Town of Topsail Beach:

30-Year Beach Management Plan

Topsail Beach, North Carolina

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24 June 2011

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FINAL REPORT

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1 Introduction

1.1 Purpose

The Town of Topsail Beach, North Carolina recently completed its first beach nourishment project. The project entailed the placement of approximately 1,000,000 cubic yards (CY) of sand along 4.5 miles of beachfront. This project was originally implemented to provide storm protection to the Town's properties while seeking authorization of a 50-Year Federal Project. However, uncertainty in current and future federal budgets and policies necessitates a local commitment to beach management and funding to provide for the long-term maintenance of the Town's beaches.

For most beach communities, the beach itself is the centerpiece of the community and as such it needs to be maintained. The main concern with any infrastructure maintenance program is usually finding and organizing the necessary funding. The Town has made a substantial long-term commitment to funding its beach nourishment project and has maintained a dedicated local funding source. Because a properly maintained beach helps reduce storm-related damage to existing structures, the Federal Emergency Management Agency (FEMA) maintains a program for assisting communities in restoring their maintained beaches when excessive erosion occurs during major storm events. In order to be eligible for this program, the Town must meet several criteria:

1. The beach must be constructed of imported sand (of proper grain size) to a designed elevation, width, and slope.
2. A maintenance program involving periodic renourishment with imported sand has been established and adhered to by the Town.
3. The maintenance program preserves the original design.

To document eligibility of the beach as a designed and maintained facility, the Town should be able to provide the following information to FEMA:

1. All design studies, plans, construction documents, and as-builts for the original nourishment.
2. All studies, plans, construction documents, and as-builts for every renourishment.
3. Documentation and details of the Maintenance Plan, including how the need for renourishment is determined and funded.
4. Pre- and Post-storm profiles of that extend at least to the seaward edge of the sub-aqueous nearshore zone (closure depth, usually –15 to –20 feet).

From FEMA Disaster Assistance Fact Sheet DAP580.9

The objective of this document is to establish a long-term management program for the Town of Topsail Beach. A goal of the management plan is to combine interests regarding the state of the beach and inlet/interior channels into a regional strategic plan that works in concert with one another to mutually benefit all areas.

1.2 Study Area

The Town of Topsail Beach is one of three coastal communities located on the 22-mile extent of Topsail Island in Pender County, North Carolina (Figure 1). Topsail Island, the second longest barrier island within the Onslow Bay section of southeastern North Carolina, is bordered by New River Inlet to the northeast and New Topsail Inlet to the southwest. New Topsail Inlet separates developed Topsail Island from the undeveloped 3.7-mile long, barrier island of Lea Island (Figure 2). The island has a northeast to southwest orientation leaving the island vulnerable to impacts from frequent winter storm events.

Figure 1. Map depicting study area and surrounding coastal zone.

Topsail Island is generally low in topography and protected by a narrow, (< 10 ft wide) single foredune. Island width averages approximately 900 ft. It is also situated within a recurring overwash zone. Storms over the past 65 years have caused extensive damage to the island, destroying infrastructure and transporting sand from the oceanfront beach across the island to the marsh and sound creating overwash fans. The Town of Topsail Beach is situated within the southern 5.0-mile extent of Topsail Island and is bordered to the north by Surf City, to the west by Topsail Sound, and to the south by New Topsail Inlet. The island is accessible to the public by Highways 50 and 210 with Highway 50 being the only entry road to the Town of Topsail Beach. The Town's geographic coordinates are Latitude 34° 22'10" N; Longitude 77° 37'30" W (NAD83).

1.3 Background

The Town of Topsail Beach has experienced substantial shoreline erosion, exacerbated by multiple direct and near direct encounters with tropical storm systems. In order to mitigate loss of property and infrastructure, a Federal Storm Damage Reduction Project was authorized under the Water Resources Development Act (WRDA) of 1992. In November 1989, the United States Army Corps of Engineers (USACE) released a Final Environmental Impact Statement (FEIS) detailing the proposed federal beach nourishment project and preferred borrow sources. Federal funds were not secured for the project however, and the project became inactive when the Town withdrew its support in 1994 due to funding limitations. The Wilmington District completed a General Reevaluation Report (GRR) of the federal project and the combined GRR/EIS was released for final public review in August 2008.

Due to the expected timeline associated with re-authorization of the federal project, the Town applied for a Department of the Army (DA) permit to conduct a privately funded interim beach nourishment project. The USACE released a supplement to the FEIS (SFEIS) detailing the proposed project on April 10, 2009. Several borrow source alternatives were considered during the development of the SFEIS including the existing federal navigation channels (i.e. Topsail Creek, Connector Channel, and Banks Channel) and existing federal disposal areas. It was determined, based on the information available at the time, that the volume of material that could be removed from within the limits of the authorized navigation channel was not sufficient to meet the interim shore protection needs. It was also determined that the disposal areas along the Atlantic Intracoastal Waterway (AIWW) did not contain enough material meeting the North Carolina sediment criteria to complete the proposed nourishment project. Thus, alternatives involving these options were not carried forward.

