Ocean Isle Beach 30-Year Beach Management Plan
FINAL

Prepared for:

Ocean Isle Beach, North Carolina

Prepared by:

Coastal Planning & Engineering of North Carolina, Inc.

March 2015

Executive Summary

One common concern of residents and owners of oceanfront properties at Ocean Isle Beach are the threats of economic losses resulting from damages to structures and their contents due to hurricane and storm activity and the loss of beachfront land due to the ongoing shoreline erosion. In an attempt to reduce the potential damages from storm activity, the federal government authorized and implemented the nourishment of a 3.25 mile segment of the Town's 5.5 miles of oceanfront shoreline. In addition, the Town is actively pursuing the construction of a terminal groin and beach fill that will address shoreline erosion issues along the extreme eastern 0.5 miles of the island. The western portion of the island, covering approximately 1.75 miles from the west end of the federal project to the east shoulder of Tubbs Inlet, is currently unmanaged.

This report explores the existing management strategies, preliminary engineering analysis of an island-wide management program, the capacity of possible borrow sources, and environmental documentation and permitting approaches designed to help develop a single comprehensive, long-term management plan for the Town's entire oceanfront shoreline. This long-term plan was developed using the historical performance of the federal project, the anticipated shoreline protection provided by the yet-to-be constructed terminal groin, and the erosion rates documented along the unmanaged western portion of the island.

The island-wide management plan would utilize the existing borrow area within Shallotte Inlet as the primary borrow source for initial construction of the projects along the east and west ends of the Town as well as periodic nourishment of the entire 5.5 mile ocean shoreline which includes the federal storm damage reduction project. Current estimates indicate approximately 645,000 cubic yards of material will be needed every 5 years to maintain the Town's oceanfront shoreline once all shoreline management plans are implement.

Initial construction of the east end project that includes a terminal groin would likely take place during the 2015-2016 environmental dredging window and would cost an estimated $5,700,000. Construction of a project along the west end of Ocean Isle Beach could occur as early as 2016-2017 and would cost an estimated $4,266,000. Construction of the west end project would be performed in conjunction with the scheduled periodic nourishment of the federal project. Once all three components of the shoreline management plan are in place, i.e., the east end project, the west end project, and the federal project, periodic nourishment of the three components would be scheduled every 5 years beginning with the 2021-2022 dredging window.

Several environmental documents, including an Environmental Assessment (EA) would be required in support of the permitting process. It is estimated that it would take approximately 12-16 months for the Town to obtain the required authorizations and permits to manage their entire oceanfront shoreline at a cost of approximately $40,000-$60,000. Should the Town desire, a tandem permitting approach may be implemented to provide an expedited process leading to

the Town's ability to manage the oceanfront shoreline currently managed by the federal government. This would be beneficial should the federal government experience a funding shortfall for this project.

TABLE OF CONTENTS

1.0 Introduction 1
2.0 Existing Beach Management 2
2.1 Federal Project 2
2.2 Beach Fill at East End 5
2.3 Terminal Groin with Beach Fill 6
2.4 West End of Ocean Isle Beach 7
2.5 Static Line Exception 7
2.6 Beach Monitoring 7
3.0 Engineering Analysis 7
3.1 Development of Design Beach Fill Template 7
3.2 Influence of Tubbs Inlet 12
3.3 Behavior of West End Shoreline. 16
3.4 West End Beach Periodic Nourishment Requirements. 18
3.5 Island-wide Periodic Nourishment Requirements 20
3.6 Implementation Schedule for a West End Project. 21
3.7 Initial Construction Cost for West End Project. 22
3.8 Periodic Nourishment Cost for West End Project. 24
4.0 Geotechnical Services 24
4.1 Shallotte Inlet 25
4.2 Tubbs Inlet 26
4.3 Offshore Ocean Isle Beach 27
4.4 Cost Comparisons for Utilizing Alternate Borrow Areas 29
4.4.1 Tubbs Inlet Potential Borrow Area 30
4.4.2 Offshore Potential Borrow Areas 30
5.0 Environmental Documentation and Permitting Assessment 31
5.1 Option 1: One Federal and One State Permit 32
5.1.1 Permitting Overview 32
5.1.2 Environmental Documentation Required 32
5.1.3 Available Sand Sources 33
5.1.4 Anticipated Timeline 33
5.1.5 Anticipated Cost Estimate 36

