OCEAN ISLE BEACH & SHALLOTTE  
INLET BORROW AREA  
OCEAN ISLE BEACH SHORELINE MANAGEMENT PROJECT**

**Prepared For:**

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**January 2015**

## **Executive Summary**

In 2012, Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC) was authorized to provide services in support of the effort by the Town of Ocean Isle Beach (TOWN) to evaluate the feasibility of constructing a terminal groin on the east end of the TOWN's shoreline near Shallotte Inlet. The terminal groin is designed to mitigate the chronic erosion problem caused by Shallotte Inlet's influence on the movement of littoral sediment in this area.

During the Ocean Isle Beach geotechnical investigations, CPE-NC researchers utilized existing U.S. Army Corps of Engineers (USACE) vibrocore data from 1994, 1998, 2005, and 2009 to assess the proposed beach fill sediment characteristics. On April 5, April 9, 2013, and January 23, 2014, CPE-NC collected beach samples and nearshore sediment samples along four (4) profiles, extending from the dune out to -20 ft. NAVD, to facilitate an evaluation of the borrow area's compatibility with the existing beach. The beach and nearshore samples analyzed by CPE-NC were obtained from the east end of Ocean Isle Beach between stations 0+00 and 60+00 and incorporated with USACE data from native beach samples collected along profile station 40+00, extending from the dune out to -20 ft. NAVD.

CPE-NC concentrated their investigation on the federally approved borrow area used for the Ocean Isle Beach storm damage reduction project. The federal borrow area extends from the Atlantic Intracoastal Waterway (AIWW) through the throat of the channel and turns south over the ocean bar, realigning the channel perpendicular to the adjacent shorelines. The original USACE borrow area was designed to have a maximum dredging depth of 15 ft. below MLW (-17.97 ft. NAVD) (USACE, 2002); creating a channel with 3H:1V sides slopes measuring approximately 950 ft. wide at the AIWW and 1,400 ft. wide at the bar channel. The footprint of the borrow area covers approximately 4.8 million sq. ft. (110 ac) and was divided into eight (8) sub areas.

CPE-NC conducted an independent review of the borrow area using multiple historic vibrocore data sets obtained by the USACE, as well as considering the state sediment criteria rules (15A NCAC 07H .0312) and environmental concerns voiced by resource agencies through the Project Review Team (PRT) process. This independent analysis resulted in the identification of a sub portion of the federally approved borrow area which is limited to the area dredged during the initial construction of the project in 2001. The recommended borrow area has an estimated dredgeable volume of approximately 1,312,000 cy based on pre-construction surveys conducted in 2013. The compatibility of this borrow area with the existing beach was evaluated according to wet Munsell color, silt content, carbonate content and grain size. The compatibility analysis verified that the borrow area material met the allowable limits defined by Rule 15A NCAC 07H .0312.

**GEOTECHNICAL INVESTIGATION OF OCEAN ISLE BEACH & SHALLOTTE  
INLET BORROW AREA, BRUNSWICK COUNTY, NORTH CAROLINA**

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## INTRODUCTION

Ocean Isle Beach is approximately 29,200 feet (5.5 miles) long and is located on the Atlantic Coast of southeastern North Carolina, in Brunswick County, 44 miles from Wilmington, North Carolina. It is situated between Shallotte Inlet on the east and Tubbs Inlet on the west and bound to the north by the Atlantic Intracoastal Waterway. To the south the Town is bound by the Atlantic Ocean (Figure 1).

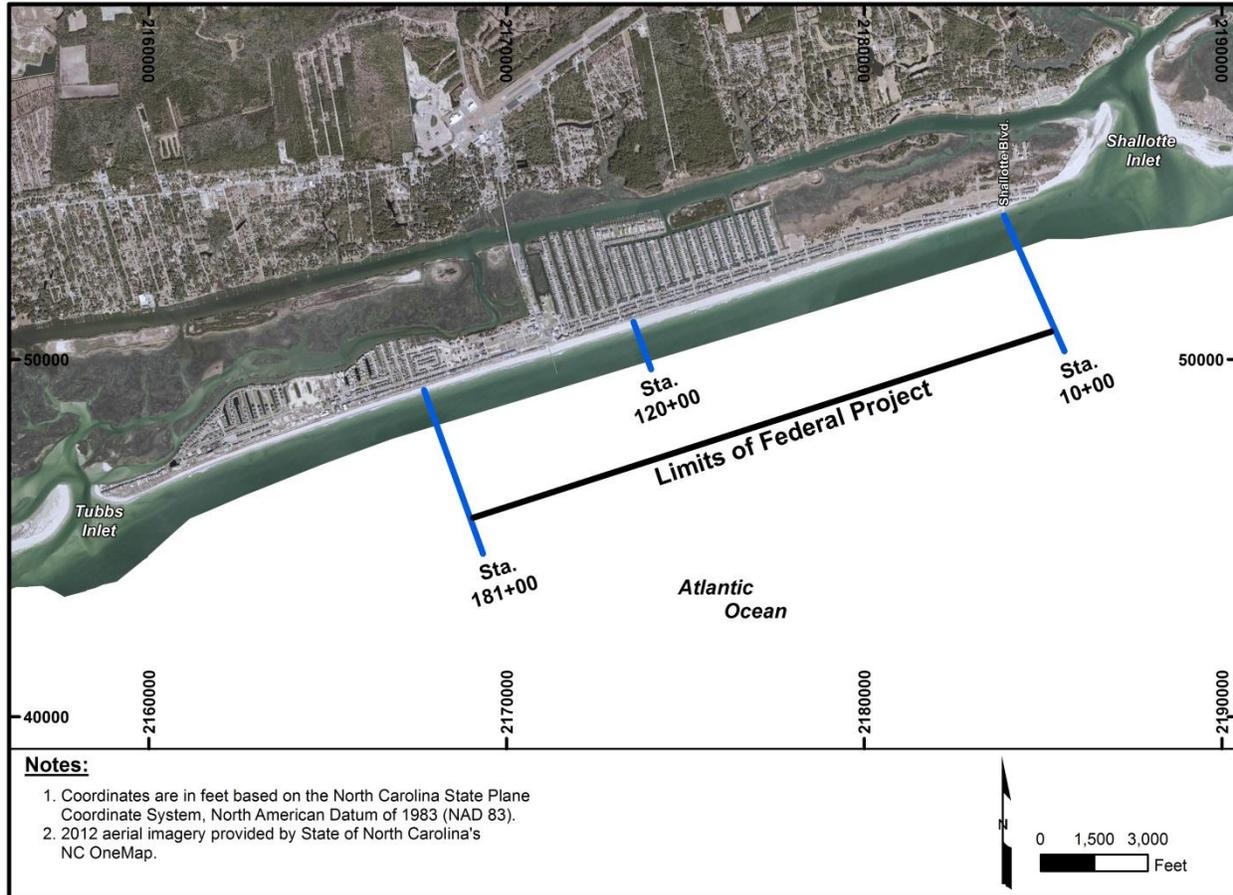


Figure 1. Location map showing Ocean Isle Beach and the limits of the federal project.