A Record of Decision (ROD) completing the National Environmental Policy Act (NEPA) process was signed on June 12, 2009. A DA permit was issued to the town on June 15, 2009 to place approximately 1,000,000 CY of beach quality sand along the 24,700 linear feet of developed shoreline on Topsail Beach from an ocean borrow area, designated as “Borrow Area X”, located immediately southeast of New Topsail Inlet.

The unexpectedly high bids received during the contract procurement process in 2009 and delays in project implementation prompted the Town to re-investigate alternative sand sources. As a part of this effort, the Town contracted Gahagan & Bryant Associates of NC, PLLC (GBA) to conduct more detailed vibracore surveys of disposal areas along the AIWW as well as some areas within the existing federal channels. GBA also examined recent hydrographic surveys of the existing federal channels. This new information revealed that removal of material accumulated in the existing federal channels within Topsail Creek, Connector Channel, and Banks Channel combined with removal of suitable material from within two federal disposal areas along the AIWW would generate adequate volumes of material suitable to complete the beach nourishment project.

The Town proposed to modify its DA permit to eliminate the offshore area, “Borrow Area X” as a sand source for the project and instead utilize material from the above-mentioned federal channels and disposal areas. The Town asserted that utilizing these inland borrow sources would result in substantial cost savings with less environmental impacts and would fully meet the Town’s interim beach nourishment needs. To minimize environmental impacts, the Town proposed to limit borrow activities to only that material accumulated within the authorized dimensions of the federal navigation channels and within two active USACE disposal areas, owned by the State of North Carolina, and located within the USACE’s AIWW easement. Regularly conducted federal channel maintenance activities are currently authorized to utilize portions of the proposed beach nourishment project area for disposal.

During the winter of 2011 the Town of Topsail Beach conducted their first beach nourishment project with the placement of approximately 1 million CY of sand across the oceanfront beach.

2 Physical Processes

2.1 Regional Geologic Setting

The southeastern coast of North Carolina, from Cape Lookout to the South Carolina border, is underlain by geologic units ranging in age from Upper Cretaceous to Pliocene (SNYDER *et al*., 1994). Onslow Bay shelf sediment cover has been classified as residual (i.e. material derived from the erosion of underlying geologic units) by MILLIMAN *et al*. (1972). Offshore sediment cover is usually thin (< 6 ft in most areas) and relatively sand-poor. Widespread exposures of rock exist across the shoreface. A deficiency of Holocene sediments in Onslow Bay exists due to a lack of fluvial input and sediment exchange with neighboring Raleigh Bay and Long Bay (CLEARY and PILKEY, 1968 and RIGGS *et al*., 1995).

Spits and narrow barrier islands comprising the coastline of Onslow Bay overlie older geologic units across the shoreface (CLEARY and HOSIER, 1987; RIGGS *et al*., 1995). RIGGS *et al*. (1995) described a paleo-drainage system consisting of large-scale river channels incised into Tertiary units in the region. This drainage pattern has dictated the formation of headland and non-headland segments currently comprising the area. Headlands exist where the underlying rock units outcrop as submarine features across the shoreface. Geologic units extend beneath a barrier island and become exposed on the shoreface, forming a headland. One such headland characterizes a portion of shoreface along North Topsail Beach. Non-headland shoreline segments are common in this region. Surf City and Topsail Beach are situated upon a non-headland shoreline segment and underlain by inlet-fill or transgressive sequences (CLEARY *et al*., 2006).

2.2 Topsail Beach Geologic Setting

Limestone and siltstone units of Oligocene age form the outcrop and subcrop units off Topsail Beach (MCQUARRIE, 1998; HDR and CLEARY, 2002).   The shoreface in the region is characterized by paleo-fluvial channels of Holocene and Pleistocene age incised into underlying rock units, notably the Oligocene siltstone sequence. A majority of the channels are filled with estuarine mud and silt deposits.

Several distinct zones of seafloor morphology exist offshore Topsail Beach. Across the northern portion of the shoreface a variable distribution of low-relief, limestone hardbottoms are covered by a thin layer of gravel and sand. Exposed limestone offshore the southern 2 miles of Topsail Beach is extensive. Concentrations of channel-like features flank the hardbottom areas and are floored with rippled, very coarse shell and lithic gravels. South of New Topsail Inlet the shoreface is underlain by Oligocene siltstone (CLEARY *et al*., 2006).