5.2 Option 2: Obtain an additional General Permit 291 for the federal project. 36
5.2.1 Permitting Overview 36
5.2.2 Environmental Documentation 36
5.2.3 Available Sand Sources 36
5.2.4 Anticipated Timeline 37
5.2.5 Anticipated Cost Estimate 37
5.3 Monitoring Requirements 39
5.4 Permitting Recommendations 40
6.0 FEMA Monitoring and Maintenance Plan Outline 40
6.1 FEMA Maintenance Plan Outline 41
7.0 Literature Cited 42

LIST OF FIGURES

Figure 1. Location of Ocean Isle Beach, NC 1
Figure 2. Authorized limits of the Ocean Isle Beach Storm Damage Reduction Project 4
Figure 3. Map showing location of USACE approved borrow area within Shallotte Inlet and approximate locations of previously dredged areas during initial construction and maintenance events. 5
Figure 4. Location of the proposed terminal groin and associated beach fill located on the eastern portion of Ocean Isle Beach 6
Figure 5. Example of area used to compute volume of material on the existing profiles between station 70+00 and 120+00 (Example shown is station 100+00). 8
Figure 6. Recommended beach fill design template for the west end of Ocean Isle Beach. 10
Figure 7. Baseline stationing and limits of proposed beach fill on west end of Ocean Isle Beach. 11
Figure 8. Google Earth images of Tubbs inlet during (a) September 2006 (b) October 2007, (c) October 2009, and (d) March 2011 13
Figure 9. Most recent Google Earth image of Tubbs Inlet – December 2012. 14
Figure 10. Comparison of February 2001, April 2007, and June 2013 profile surveys for (top) station 260+00 and (bottom) station 270+00. 15
Figure 11. Cumulative volume changes between station 170+00 and 240+00 – May 2002 to June 2013 16
Figure 12. Cumulative volume changes stations 250+00 and 260+00 – May 2002 to June 2013. 17
Figure 13. Average cumulative volume change for stations 60+00 to 120+00 since initial construction of the federal project in 2001. 20

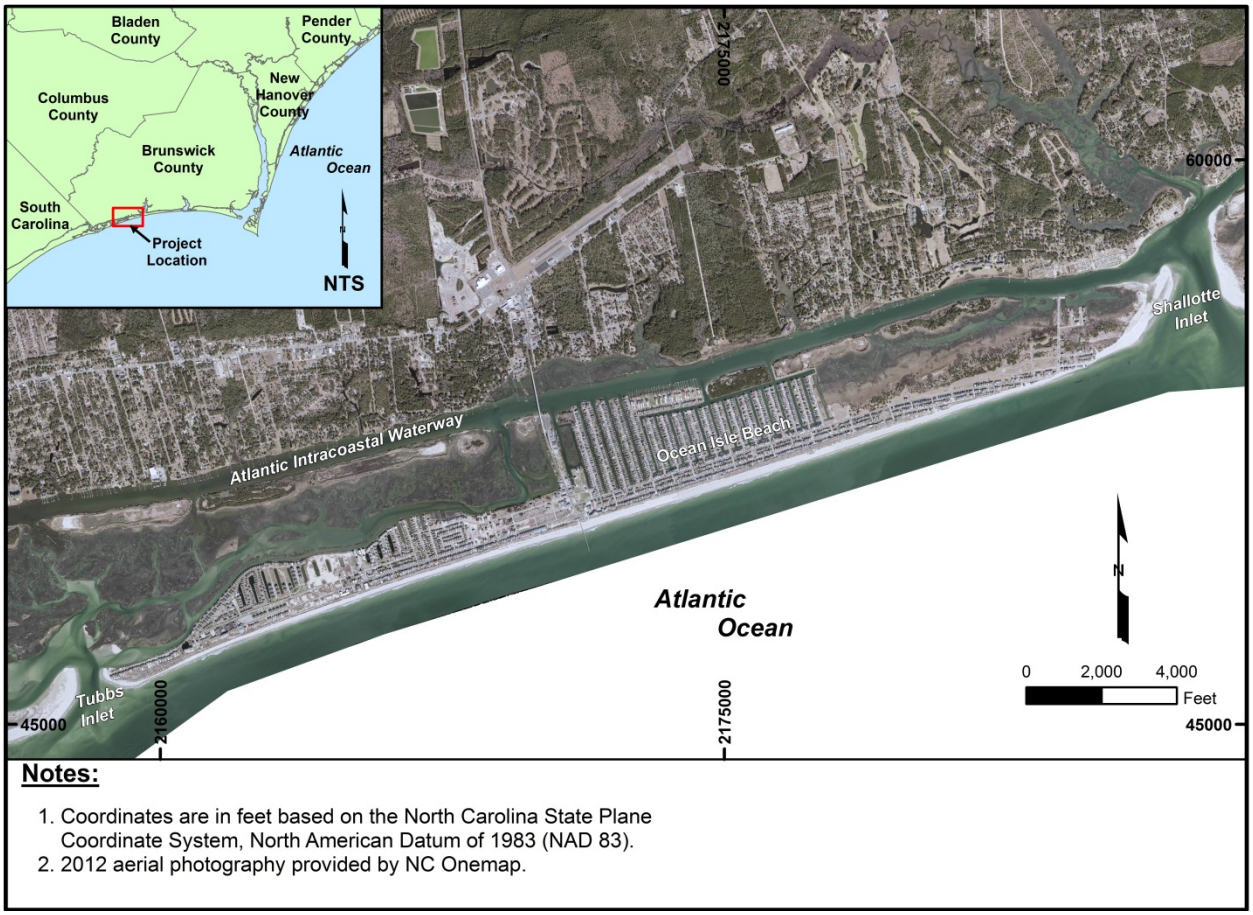
Figure 14. Tubbs Inlet boring locations. 27
Figure 15. Ocean Isle Beach offshore boring locations. 28
Figure 16. Ocean Isle Beach offshore boring locations color coded to indicate beach compatibility. 29
Figure 17. Timeline of events associated with Option 1. The pathway for pursuing the CAMA permit is represented in light blue, and the USACE IP pathway is in dark blue. 35
Figure 18. Timeline of events associated with Option 2 in comparison to Option 1 38