Brunswick County's beaches are a major economic engine to the tourist based economies of the local Towns, the County, and the entire southeastern North Carolina region. In 2001, the U.S. Army Corps of Engineers (USACE) constructed a federal beach fill project for storm damage reduction that covered 17,100 feet (3.25 miles) of the Town of Ocean Isle. The Ocean Isle Beach project is part of a larger project - the Brunswick County Beaches, North Carolina. The project was authorized by Public Law 89-789 (House Document 511/89/2) dated November 6, 1966 (Flood Control Act of 1966). The Town of Ocean Isle Beach is the project sponsor. As originally authorized, the project consisted of a main fill area with a 25-foot wide dune with a crest elevation of 9.5 ft. NGVD and a 50-foot wide berm constructed to 7 ft. NGVD with transition zones on either end. The authorization also included periodic nourishment of the project with the nourishment interval of approximately three (3) years. Fill material for the

proposed project was identified within Shallotte Inlet. Figure 2 shows a map of the approved borrow area for the federal project. Initial construction of the project in 2001 dredged 1.6 million cubic yards of sand from the inlet borrow area. Maintenance events constructed since the 2001 initial construction have also utilized the inlet borrow area.

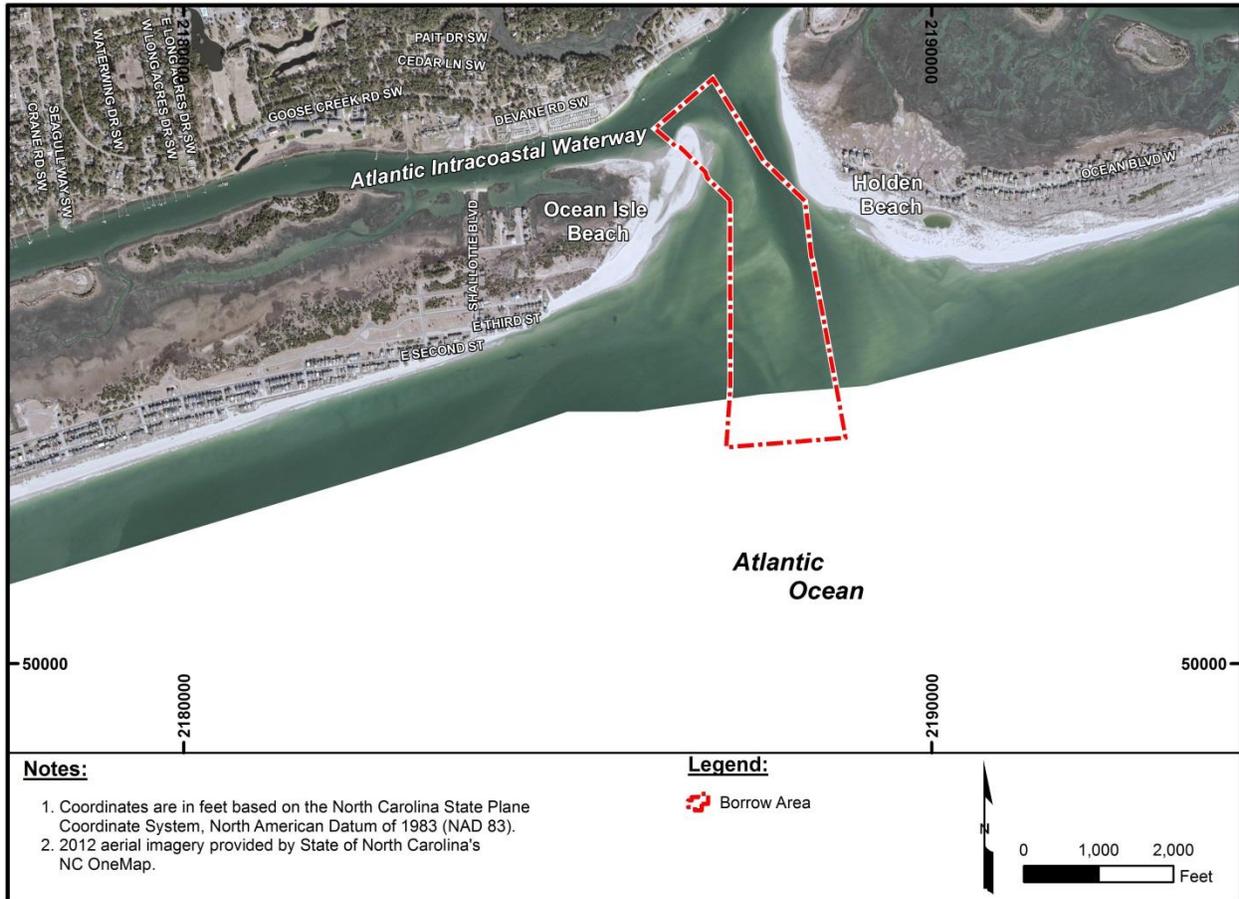


Figure 2. Map of approved borrow area for the federal project at Shallotte Inlet.

The eastern end of Ocean Isle Beach between Shallotte Boulevard (Station 10+00) and Shallotte Inlet was not included in the federal project due to the predicted high rates of loss that would occur from beach fill placed in this area. Based on the USACE economic evaluation, the cost of protecting the extreme east end of the island exceeded the value of the development and infrastructure it would protect, and was therefore excluded from the federal project. Although the western and central portion of the federal storm damage reduction project has performed very well, the eastern end of the island has seen continued erosion since initial construction in 2001 despite substantial beach nourishment efforts. The federal beach nourishment project was unable to provide adequate and dependable protection against the chronic erosion and the damage caused by coastal storms. The Town and affected property owners have undertaken a concerted effort to lessen the erosional impacts by installing sandbag revetments along approximately 1,400 feet of shoreline, beginning at a point west of Shallotte Boulevard and extending to the east end of the development.

An evaluation of the shoreline and volume changes along Ocean Isle Beach conducted by Coastal Planning & Engineering of North Carolina (CPE-NC) indicated that effects associated with Shallotte Inlet are the primary cause of the high rates of erosion along the eastern end of Ocean Isle Beach (Raleigh Street and east) (CPE-NC, 2012). The Shallotte Inlet and associated ebb tide delta contribute to the high erosion rates on the eastern end of Ocean Isle Beach via higher levels of wave energy striking the shore just west of Shallotte Inlet, flood tidal currents concentrated close to shore, and wave refraction patterns around the ebb tide delta.

Given the failure of past efforts to address the erosion problem on the east end of the island with beach nourishment and temporary sandbag revetments, construction of a terminal groin has been proposed as an effective way to slow the rate of erosion. During the 2011 legislation session, the North Carolina Legislature passed Session Law 2011-387, Senate Bill 110, which allows consideration of terminal groins adjacent to tidal inlets. This legislation included a number of provisions and conditions that must be met in order for the terminal groin to be approved and permitted by both the Federal and State government. One such requirement is that the “fillet” that would result on the up-drift side of the terminal groin be pre-filled with beach compatible material.

The State of North Carolina has adopted specific sediment criteria for the emplacement of beach fill along the oceanfront shoreline (15A NCAC 07H.0312). These rules were adopted by the North Carolina Coastal Resource Commission (CRC), in February 2007, and later amended in April 2008 and September 2013. The material used to pre-fill the terminal groin fillet must adhere to these standards in order to obtain a Major CAMA Permit for the project.

The proposed source of sand for the terminal groin project is the existing authorized borrow source within Shallotte Inlet that was used by the USACE for the Federal Storm Damage Reduction Project for Ocean Isle Beach (Figure 2). Recent changes to the State Technical Standards for Beach Fill Projects (15A NCAC 07H.0312) allow for an applicant to use two sets of sampling data (with at least one dredging event in between) from maintained navigation channels or sediment deposition basins within the active nearshore, beach or inlet shoal system to characterize material for subsequent nourishment events from those areas. This report examines two sets of sampling data collected by the USACE within the Shallotte Inlet Borrow Area, and compares sediment characterization data from the borrow area with the existing beach sediment characteristics to verify that the proposed source of sand meets the State Technical Standards.