Sediment cover in the area is intermittent and thickness varies greatly. Most sand units measure less than 1.5 ft in thickness. Gravel-rich units are prevalent and constitute a major fraction of the sedimentary concentrations near hardbottoms. Thicker concentrations (> 6 ft) of highly irregular Holocene sediment are mainly situated in depressions amongst limestone hardbottoms and underlain by siltstone (CLEARY *et al*., 2006).

2.3 Wave Climate and Littoral Transport

Topsail Island is situated within a mixed energy hydrodynamic setting. Mean wave height is 3.3 ft and mean tidal range is 3.0 ft (CLEARY, 1994 and USACE, 2006). Annually, the most frequent occurring wave heights range from 1.6 to 3.2 feet. During winter months, the most frequent wave heights range from 1.6 to 4.9 ft due to storms and easterly to northeasterly approaching waves increase in occurrence. Waves during the summer months propagate from a southeasterly direction and often reach 1.0 to 3.0 ft in height. Tropical systems, although infrequent, can generate waves exceeding 15.0 feet (USACE, 2006).

A USACE study (1989) determined the dominant direction of wave propagation originates from the south-southwest and accounts for over half the annual wave energy. The USACE estimated that 55% of the 654,000 CY/yr gross rate of sediment transport across New Topsail Inlet moves in a northerly direction (CLEARY, 1994; JARRETT, 1976). Sediment transport modeling across the length of Topsail Island indicates an average net sediment transport of approximately 200,000 CY/yr to the north in the vicinity of Topsail Beach. This northerly sediment transport is consistent with the findings of the August 1992 Design Memorandum for the USACE Integrated GRR and EIS Shore Protection Project, which reported a northerly transport rate of 325,000 CY/yr for Topsail Beach (USACE, 2006).

2.4 Storm Events

Storms over the past 65 years have caused extensive damage to the island, destroying infrastructure and transporting sand from the oceanfront beach across the island to the marsh and sound creating overwash fans. Topsail Island is located along major historic storm tracks, and as a result has been repeatedly impacted by tropical and extra-tropical storms (Figure 3). Storm activity between 1944 and 1962 and in the late 1980's was significant and caused extensive damage island-wide. Hurricane Hazel (1954) and the Ash Wednesday Storm of 1962 were significant events causing massive damage. Hurricane Hazel destroyed approximately 90% of the buildings in existence on the island. That storm generated a 9.5 ft storm surge above mean sea level (MSL). The island's average elevation was 8.9 ft above MSL (CLEARY and PILKEY, 1996). Hazel removed 850,000 CY of sand from the oceanfront beaches of Surf City and Topsail Beach. A portion of sand lost from the beach was carried onto and across the island into the sound and marsh in the form of overwash terraces. A large volume of this sand was lost from the oceanfront system as it became trapped beneath grasslands and incorporated into dune fields perched above washover deposits. Prior to 1996, southeastern North Carolina had not experienced a hurricane stronger than a category 2 since 1954 (Hurricane Hazel) and a single dune, often scarped and sometimes nonexistent, fronted a majority of Topsail Island. However, between 1996 and 1999, four major hurricanes made landfall in the region with two others passing nearby. The southern 2-mile length of Topsail Beach experienced some of the most extensive formation of washover terraces during the hurricanes of the late 1990's. Overwash terraces extended as far as 328-656 ft across the leveled barrier island (CLEARY *et al*., 2006). Bertha and Fran (1996) and Floyd (1999) were among the most destructive and costly storms ever to impact North Carolina. Frequent storm events affecting the region have increased erosion of oceanfront property.

2.5 Beach Erosion & Shoreline Change

Extensive development of beachfront structures and infrastructure along Topsail Beach began in the 1950's. Many of the oceanfront homes built during this era were placed along the existent primary dune line that paralleled the southerly growing spit. New Topsail Inlet has a history of migration. Upon opening in 1720's, the inlet steadily moved southwest. As the inlet migrated Topsail Island's southern spit progressively extended further southwest. Inlet migration has resulted in a realignment of the trailing northerly shoreline in landward direction (CLEARY, 1994). Couple this related inlet influence to the northerly shoreline with the influence of storm events and one can understand that Topsail Beach experiences chronic erosion along its oceanfront shoreline.

The USACE (2006) measured long-term shoreline changes along Topsail Beach by comparing mean high water (MHW) positions between 1962 and 2002. Shoreline change rates across the northern half of the Town's oceanfront beach was < 1 ft/yr of erosion. Across the southern half of the Town's oceanfront, erosion rates increased to > 3 ft/yr over the same 40-year period.