LIST OF TABLES

Table 1. Station numbers and nearby cross street names 4
Table 2. Difference in volume on the existing west end profiles (June 2013 survey) and the average volume on the profiles of the federal project between stations 70+00 and 180+00. 9
Table 3. Implementation schedule and volumes of beach nourishment projects along Ocean Isle Beach 22
Table 4. Cost Estimate for West End Project – Ocean Isle Beach 23
Table 5. Estimated project costs. 24

1.0 Introduction

The Town of Ocean Isle Beach (Town) is located on a coastal barrier island along the Atlantic Ocean on the coastline of Brunswick County in southeastern North Carolina (Figure 1). The island is situated midway between the metropolitan cities of Wilmington, NC and Myrtle Beach, SC. Spanning approximately 5.5 miles, Ocean Isle Beach is oriented in an east/west direction with Shallotte Inlet located along its eastern end and Tubbs Inlet at its western end. The island has a current year-round resident population of approximately 554, with a seasonal population of 25,000.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2012 aerial photography provided by NC Onemap.

Figure 1. Location of Ocean Isle Beach, NC

Barrier islands such as Ocean Isle Beach are dynamic systems that erode and accrete depending on various factors like storms, sea level rise, their underlying geology, and stabilization efforts of the shoreline. Coastal erosion resulting from these factors is a very important issue that can present a major problem for property owners. Though these forces have chronic effects over a long period of time, any individual large storm can bring large-scale changes to a barrier island in a matter of a few hours. As such, a common concern of residents and owners of oceanfront properties at Ocean Isle Beach are economic losses resulting from damages to structures and their contents due to hurricane and storm activity and the loss of beachfront land due to the ongoing shoreline erosion. With a total tax value of property within the limits of Ocean Isle

Beach of approximately $1,816,012,300 (based on the 2012 reappraisal), the Town realizes the need to protect homes and infrastructure along its oceanfront. This assessment includes the valuation of 3,247 commercial and residential structures and property and 1,456 vacant lots (Ivey, pers. comm.).

To address this concern, the Town has worked with the US Army Corps of Engineers (USACE) since 1965 to plan and provide storm protection for a portion of its oceanfront shoreline. As described in more detail below, the USACE's federal storm damage reduction project spans 3.25 miles of the Town's approximate 5.5 mile oceanfront shoreline. The remaining 2.25 miles of oceanfront shoreline, which consist of approximately 0.5 miles east of the federal project and 1.75 miles west of the federal project, remain unmanaged today; however, the Town is actively pursuing a shoreline protection project involving the construction of a terminal groin in proximity to Shallotte Inlet which will provide added shoreline protection to the area east of the federal project.

Although the existing federal coastal storm damage reduction project and the proposed terminal groin will serve to protect the majority of the Town's oceanfront shoreline, these actions will not provide comprehensive island-wide protection. In addition, the cost sharing agreement established for the Federal project in 2001 will expire in 2051. Furthermore, federal appropriations for the project have historically been challenging and all indications suggest that funding challenges will continue jeopardizing the integrity of this vital project.