## **INVESTIGATION SEQUENCING**

A systematic approach to marine sand searches has been developed over the years by the CPE-NC Coastal Geology and Geomatics team (*e.g.* Finkl, Khalil and Andrews, 1997; Finkl, Andrews and Benedet, 2003; Finkl, Benedet and Andrews, 2005; Finkl and Khalil, 2005). In a comprehensive marine sand search, the investigation is typically divided into three (3) sequential

phases. This phased approach can be modified to meet the scope of the investigation and accommodate the level of work previously performed. Regardless of the phases executed during a sand search, this investigation sequence is preserved in order to maintain efficiency and completeness to provide confident results.

Phase I investigations typically consist of a comprehensive review of the project area and sediment resources in the vicinity of the project area. This desktop study examines previously collected information within the geologic context of the investigation area in order to identify features having the highest potential of containing project-compatible sand. The geological background of the area is assessed to identify the geomorphic features that may contain material suitable for the project. Information related to previously investigated areas, potential sand resources and borrow areas, is compiled and related back to the geomorphic features. Geophysical and geotechnical data previously collected within these areas, as well as any reports discussing the findings, are then reviewed. Based on this analysis, deposits potentially containing project-compatible material are identified. Due to the amount of existing data on the proposed sand resource for this project, no additional geophysical or geotechnical data has been collected to characterize the borrow source.

Phase II investigations usually consist of reconnaissance level geophysical and geotechnical surveys; however, as previously stated, additional data collection was not required for this investigation. Samples are also collected from the project area during this phase to characterize the project area/existing beach in terms of grain size, color and composition (*i.e.* how well the potential borrow area sediment matches the existing material in the project area).

Phase III typically consists of design level geotechnical and geophysical investigations, a cultural resource investigation, and borrow area design. No additional design level geotechnical or geophysical data collection were required for this investigation due to the pre-existing data available for the inlet borrow area. The USACE has previously conducted a cultural resource survey of the borrow area, so no additional cultural resource surveys were required (Southerly, pers. comm., 2014). For this investigation, Phase III consisted of an independent assessment of borrow area material. Sediment data and survey data provided by the USACE was evaluated, and a modified borrow area was designed based on sediment quality and environmental concerns. Proposed borrow area boundaries and excavation depths were developed from the data collected during the Phase I, II and III investigations.

## **PHASE I INVESTIGATIONS**

During the Phase I investigation, CPE-NC researchers conducted archival literature studies of Shallotte Inlet and the inner continental shelf area offshore of Ocean Isle Beach. Previously identified investigation areas, sand sources, developed borrow areas and historic geotechnical and geophysical data were compiled for the recipient beach. Much of this information was provided by the USACE Wilmington District associated with the Ocean Isle Beach Federal

Storm Damage Reduction Project. The information and data compiled during the Phase I investigation is discussed below.

### **Geological Background**

The southeastern coast of North Carolina is characterized by short barrier islands with an average length of five (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 ends adjacent to tidal inlets typically exhibit pronounced shoreline changes (repositioning of shorelines) associated with tidal inlet processes (migration, channel switching, sediment bypassing and opening/closing) (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.

Ocean Isle Beach is an east west trending (south facing ocean shoreline) barrier island located along the low energy flank of Cape Fear in Brunswick County, North Carolina. It is a mid-compartment barrier island located between the two subaerial headlands of Oak Island, North Carolina and Myrtle Beach, South Carolina. The shelf directly seaward of Ocean Isle Beach is primarily composed of Cretaceous aged (Meisburger, 1979) consolidated rock units partially covered by a thin veneer of mobile fine sand and muddy sand. Marden *et al.* (1999) described the outcropping hardbottom as the Rocky Point Member of the PeeDee Formation

Presently, twenty (20) inlets occur along the North Carolina coast. Five (5) of these are located north of Cape Lookout, which includes an inlet that opened during Hurricane Irene in August of 2011 between Oregon Inlet and Rodanthe, North Carolina, which has closed and reopened on several occasions since 2011. Eleven (11) are located in Onslow Bay. The remaining four (4), including Shallotte Inlet, are located in Long Bay. Shallotte Inlet is an ebb-dominated system, having a much larger ebb tide delta than flood tide delta (Marden, 1999). Low energy and relatively higher tidal ranges have been identified as the primary factors in establishing large ebb tide deltas and small flood tide deltas (Dean and Walton, 1973). A lack of accommodation space for a flood tide delta at Shallotte Inlet also restricts the size (Marden, 1999).

### **Previous Investigations**

In 1994, offshore vibracore samples were taken 1-3 miles off the shoreline of Ocean Isle Beach, immediately west of the present project area (USACE 1997a, p. A-14; pp. B11/12). The investigation area was selected to be near enough to the project site for dredging to be practical, but distant enough so that removal of material would not affect beach sediment transport processes. Most of the sediment in these samples were silty sand, clayey sand, or sandy clay. The USACE determined the material would be unsuitable for use as beach fill due to high turbidities resulting from the placement of silty or clayey materials (USACE 1997a, p. B-11). This work

determined that “. . . suitable borrow material seemed to occur only in erratic pockets, and the search for offshore borrow areas was abandoned without success.”

The USACE eventually identified Shallotte Inlet as the most promising source of sand for the Ocean Isle Beach federal project. Since 1994, the USACE has collected at least four (4) sets of vibracore data within Shallotte Inlet. Table 1 provides a summary of these investigations.

Table 1. Summary of Shallotte Inlet Vibracores

Number of Vibracores collected 1994	11
Number of Vibracores collected 1998	13
Number of Vibracores collected 2005	10
Number of Vibracores collected 2009	17

Current estimates suggest that approximately 264,000 cubic yards of sand may be required to fill the fillet associated with a terminal groin on the east end of Ocean Isle Beach. Independent analysis conducted by CPE-NC (2012), as well as discussions between CPE-NC and the USACE Wilmington District (Wutkowski, pers. comm., 2012), suggest the current borrow area could support both routine maintenance of the Federal Project and the construction and maintenance of the proposed terminal groin project. Actual volume calculations supporting this suggestion were conducted by CPE-NC and are discussed in the Phase III description below.

### **Targeted Sand Source**

The borrow area targeted as a sand source for the proposed terminal groin project at the east end of Ocean Isle Beach is a portion of the approved borrow area for the federal storm damage reduction project. The borrow area, which was used for the initial construction and subsequent maintenance of the federal project, is contained within the Shallotte Inlet complex as shown in Figure 2. The borrow area extends from the Atlantic Intracoastal Waterway through the inlet gorge and out across the ebb tide delta to a depth of -15.0 ft. MLW. The entire area was designed to be dredged to a depth of -15.0 ft. MLW (-17.97 NAVD88) (USACE, 2002).

### **Cultural Resources**

During the process of designing the federal storm damage reduction project at Ocean Isle Beach, the USACE coordinated a submerged cultural resource investigation of the Shallotte Inlet borrow area in 1992 and 1995. The two separate cultural resource surveys were conducted in Shallotte Inlet by Tidewater Atlantic Research, Inc. (TAR). Both surveys deployed magnetometer and high resolution side scan sonar units in an effort to identify submerged artifacts of cultural or historical significance. Although, several ships were identified as potentially wrecked/lost in Shallotte Inlet during the historical review, no targets were located during the course of either survey. TAR concluded that no additional cultural resource investigations were necessary to perform dredging operations within the surveyed areas in 1992 and 1995 (Watts 1992, 1995).