2.6 New Topsail Inlet

New Topsail Inlet has played a major role in shaping the dynamic morphology of this coastal zone through a historic pattern of migration. Since opening, south of Sloop Point in the late 1720's, the inlet has migrated southwest approximately 6.8 miles (CLEARY, 1994). Between 1938 and 2006, the inlet migrated nearly 1 mile to the southwest at rates as high as 160 ft/yr (McLean, 2009). Previous migration of the inlet is evidenced by the presence of Banks Channel (6-mile long channel) paralleling the sound-side extent of Topsail Beach. Other indicators of inlet migration, observed today, include a series of narrow marsh islands, constructed upon previous flood tidal delta shoal complexes as flood currents and storm-generated wave energy transported sediments into the inlet (CLEARY *et al*., 1996). These marsh islands are situated along the marsh-side length of Banks Channel. The presence of re-curved dune ridges along the southern end of Topsail Island serve as another indicator of the inlet's migration. As New Topsail Inlet migrated, it created a progressive series of re-curved dune ridges separated by low-lying areas, indicating lateral sedimentation (HAYES, 1980).

3 Previous Work

3.1 Overview

The USACE is tasked with providing protection for coastal areas such as the oceanfront shoreline, tidal inlets, and navigable waterways. Each coastal zone possesses different physical parameters shaping the shoreline, as well as economic factors, that must be considered in determination of the feasibility of coastal management (i.e. beach nourishment) in a specific area. Beach nourishment involves the placement of sand from an outside borrow source on a beach. Sand can be placed on the beach by dredging and transporting material from nearby borrow areas or may involve the use of trucks to haul material from inland sites. Justification for federal expenditure on beaches requiring nourishment is usually based on storm protection of beachfront structures. In order to minimize cost of a nourishment project, finding an adequate borrow source in the immediate area of the beach in need is of utmost importance.

Section 101 of the WRDA of 1992 authorized the construction or implementation of the West Onslow Beach and New River Inlet (Topsail Beach) Shore Protection Project at Topsail Beach. This effort recommended an inland borrow source area and a dune and berm system across 19,200 ft of Topsail Beach's oceanfront shoreline.

During 2001, the USACE began preparing a GRR for the storm reduction project along Topsail Beach. USACE focus was the availability of a sufficient volume of suitable beach fill material for an initial nourishment project and following renourishment events over the next 50 years. The GRR's principal purpose was to reevaluate feasibility of constructing a nourishment project that would serve to diminish damage associated with hurricane and storm impacts. The USACE previously identified (USACE 1989 and 1992) and evaluated several Topsail Sound sand resource areas for use on Topsail Island. Potential inland borrow sources included portions of Topsail Creek and bars associated with the flood-tidal delta of the inlet. A considerable quantity of high quality beach fill material was found. However, the environmental restrictions involved with dredging these areas were perceived to be a severe limitation to their potential as primary sand source areas (USACE, 1989; HDR, 2002). As a result, the USACE shifted their efforts and focus offshore to find suitable sand sources.

3.2 HDR & CLEARY, 2002

HDR ENGINEERING INC. OF THE CAROLINAS and William J. Cleary, Ph.D./PG were contracted by the USACE Wilmington District Office in 2002 to conduct a study of the offshore area of Topsail Beach. The intent of this investigation was to serve as a preliminary sand search effort by delineating suitable borrow areas, containing a minimum of 500,000 CY of native beach compatible material. A secondary goal was the identification of areas of environmentally sensitive hardbottoms. The study area encompassed the shoreface within an area from the Town of Topsail Beach/Surf City boundary to a distance of 3 miles southwest of New Topsail Inlet and extended from the 30-ft contour offshore to a distance of 5 miles. This effort consisted primarily of geotechnical investigations (i.e. diver probes, cores, samples, video), bathymetric profiles, and sidescan sonar imagery. Limited seismic reflection profiling of the subsurface had been completed to date in Onslow Bay. Previous seismic work had been conducted by MEISBURGER (1977 and 1979) and MCQUARRIE (1998) with the general intent to generate an overview of the geologic framework of Onslow Bay.

HDR & CLEARY identified four target areas across the shoreface that potentially contained high volumes of suitable beach fill material. The exact volume of suitable material within each target area was not determined due to a lack of vibracore and seismic data. HDR & CLEARY (2002) stated that the ebb-tidal delta of New Topsail Inlet contains as much as 7 million CY of material. This work provided the foundation for the USACE to pursue further investigations of specific target areas thought to retain potential beach fill compatible material for nourishment efforts on Topsail Island.