With these factors in mind, this study was conducted to assist the Town with the development of a comprehensive 30-year Beach Management Plan. The management area will consist of the beach strand from the location of the proposed terminal groin, located on the east end of the island, to the east shoulder of Tubbs Inlet, a total distance of about 5.1 miles. Components of the study include an engineering analysis of the existing federal project, a sand resource assessment, and an assessment of the environmental documentation and permitting requirements that would be necessary for the Town to manage its entire oceanfront shoreline.

2.0 Existing Beach Management

As stated above, the Town has an active beach management plan made up of several components. These include a Federal coastal storm damage reduction project, a terminal groin project (currently under design for the east end), a static line exception requiring the Town to maintain a portion of the federal project, and a beach monitoring program. This 30-Year Beach Management Plan provides an assessment of each of these components, and incorporates them into future management strategies to form one comprehensive, long-term management plan.

2.1 Federal Project

The Brunswick County Beaches, NC Federal Storm Damage Reduction Project (including a portion of the Ocean Isle Beach oceanfront shoreline was authorized by the 1966 Flood Control Act (H.D. 511, 89th Congress, 2nd session). Initial construction of the project within Ocean Isle Beach occurred between March and May 2001, the USACE constructed a federal beach fill project for coastal storm damage reduction that encompassed 17,100 feet (3.25 miles) of the Town's shoreline beginning at Shallotte Boulevard (USACE baseline station 10+00) on the east and extends to a point approximately 3,700 feet west of the Ocean Isle Beach Pier & Arcade (USACE baseline station 181+00) (Figure 2, Table 1). The westernmost 9,400 feet of the Town's

shoreline was not included in the federal project as this area was fronted by an established dune system during the time the initial feasibility study was conducted and thus was determined to be stable during the project formulation. The extreme eastern end of Ocean Isle Beach between Shallotte Boulevard and Shallotte Inlet was not included in the federal project due to predicted high rates of loss that would occur from a 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. The federal cost-sharing for the 3.25 mile federally authorized project is set to expire in 2051.

The initial construction of the project in 2001 involved the placement of 1,866,000 cubic yards of material obtained from a borrow area located in Shallotte Inlet (Figure 3). The Shallotte Inlet borrow area was also designated as a source for future periodic beach nourishment, which was scheduled to occur every three years. Based on USACE estimates, 300,000 cubic yards (100,000 cubic yards/year) would be needed every three years to maintain the federal project.

Since initial construction, Ocean Isle Beach has been nourished three times. The first periodic nourishment operation was accomplished between December 2006 and January 2007 and involved both a federal and a non-federal component. The federal component, which was completed in December 2006, placed 449,400 cubic yards of material between stations 10+00 and 72+00 (Shallotte Blvd. to approximately Southport St.), while the non-federal component, completed in January 2007, placed 155,000 cubic yards between stations -3+00 and 17+00 (near Charlotte St.). The portion of the fill placed between stations 10+00 and -3+00, was estimated to be 115,000 cubic yards, and was outside the authorized limits of the Federal project and represented an attempt by the Town to address the chronic erosion with beach nourishment alone.

The second periodic nourishment operation occurred between April and May 2010 and involved the placement of 509,200 cubic yards of material with federal funds. The western 6,000 feet of the federal project continues to perform very well and has not required periodic nourishment since construction in 2001. The Town did not attempt to place any additional fill east of station 10+00 during the 2010 operation due to poor performance of the fill placed east of station 10+00 in January 2007. As mentioned above, the Town placed 155,000 cubic yards of fill between baseline stations -3+00 and 17+00 in January 2007 and, as documented by beach profile surveys, essentially all of this material was lost by September 2007. This supplemental fill cost the Town $720,000 (including the cost of permitting). As a result, the Town determined continued nourishment of this portion of its shoreline was not an economical erosion response measure.

The third periodic nourishment operation for the Ocean Isle Beach storm damage reduction project was completed in April 2014 with the placement of approximately 800,000 cubic yards of material between stations 10+00 and 90+00 (Shallotte Boulevard to Leland St.).