## PHASE II INVESTIGATIONS

### Beach Assessment

The suitability of a sand source for beach nourishment is directly linked to the characteristics of the recipient beach. State and federal regulatory agencies require that sand resources used for nourishment be “beach compatible”, that is, “similar” to sand existing in the project area. Qualities such as grain size, silt content, granular content, gravel content, color, and mineralogical composition are taken into account. It is, therefore, important to accurately characterize existing beach sediments during a sand search investigation. This procedure allows researchers to target potential sand resources that are most similar to the recipient beach. The compatibility of material to be placed on North Carolina’s beaches is governed by Rule 15A NCAC 07H .0312. Section 1 of the rule describes how the recipient beach is to be sampled and evaluated. This evaluation included beach profiles (Sub-Section c), sand sampling and assessment of percent by weight fines, granular, and gravel (Sub-Sections d, e, and f), an assessment of the percent by weight calcium carbonate (Sub-Section g).

**Beach Profiles:** The Town of Ocean Isle Beach contracted with McKim and Creed, Inc. to conduct beach profile surveys along the eastern end of the Town. On June 10, 2013, McKim and Creed surveyors conducted beach profile surveys along 13 profiles from Shallotte Inlet to USACE baseline station 20+00 (approximately 1,000 ft. west of Shallotte Blvd.) (Figure 3).

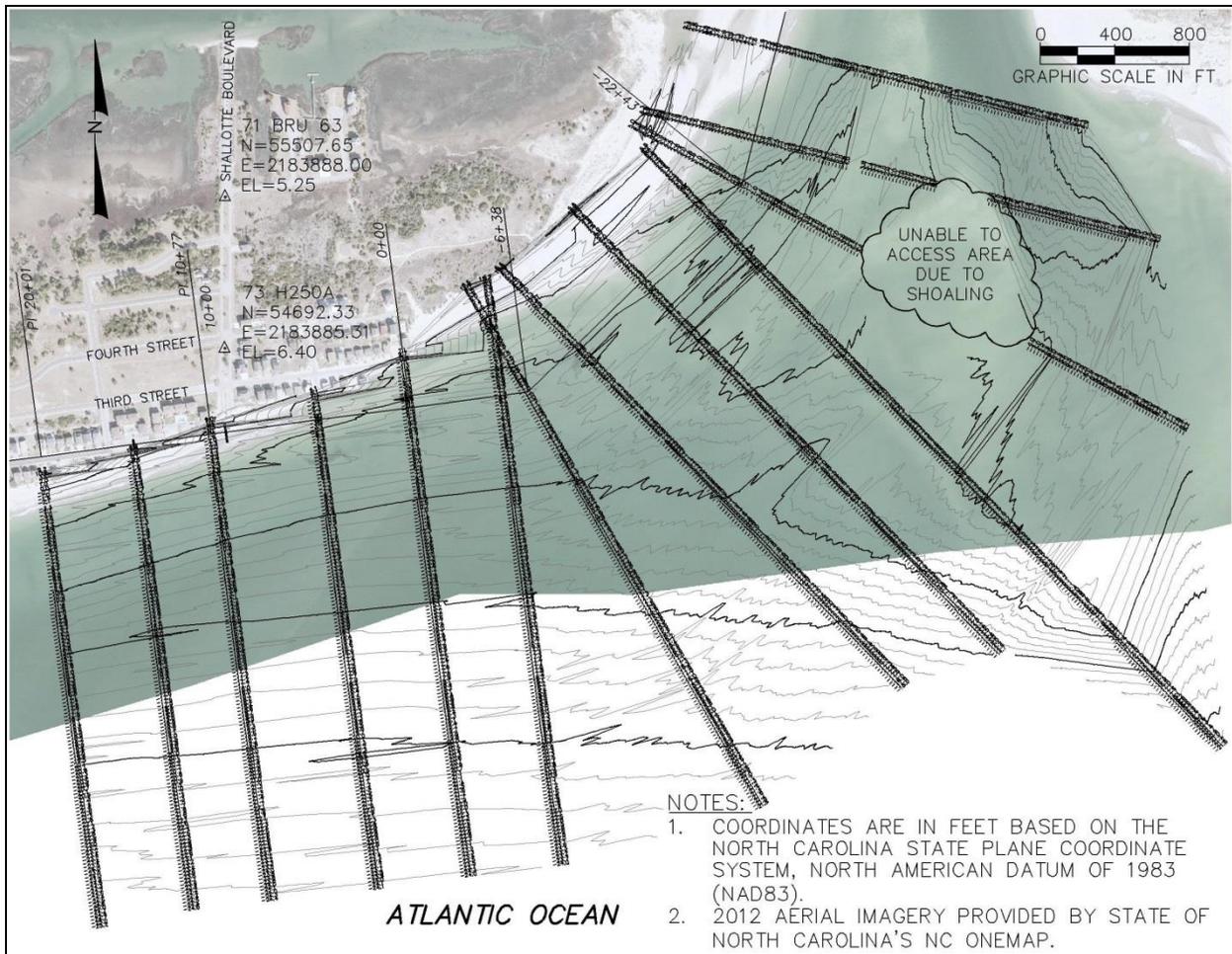


Figure 3. Map depicting the location of beach profile surveys conducted by McKim and Creed in June, 2013 (Modified from Plan drawing VT101-005160006 by McKim and Creed)

**Sand Sampling and Grain Size Analysis:** During preparation of the General Reevaluation Report for the Ocean Isle Beach project, completed in 1994, the USACE collected beach samples along three (3) profiles within the federal project area. Samples were collected from the dune out to a depth of -30 ft NGVD29. The state sediment standards dictate a specific number of samples along at least five (5) profiles within the project area (15A NCAC 07H.0312)(1)(c and d). However, 15A NCAC 07H.0312 (1)(i) provides language that would allow special consideration of projects which were constructed prior to the adoption of the rules.

In order to meet state requirements, CPE-NC obtained samples along four (4) additional profiles on the east end of Ocean Isle Beach. On April 5, 2013, April 17, 2013 and January 23, 2014 CPE-NC collected beach samples and nearshore sediment samples along four (4) profiles (0+00 (OIB000), 10+00 (OIB010), 25+00 (OIB025), and 60+00 (OIB060) (Figure 4). Along these profiles, samples were collected from the Dune, Toe of Dune, Midberm, Berm Crest, Mean High Water (MHW), Mean Tide Level (MTL), Mean Low Water (MLW), Trough, Bar Crest, and four (4) additional depths evenly spaced between the Bar Crest and -20 ft. NAVD. Sediment

characteristic data obtained by the USACE along baseline station 40+00 were also used to determine composite beach characteristics.

During sieve analysis, dry and washed Munsell colors were noted. Sieve analyses were conducted on all sediment samples in accordance with American Society for Testing and Materials (ASTM) 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 Materials Designation D1140-00 was followed (ASTM, 2006). Mechanical sieving was accomplished using calibrated sieves with a gradation of half phi intervals. Additional sieves representing key ASTM sediment classification boundaries were included to meet North Carolina Division of Coastal Management standards (Table 2). Weights retained on each sieve were recorded cumulatively.

Grain size data were entered into the gINT<sup>®</sup> software program, which computes the mean and median grain size, sorting, and fine (< 0.0625 mm) percentages for each sample using the moment method (Folk, 1974).