3.3 OCEAN SURVEYS INC., 2004

OCEAN SURVEYS, INC. (2004) conducted a marine geophysical investigation in the spring of 2003 searching for and evaluating potential sand resource (borrow) areas offshore Topsail Island and Lea Island as part of the USACE GRR. The area designated for investigation included the inner continental shelf from as far north as New River Inlet to Rich Inlet to the south, and seaward of the 30-ft contour extending 5 nautical miles offshore. This investigation was part of the continuing effort to replenish the oceanfront beach of Topsail Island with sand for shoreline stabilization and the protection of structures from storm events. The study was performed under contract with Greenhorne & O'Mara, Inc. (G&O) for the Wilmington District (WD) of the USACE. OCEAN SURVEYS INC. (2004) primary objectives included (1) determining water depths and general bottom morphology, (2) mapping the areal extent and thickness of unconsolidated sediments (primarily sand suitable for beach nourishment), and (3) delineate the extent of bedrock units on and below the seafloor. The results from this study intended to further refine potential offshore resource areas and allow design of a following, more intensive mapping phase of sand resource areas exhibiting the highest potential for economic mining. Consequently, specific borrow areas were intentionally left undefined with the expectation that the USACE would designate such areas at a later date, following complete examination of the study's results (OCEAN SURVEYS, 2004). Similarly, volume estimates for sand resource areas were not calculated.

OCEAN SURVEYS INC. (2004) split their investigation area into five zones. Zone 2 encompassed an area from the town line separating Surf City and the Town of Topsail Beach to New Topsail Inlet to an approximate distance of 5 nautical miles offshore. Their investigation revealed the region (Zone 2) offshore Topsail Beach to be dominated by a broad, shallow limestone rock outcrop (Trent Formation). This unit is characterized as moldic, sandy limestone (HDR, 2002). OCEAN SURVEYS INC. (2004) determined the offshore area of Topsail Beach to be the most expansive hardbottom area in their study area. A thin veneer of sediment overlies the rock across much of the area. Several patches of suitable sand were delineated within this veneer of sediment. However, the horizontal extent of sediment overlying the rock in this area (Zone 2) appeared to retain the lowest volume of usable beach fill material of the five zones investigated. OCEAN SURVEYS INC. (2004) estimated the percentage of suitable sand within Zone 2 to be 5%.

3.4 CLEARY *et al.*, 2006

A study conducted by CLEARY *et al*. (2006) summarized findings related to research of sediment quality and bottom conditions offshore Topsail Beach and New Topsail Inlet. It was initially hypothesized that beach fill quality sand may occur in considerable volumes in four target areas within a 40 square mile area offshore Topsail Beach and Lea Island. However, vibracore data revealed that accumulations of unsuitable material (i.e. silty sands and muddy gravels) reside below a majority of the target areas. It was concluded that these sediment sequences represent Holocene estuarine fill. Immediately seaward of New Topsail Inlet, specific sites consisting of beach fill quality sand were delineated.

Given the prevalence of hardbottoms and unsuitable material residing in paleo-channels, this study concluded that the only viable borrow source for nourishment events on Topsail Beach would include New Topsail Inlet's throat, ebb-tidal delta, and immediate portions of the shoreface.

3.5 USACE, 2006

A draft of USACE GRR was released in 2006. The study concluded that the Topsail Beach shoreline is susceptible to major damage and erosion from coastal storms. It selected a beach fill construction plan that would substantially reduce economic losses due to storm activity and progressive erosion. The selected plan consisted of a 26,200-ft long dune system to be constructed to an elevation of 12 ft NGVD and fronted by a 50-ft wide berm, at elevation 7 ft NGVD, and spanning 23,200 ft of developed, oceanfront shoreline within the Town's limit. The USACE recommended a renourishment cycle of 4 years. The selected plan was deemed feasible based on engineering and economic criteria. It was consider acceptable by environmental, cultural, and social laws and standards. The non-Federal sponsor, the Town of Topsail Beach, supported the plan. It was concluded that the sponsor possessed the capability to provide the necessary non-Federal requirements identified and described in report Section 9.02, Division of Plan Responsibilities.

The preliminary identification of borrow areas for the project included New Topsail Inlet, Topsail Creek, Banks Channel, and shoreface offshore Topsail Beach in water depths greater than 30 ft below NGVD. OCEAN SURVEYS INC. (2004) investigation was used to delineate boundaries of offshore borrow areas.

A sediment compatibility analysis was conducted for samples from New Topsail Inlet and the connecting channel between the inlet and the AIWW. The analysis indicated New Topsail Inlet material was compatible with native material on Topsail Beach. However, connecting channel material was determined incompatible. Regardless, the potential borrow areas of the inlet and the connecting channel were eliminated as options because they are situated within the Lea Island complex (L07) of the Coastal Barrier Resource System (CBRA) zone, and contain constituent elements of piping plover habitat and other estuarine resources to the extent that other alternatives were environmentally preferable. The USACE, Wilmington District, maintains a policy of not pursuing borrow sites existing within CBRA zones.