When combined with the historic USACE samples collected along profile OIB040, analysis of the beach samples capture the three-dimensional spatial variability of the sediment characteristics including grain size, sorting and mineralogy within the natural system. Appendices 2 and 3 contain granulometric reports and grain size curves/histograms. Composites were created for each profile line as well as for each position along the beach profile. Composites are presented in Appendices 4, 5 and 6.

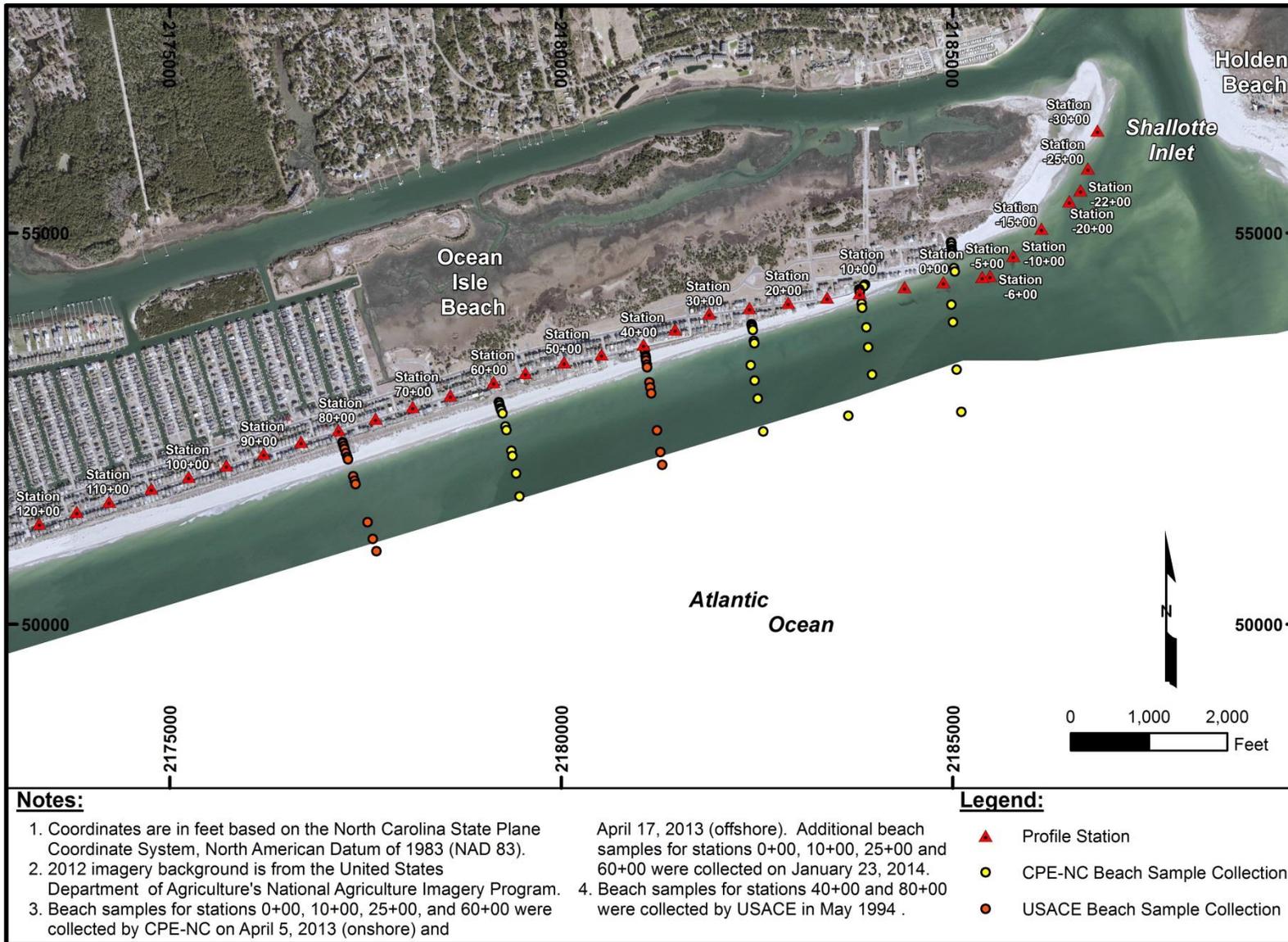


Figure 4. Map showing locations of the beach sand samples collected and used to determine existing beach characteristics.

Table 2. Sieve sizes used for grain size analysis. Classifications are based on percent retained in each sieve.

<b>Classification</b>	<b>Sieve Size (number)</b>	<b>Sieve Size (phi)</b>	<b>Sieve Size (mm)</b>
<b>gravel</b>	3/4"	-4.25	19.00
	5/8"	-4	16.00
	7/16"	-3.5	11.20
	5/16"	-3	8.00
	3 1/2"	-2.5	5.60
<b>granular</b>	4	-2.25	4.75
	5	-2	4.00
	7	-1.5	2.80
	10	-1	2.00
	14	-0.5	1.40
<b>sand</b>	18	0	1.00
	25	0.5	0.71
	35	1	0.50
	45	1.5	0.36
	60	2	0.25
	80	2.5	0.18
	120	3	0.13
	170	3.5	0.09
	200	3.75	0.08
	230	4	0.06
<b>fine</b>	pan	-	-

Analyses of the samples collected from the existing beach by CPE-NC and the USACE indicate that sediment along the eastern end of Ocean Isle Beach has a mean grain size of 0.23mm. The percent by weight of fines (less than 0.0625 millimeters) for the sampled area is 1.34%. The percent by weight of granular (greater than or equal to 2 millimeters and <less than 4.76 millimeters) and gravel (greater than or equal to 4.76 millimeters) for the sampled area is 0.43% and 0.40%, respectively. The wet Munsell Color value ranges from 4 to 7, with a typical value of 5. The dry Munsell Color value ranges from 6 to 8, with a typical value of 7. These characteristics represent the existing beach, which is a composite of the characteristics of material that has been placed on the beach during past nourishment projects and native beach sediment.

**Calcium Carbonate Analysis:** Calcium carbonate content was determined on composite beach samples collected by CPE-NC in 2013 and 2014. Calcium carbonate content was determined by percent weight using the acid leaching methodology described in Twenhofel and Tyler (1941). Results were entered into the gINT<sup>®</sup> software and are displayed on the composite granulometric reports (Appendix 5) and in the Carbonate Analysis Results spreadsheet (Appendix 12). The carbonate content of the existing beach ranges from 5 to 7% with a composite value of 6%.

## PHASE III INVESTIGATIONS

### Investigation Details

The North Carolina state standards (15A NCAC 07H.0312) (2) (e) allow an applicant to use two sets of sampling data with at least one dredging event in between to characterize material for future nourishment events. If both sets of data are shown to be compatible as stated in the Rule, subsequent projects can use the material from the same borrow area. In addition, section (3) (a) of the rule states that sediment completely confined to the permitted dredge depth of a maintained sediment deposition basin within an inlet shoal system is considered compatible if the average percentage by weight of fine-grained (less than 0.0625 millimeters) sediment is less than 10%. These changes took effect in September 2013 after beach sampling and analysis were completed. Although compatibility of the borrow area as it relates to the state sediment criteria only require sediment to contain less than 10% by weight fines, this analysis considers color, grain size, and percent calcium carbonate as well.

The USACE developed composite information for the approved borrow area within Shallotte Inlet based on vibracores collected in 1994 (USACE, 1997c). These data were used in the General Reevaluation Report (GRR) study conducted by the USACE to determine preliminary borrow areas (USACE, 1997b). The USACE later collected additional vibracores in 1998 as part of the Preliminary Engineering and Design (PED) for the initial construction of the Ocean Isle Beach project. CPE-NC used available data from those vibracores collected in 1998 to establish a pre-2001 composite for the area dredged in 2001. Likewise, vibracores collected by the USACE in 2005 and 2009 were used to establish after-dredge composites for the same area. In order to comply with the state Rule, specifically Section (2) (e), the borrow area proposed by CPE-NC as a result of this investigation is limited to the area dredged during the initial construction of the Ocean Isle Beach federal project in 2001. This area is slightly different from the approved borrow area established in the GRR as shown in Figure 5.

### Borrow Area Bathymetry

The USACE has conducted numerous hydrographic surveys of the borrow area in Shallotte Inlet associated with the federal beach fill project for storm damage reduction at Ocean Isle Beach. Figure 2 shows the location of the approved borrow area for the federal project. CPE-NC used historic pre- and post-construction surveys to determine the locations in which dredging occurred in the borrow area during initial construction and two subsequent maintenance events. Initial construction of the project took place in 2001. The first maintenance event was constructed between December 2006 and January 2007. The second was constructed between April and May 2010. Figure 5 shows the outline of the areas dredged during initial construction and the maintenance events conducted in 2006/2007 and 2010.

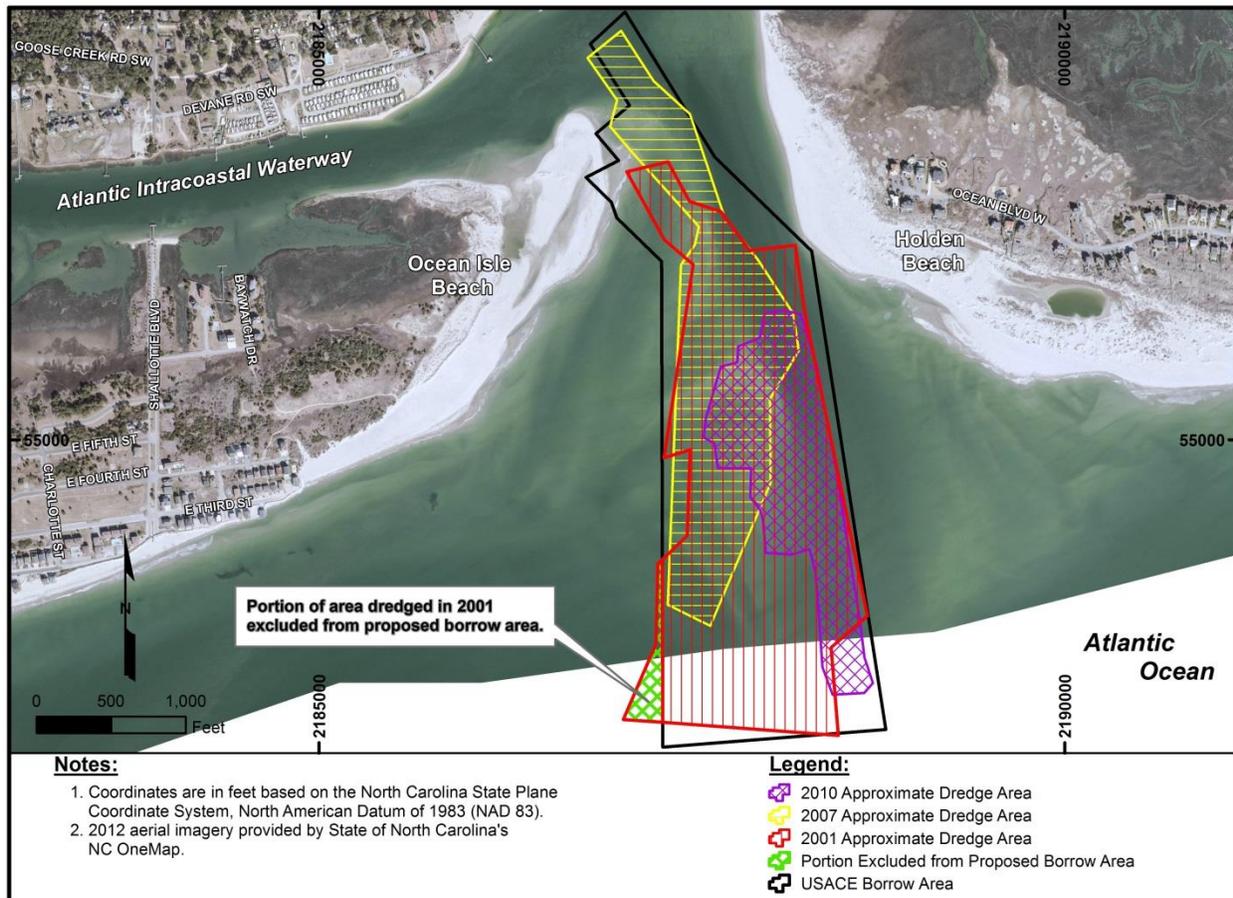


Figure 5. Map depicting the estimated location of areas dredged during initial construction (2001) and subsequent maintenance events (2006/2007 and 2010).

In preparation for a third maintenance cycle conducted by the USACE in the spring of 2014, the USACE conducted a pre-construction survey of the borrow area in July and August 2013. This data was used by CPE-NC to create a bathymetric surface to be used to calculate the current volume of material available within the borrow area.

### Vibracore Analysis

**Pre-2001 USACE Vibracores:** The USACE collected vibracores at 11 locations within Shallotte Inlet in 1994 during their investigations to delineate borrow areas for the federal project (Figure 6). The material in the core samples was described as primarily gray or tan poorly graded sand with little silt content, underlain in some cases by layers of clay or silt. Some sand layers were described as containing pockets of clay and gravel sized shell. From these core data, the USACE developed composite values for the textural properties of the material in Shallotte Inlet. The mean grain size of the material above -15 ft. MLW (-17.97 ft. NAVD) was stated as 0.38 mm with a standard deviation of 0.97 and a silt content of 1.1% (USACE, 1997c). Appendix 7 contains vibracore logs of the 11 vibracores collected by the USACE in 1994.