A Federal shore protection project was authorized for the Town of Topsail Beach in 1992. The proposed borrow area for that 1992 project included a portion of Banks Channel, similar to this federal project. Banks Channel is a Federal authorized connecting channel (80-ft wide, 7 ft +2 ft depth) extending 6.27 miles from the AIWW to the CBRA zone at New Topsail Inlet. The USACE, Wilmington District, collected 32 vibracores within Banks Channel in 2003. A total of 82 Banks Channel sediment samples were grain size tested and compared to the native beach sediment of Topsail Beach. The analysis concluded an overfill ratio of 1.08. Material from Banks Channel was compatible with the native beach sediment. Based on hydrographic surveys and vibracore data, the USACE calculated approximately 94,000 CY of material available within the Federally authorized navigation boundaries of Banks Channel.

The USACE GRR (2006) concluded the dredging of Banks Channel to supplement a renourishment cycle would require the mobilization of a second dredge for a negligible amount of material. The USACE considered expansion of dredging limits associated with the channel but ultimately did not pursue this avenue because it would require extensive effort with environmental agencies and potentially increase mitigation requirements. As a result, the USACE eliminated Banks Channel as a borrow area for this project.

Six offshore borrow areas, located beyond a depth of 30 ft NGVD to approximately 5.5 miles offshore, were identified for further evaluation as potential borrow areas for the Town of Topsail Beach. The offshore borrow areas beyond 3 nautical miles offshore are subject to federal mining requirements of the Mineral Management Service (MMS). It was determined that approximately 62% of the sand within all six offshore borrow areas (A, B, C, D, E, and F) was situated in borrow area A. Borrow area A is located approximately 1.5 miles south of New Topsail Inlet. It was selected as the sole source of sand for the USACE's proposed initial beach construction project on Topsail Beach. Material contained in areas B, D, E, and F was limited and would be used in periodic, subsequent renourishment cycles. Borrow area C, approximately 5 miles from the project area, would be used only for contingency purposes. Borrow area F, based on preliminary investigation, potentially contained incompatible material for use on the beach.

Initial construction volume required for the original project was calculated at 3,223,000 CY. Subsequent renourishment would require 866,000 CY every 4 years. Over 50 years, the total of 12 renourishment events would amount to 10,392,000 CY of material placed. Including the initial construction project volume, total project requirement would be 13,615,000 CY placed on the oceanfront beach of Topsail Beach.

3.6 FINKL *et al.*, 2009

Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC), working for the Town of Topsail Beach, conducted a three-phased marine sand search investigation to meet the needs of the Town's Interim (Emergency) Beach Nourishment Project. The objective of this investigation was to identify and develop a suitable borrow area for the Town in a quick and cost-effective manner.

As part of this investigation, CPE-NC reviewed previous work completed in the area and supplemented this with further geophysical and geotechnical efforts. CPE-NC reviewed USACE identified borrow areas and determined USACE Borrow Area A to be the most promising area delineated. CPE-NC focused on the portion of Borrow Area A located landward of the State/Federal boundary for their further investigation. A geophysical survey was conducted of this area within Borrow Area A consisting of seismic reflection profiling, sidescan sonar, magnetometer, and bathymetric surveys. Last final portion of their investigation involved a vibracore survey of a further refined area (i.e. Area A1) delineated from the geophysical portion of the study. Twenty vibracores were collected by CPE-NC in 2006. Results of the geophysical and geotechnical surveys indicated material in Borrow Area A1 was comprised of silt percentages (7.30%) in excess of limits allowed by N.C. DCM. It was also concluded that the material was too fine to meet the Town's performance goals. CPE-NC calculated this area to contain approximately 2.14 million CY of material across 230 acres (FINKL *et al*., 2009).

The Town of Topsail Beach approved a second three-phase sand search investigation by CPE-NC in January 2007. CPE-NC re-examined vibracore data collected previously by the USACE to delineate other possible target areas. This inspection resulted in CPE-NC delineating a potential target area of interest offshore New Topsail Inlet. The geophysical portion of this second investigation was conducted in February 2007 and focused on the ebb-tidal delta of the inlet. Utilizing the geophysical data, twenty-three vibracores were collected during the summer of 2007 and targeted areas of highest potential for containing suitable beach fill sand. The culmination of these investigations resulted in a sand source area comprised of material with a fraction coarse enough to comply with the performance needs of the project and meet N.C. DCM requirements. Another set of geophysical surveys were conducted at the end of 2007 to further refine the limits of the borrow area located across the southeastern portion of New Topsail Inlet's ebb-tidal delta. This 127 acre area was designated Borrow Area X. CPE-NC determined that Borrow Area X contained approximately 1.58 million CY of sand with a mean grain size of 0.20 mm (fine sand), with a phi sorting of 1.21 (poorly sorted), and 2.17% silt fraction.

4 Physical Monitoring Plan

4.1 Overview

The following plan describes various components of the physical monitoring that will be used to establish a record of existing beach conditions and track morphologic change effectively in order to implement effective maintenance events.

4.2 Beach and Offshore Profiles

Beach and offshore profiles shall be measured at 26 reference stations established along the Town of Topsail Beach parallel to the oceanfront shoreline. Similarly, 10 reference stations will be established along the oceanfront shoreline of Lea Island's northern end. Profiles will extend along the shore-normal azimuths, from the backbeach (i.e. west of the existing dune feature) to approximately 2,000 ft offshore (to the –30 ft NAVD contour). Average spacing between profile stations measures approximately 950 ft.

Beach profile data has been previously collected both prior to and following the original nourishment project. Additional surveys will be performed annually to track morphologic profile change. Profile surveys will also be conducted following significant storm events.

Vertical and horizontal control is established and referenced to North American Vertical Datum of 1988 (NAVD88) and North Carolina State Plane Coordinate System (NAD 1983). Each survey line azimuth is identified by their respective magnetic bearing. Survey data will be compiled in the form of cross-sectional profile plots and bathymetry and stored digitally. A report will be composed for each post-storm survey or post-maintenance event to document the results of volumetric and shoreline change analyses along the oceanfront beach.

4.3 Inlet Area and Interior Channel Bathymetry

Bathymetric surveys of the inlet channel and interior channels will be measured prior to and following any maintenance event in addition to annual surveys to monitor volumetric changes. Four specific interior channel areas have been established to monitor morphologic change. These include Topsail Creek, Banks Channel, the Connector Channel (i.e. the channel connecting Topsail Creek to Banks Channel), and the AIWW. The surveys consist of channel profile lines oriented perpendicular to each respective channel centerline on an even 100-ft interval. Topsail Creek has 77 established profile lines. Banks Channel and the Connector Channel have 52 established lines combined. The data and volumetric change analyses will be included in any monitoring report indicated above.

4.4 Aerial Photography

Color, vertical aerial photography will be flown along the Project shoreline at the time of each full monitoring survey (i.e. inclusive of beach profiles and interior bathymetric surveys). The scale of the photographs will be 1 inch equals 200 feet.

Each photograph will include New Topsail Inlet, Topsail Sound (i.e. marsh and interior channels), the AIWW, the oceanfront beach, nearshore environment, and sufficient upland features (i.e. beach-fronting buildings, roads, etc.) to determine the location of any photograph. The shoreline location in any image will be approximately halfway across the width of the photograph. Consecutive photographs will possess sufficient overlap (approximately 20%) to identify common reference points. Photographs will be captured prior to 2:00 pm to avoid shadows cast by tall objects (i.e. buildings, trees, etc.) across the beach.

Local predicted tides will be used to determine flight times so subsequent photography events will occur during similar times in the tidal cycle. Photographs will be rectified, and horizontal ground control established by setting sufficiently sized aerial targets (4 ft x 4 ft) on representative reference monuments in the days prior to flight. In the event that a monument is either not visible due to vegetation or located in an area of heavy traffic, the aerial target will be offset from the monument along the profile azimuth. This offset distance and azimuth will be kept in the target-setting party's field notes for use during any subsequent photographic analysis.

5 Managed Systems Approach For Maintenance Actions

5.1 Overview

The development of the managed system approach assumes that the oceanfront beach has undergone an original nourishment project and that monitoring, as described in the previous section, is conducted at the regularly specified intervals. The results of the monitoring plan will be analyzed to determine whether or not the following predetermined "thresholds" are exceeded. If these "thresholds" are exceeded the Town of Topsail Beach will commence dredging and the placement of sand along the oceanfront beach (i.e. beach nourishment project) during the next scheduled maintenance event or, if this work is not scheduled to occur for 2 or more years, the work will commence within an 18-month period. This schedule will allow for maintenance events to be scheduled within reasonable timeframes for planning, design, engineering and contracting for the next dredging season (i.e. November 15th to March 31st annually). If a permit is required, additional time may be required for permit processing and acquisition in order to initiate construction. The final recommended sand placement volumes, shoreline lengths and unit fill placement will be a function of the sand volume losses calculated from the Physical Monitoring program.

5.2 Trigger 1 – Time Threshold

A recommendation set forth in this plan is a maximum time span of 5 years not to be exceeded between maintenance events. This time frame is an acceptable period that will allow primarily targeted borrow areas (inlet throat and interior channels) associated with this plan to adequately recharge (i.e. shoal) with sand following a dredging/mining event. The USACE recommended an event cycle of 4 years for Topsail Beach in their GRR report (USACE, 2006).