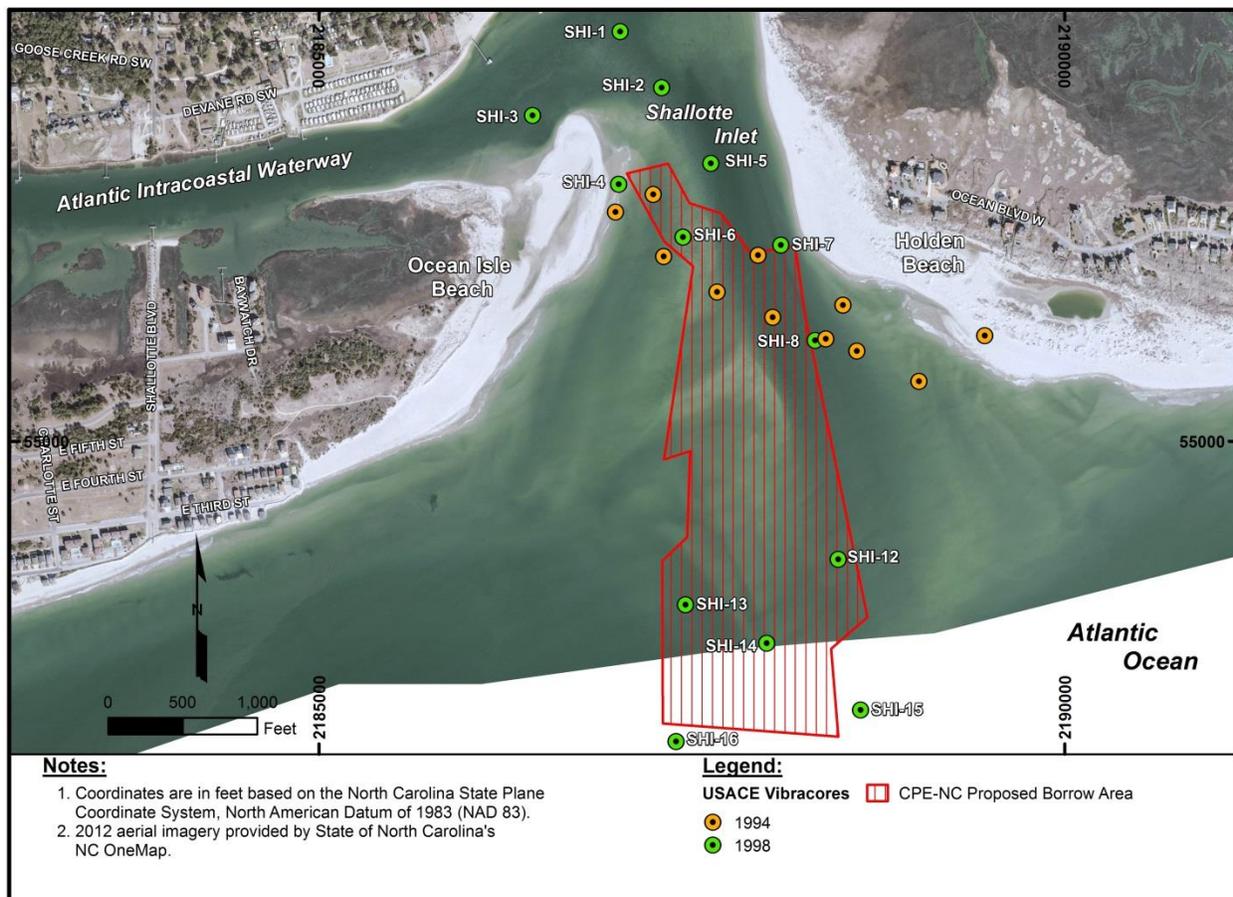


Figure 6. Map depicting the approximate area dredged in 2001 by the USACE and vibracores collected by the USACE in 1994 and 1998.

Although the 1994 USACE data provide general information on the sediment characteristics in the vicinity of the federally approved Shallotte Inlet borrow area, these data do not include samples taken from the outer portion of the ebb shoal. In order to determine sediment characteristics that better represent the entirety of the area dredged by the USACE in 2001, CPE-NC used six (6) of the 13 vibracores collected by the USACE in 1998 to determine the percent silt by weight (Figure 6). The six (6) vibracores are SHI-6, SHI-7, SHI-8, SHI-12, SHI-13, and SHI-14. Appendix 8 contains vibracore logs, granulometric reports, and grain size curves/histograms for the 13 vibracores collected by the USACE in 1998. Composite median grain size and percent silt content were computed for each of the six (6) vibracores representing the sand borrow area by calculating the weighted average (sample weighted by representative lengths of the sampled layer within the core). Composite statistics for the dredged area were compiled by averaging the weighted results for those six (6) cores within the lateral and vertical limits of the dredged areas. Some values of percent silt were estimated from the provided granulometric curves based on the #200 standard sieve. These estimated values are denoted by red text in the composite spreadsheet (Appendix 9).

The composite median grain size for the area analyzed using the 1998 vibracores is 0.16 mm, with a percent fines by weight of 1.3%.

**Post-2001 USACE Vibracores:** CPE-NC used 12 vibracores collected in 2005 and 2009 within the area dredged during the 2001 initial construction to determine composite sediment characteristics of the material that infilled the area following the 2001 initial construction (Figure 7). Appendix 10 contains vibracore logs, granulometric reports, and grain size curves/histograms for all 27 vibracores collected by the USACE in 2005 and 2009. Composite mean and median grain size, as well as percent by weight fine-grained sediments, were computed for each vibracore by calculating the weighted average (sample weighted by representative lengths of the sampled layer within the core). Composite data is included in Appendix 11. The composite statistics for the area were compiled by averaging the weighted results for all cores within the lateral and vertical limits of the borrow area. The composite mean grain size for the area analyzed using the 2005 and 2009 vibracores is 0.36 mm. The 12 vibracores used in the composite indicate that the sediment within the area dredged contains 1.95% fine-grained sediment by weight. Although no Munsell color values were available, the 2005 and 2009 vibracore logs describe the sediment as being tan to gray and tan to light gray, respectively.

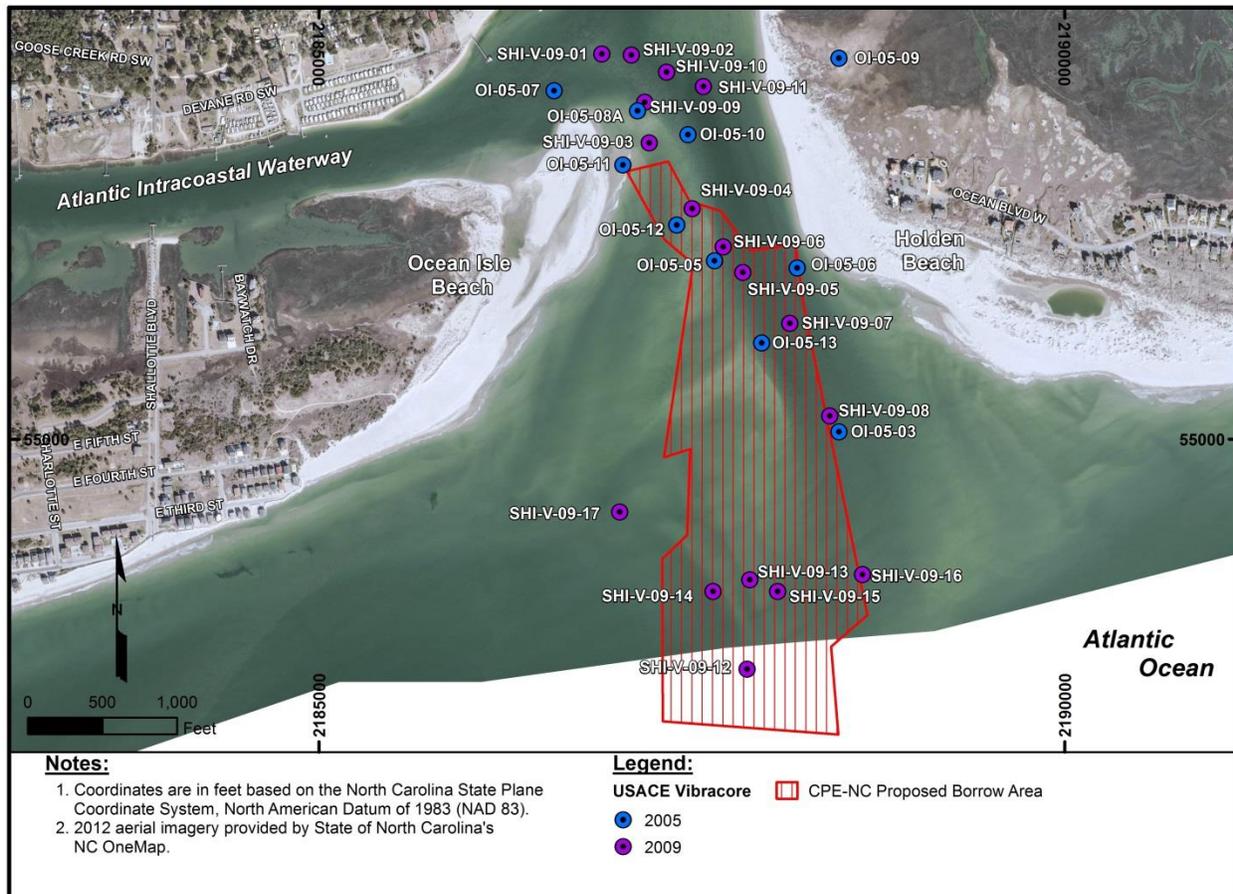


Figure 7. Map depicting the approximate area dredged in 2001 by the USACE and vibracores collected by the USACE in 2005 and 2009.

## Compatibility Analysis

Given the proposed borrow area is completely confined to the authorized dredge depth of a maintained sediment deposition basin within the inlet shoal system, compatibility as defined by the rule (15A NCAC 07H.0312), is primarily defined in Section (2) (e) and (3) (a). Section (2) (e) allows an applicant to use previously collected data to establish sediment characteristics where both a pre-dredge and a post-dredge data set exist. Section (3) (a) states that compatibility for sediment completely confined to the permitted dredge depth of a sediment deposition basins within the inlet shoal system is defined as having an average percentage by weight of fine-grained (less than 0.0625 millimeters) sediment less than 10%. As stated above, the composite fine-grained sediment within the footprint of the area dredged in 2001 based on the data from six (6) vibracores collected in 1998 (Appendix 9) is 1.3%. The composite fine-grained sediment within the same footprint of the area dredged in 2001 based on data collected after the dredging event (Appendix 11) is 1.95%. The composite percent fine grained material for the existing beach sampled along the east end of Ocean Isle beach is 1.34%. Therefore, sediment confined to the footprint of the area dredged in 2001 in Shallotte Inlet is compatible in accordance with rule 15A NCAC 07H.0312.

Sediments recovered within the vertical boundaries of the proposed borrow area were described by the USACE as having a tan and or gray color (USACE, 1997c; Catlin, 2009). The wet Munsell Color values for sediment samples collected by CPE-NC in 2013 and 2014, range from 5 (gray to olive gray) to 7 (light gray), with a typical value of 7 (light gray). The samples collected by CPE-NC in 2013 and 2014 represent the existing beach, which is a composite of the characteristics of material that has been placed on the beach during past nourishment projects and native beach sediment.

Vibracore data obtained from the 2005 and 2009 vibracores recovered from within the proposed borrow area indicate a percent carbonate by weight of 15.5%. The carbonate content of the existing beach ranges from 5% to 7% with a composite value of 6%.

## BORROW AREA DESIGN

The borrow area within Shallotte Inlet proposed for the Ocean Isle Beach terminal groin project was designed to be limited to the authorized federal borrow area (USACE, 1997c). This area is shown in Figure 5 as the “USACE Borrow Area” outlined in black. The entire borrow area was originally approved for a dredge depth of -15 ft. MLW (-17.97 NAVD88) (USACE, 2002). The conversion from MLW to NAVD88 is based on the NOAA benchmark 8661070, located at the Springmaid Pier, in South Carolina (<http://tidesandcurrents.noaa.gov/benchmarks/8661070.html>).

In order to comply with rule 15A NCAC 07H.0312 (2) (e), which allows an applicant to use two sets of sampling data with at least one dredging event in between to characterize material for future nourishment events, the proposed borrow area was also limited to the portion of the authorized federal borrow area dredged during the initial construction event in 2001. The

proposed borrow area for the Ocean Isle Beach terminal groin project, shown in Figures 6 and 7 “CPE-NC Proposed Borrow Area” outlined in red, has a total area of 83.1 acres.

An evaluation of vibracore data collected in 1998 as well as, 2005 and 2009 show the sediment in the proposed borrow area meet the criteria set forth in rule 15A NCAC 07H.0312. Furthermore, the Shallotte Inlet Borrow Area has been excavated and used for beach placement for subsequent maintenance events. Maintenance of the project was conducted in 2007, 2010, and 2014, during which material was dredged from the inlet borrow area and placed on the beach at Ocean Isle Beach.

Bathymetric data collected by the USACE in July and August 2013, during preliminary engineering and design work for the 2014 maintenance event, was used to determine volumes in the proposed borrow area. At the time of the survey, approximately 1,312,000 cy of sand were available within the proposed borrow area. Estimates available at the time of publication of this report indicate approximately 800,000 cy of sand were removed from this borrow area during the construction of the 2014 maintenance operation. Based on past performance of the project, the borrow area is expected to re-charge due to shoaling of the inlet complex.

## CONCLUSIONS

The proposed borrow area within Shallotte Inlet was designed to be confined to the footprint of both the federally authorized borrow area (USACE, 1997c), and the portion of the borrow area dredged during the initial construction of the project in 2001. The maximum dredge depth of the proposed borrow area is limited to the maximum dredge depth of the federally authorized borrow area, which is -15 ft. MLW (-17.97 NAVD88).

Section (3) (a) of rule 15A NCAC 07H.0312 states that sediment completely confined to the permitted dredge depth of a maintained sediment deposition basin within an inlet shoal system is considered compatible if the average percentage by weight of fine-grained (less than 0.0625 millimeters) sediment is less than 10%. An evaluation of vibracore data collected in 1998 as well as, 2005 and 2009 show the sediment in the proposed borrow area meet these criteria. Composite data for those vibracores within the proposed borrow area collected in 1998 indicate the percent by weight of fine-grained (less than 0.0625 millimeters) material within the proposed borrow area is 1.3%. Composite data for those vibracores within the proposed borrow area collected in 2005 and 2009 indicate the percent by weight of fine-grained (less than 0.0625 millimeters) material within the proposed borrow area is 1.95%. The composite percent fine grained material for the existing beach sampled along the east end of Ocean Isle beach is 1.34%.

Analyses of the samples collected from the existing beach by CPE-NC and the USACE indicate that sediment along the eastern end of Ocean Isle Beach has a mean grain size of 0.23mm. The composite median grain size for the area analyzed using the 1998 vibracores is 0.16mm. The composite mean grain size for the area analyzed using the 2005 and 2009 vibracores is 0.36mm.

Sediments recovered within the vertical boundaries of the proposed borrow area were described by the USACE as having a tan and or gray color (USACE, 1997c; Catlin, 2009). The wet

Munsell Color value ranges from 4 to 7, with a typical value of 5. The dry Munsell Color value ranges from 6 to 8, with a typical value of 7. These characteristics represent the existing beach, which is a composite of the characteristics of material that has been placed on the beach during past nourishment projects and native beach sediment.

Prior to the most recent maintenance event, which dredged material from the federally authorized borrow area in Shallotte Inlet, the proposed borrow area contained approximately 1,312,000 cy of fine-grained sand with trace silt and trace shell. Based on project estimates provided by the Town of Ocean Isle Beach, approximately 800,000 cy of sand were placed on the beach during the 2014 maintenance event, suggesting sufficient volumes of sand will exist to construct the proposed terminal groin project. The proposed borrow area for the Ocean Isle Beach terminal groin project has a total area of 83.1 acres.

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