5.3 Trigger 2 – Oceanfront Volumetric Loss Threshold

An oceanfront beach volume approach is proposed to analyze the Monitoring Program data and evaluate need for maintenance. Monitoring volume “cells” will be established along the Town’s oceanfront beach. Implementation of numerous cells will aid in the determination of erosive segments of oceanfront versus more erosion-resistant zones. These cells will be delineated by shoreline reach (based on location, coastal processes, etc.) and extend seaward to the –12 ft NAVD88 depth contour (based on its October 2010 position). Volumetric changes for each monitoring cell will be separated into 3 sections (Figure 4). The upland section (i.e. recreational beach) will include the onshore (i.e. berm) portion of the beach and the frontal slope. The nearshore section will be set at 500 ft wide and include the nearshore bar and the area out to approximately the –12 ft contour. The offshore section will extend from approximately the –12 ft contour seaward to the –20 ft contour.

Figure 2. Typical beach profile depicting upland and nearshore volumetric sections.

Although volume change analysis to the depth of closure (–20 ft NAVD88) will be calculated, an obstacle in identifying an “impact” can originate when volumetric gains lower in the beach profile disproportionately exceed upper, recreational beach volume losses. As a result, determining the need for maintenance work based on calculations of beach profile volumes over the entire width of the profile (i.e. from the upland to depth of closure), has the potential to underestimate the upper, recreational beach’s erosion and degree of vulnerability to subsequent wave attack. This becomes evident when a considerable volume of sand erodes from the upper, recreational beach and nearshore portion and relocates lower in the profile to the offshore area (–12 to –20 ft NAVD88). Once sand is distributed across this lower portion of the profile it is less likely to migrate back to the upper portions (> –12 ft NAVD88) of the beach. Thus, calculating volumetric losses/gains to the –12 ft NAVD88 contour, is optimal for evaluating whether an “impact” has occurred. Focusing volume calculation efforts on the upland and nearshore sections of the beach profile diminishes the potential to underestimate erosion across the recreational beach and it avoids any potential problems associated with survey error at increasing depths/distances along the profile. In addition, a typical nourishment project's beach fill template is designed with construction limits within the upland and nearshore sections of the beach profile.

Utilization of scheduled (biannual) monitoring profile surveys and post-storm surveys will allow for the evaluation of beach fill performance following the most recent nourishment event. The average end area method will be used to calculate volumes of sand lost and gained within a monitoring cell. Overall impacts and spatial variation resulting from storms will be evaluated for the purpose of factoring comprehensive storm-related erosion in a monitoring cell. It is expected that a higher degree of oceanfront erosion will occur along the adjacent shoreline with closer proximity to the inlet. This erosion will be ascribed as inlet-influenced. However, erosion of beach fill across monitoring cells further north will be used in determining the "background" storm-influenced erosion. Following a severe storm event a post-storm survey will be conducted, and the net average storm-related volumetric losses will be calculated.

The proposed threshold to trigger a maintenance event is a 60% total volumetric loss of oceanfront beach fill from the most recent nourishment's placed fill, measured across all monitoring cells along Topsail Beach. Whether this 60% volume loss is a direct result of one storm event, chronic wave energy reworking fill, or a combination of both the threshold will be considered met regardless. As stated above, this particular trigger will be evaluated using volume calculations within the upland and nearshore sections of each monitoring cell.

5.4 Trigger 3 – Inlet/Interior Channel Shoaling Threshold

Five specific borrow areas have been selected for monitoring sedimentation. These areas include the ebb channel of New Topsail Inlet, the Connector Channel, Banks Channel, New Topsail Creek, and the AIWW. Utilizing channel alignments, channel widths, and side-slopes specific channel templates with fixed boundaries will be set in each borrow area (Figure 5). These boundaries will define previously permitted areas acceptable for dredging and define the extents of where dredging can occur laterally and at depth within each channel. As a result, these established areas could be defined as shoaled to a specific percentage (i.e. % capacity) after any given monitoring survey is conducted. For the purposes of this management plan, channel templates in each of these borrow areas will be considered 100% shoaled and at capacity when filled with sediment to a depth of –4.0 ft mean low water (MLW), with the exception of the outer-bar channel. The outer-bar channel will be considered at capacity when filled with sediment to a depth of –6.0 ft MLW. The proposed threshold to trigger dredging work is shoaling of 85% capacity in a defined channel template. Periodic monitoring surveys will track the progressive accumulation of sediments transported throughout the inlet and interior channels. Rates of sedimentation within the Inlet Channel, Connector Channel, Banks Channel, Topsail Creek, and the AIWW following a dredging event will be better estimated as time elapses following the original nourishment project of 2011.