The average amount of fill placed on Ocean Isle Beach to maintain the federal project has been approximately 408,000 cubic yards every three years. The average distribution of the 408,000 cubic yards of material every three years along Ocean Isle Beach has been as follows:

Station 10+00 to 30+00 (Shallotte Blvd. to Lumberton St.)	174,000 cubic yards
Station 30+00 to 60+00 (Lumberton St. to Sanford St.)	177,000 cubic yards

Station 60+00 to 90+00 (Sanford St. to Leland St.) 42,000 cubic yards
Station 90+00 to 120+00 (Leland St. to Concord St.) 15,000 cubic yards

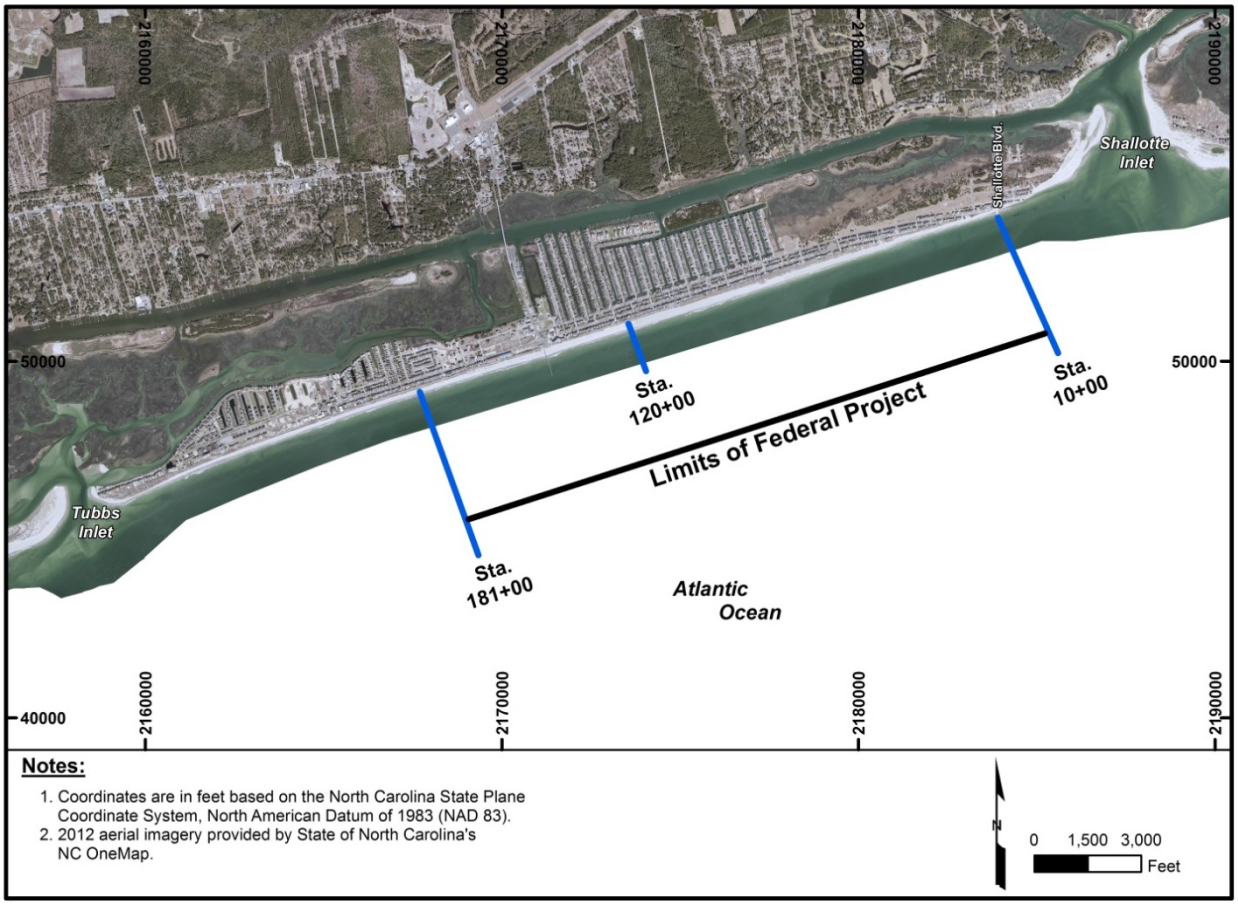


Figure 2. Authorized limits of the Ocean Isle Beach Storm Damage Reduction Project

Table 1. Station numbers and nearby cross street names

Station	Cross Street Name
-3+00	Approx. 800 ft. east of Asheville St.
10+00	Shallotte Blvd.
15+00	Charlotte St.
30+00	Approx. 215 ft. west of Lumberton St.
60+00	Approx. 200 ft. east of Sanford St.
90+00	Approx. 135 ft. west of Leland St.
120+00	Approx. 175 ft. east of Concord St.
181+00	Approx. 140 ft. east of Duneside Dr.
185+00	Isle Plaza
250+00	Coggeshall Dr.
255+00	Gate for Private Development
270+00	Approx. 480 feet east of the end of Ocean Isle W. Blvd.

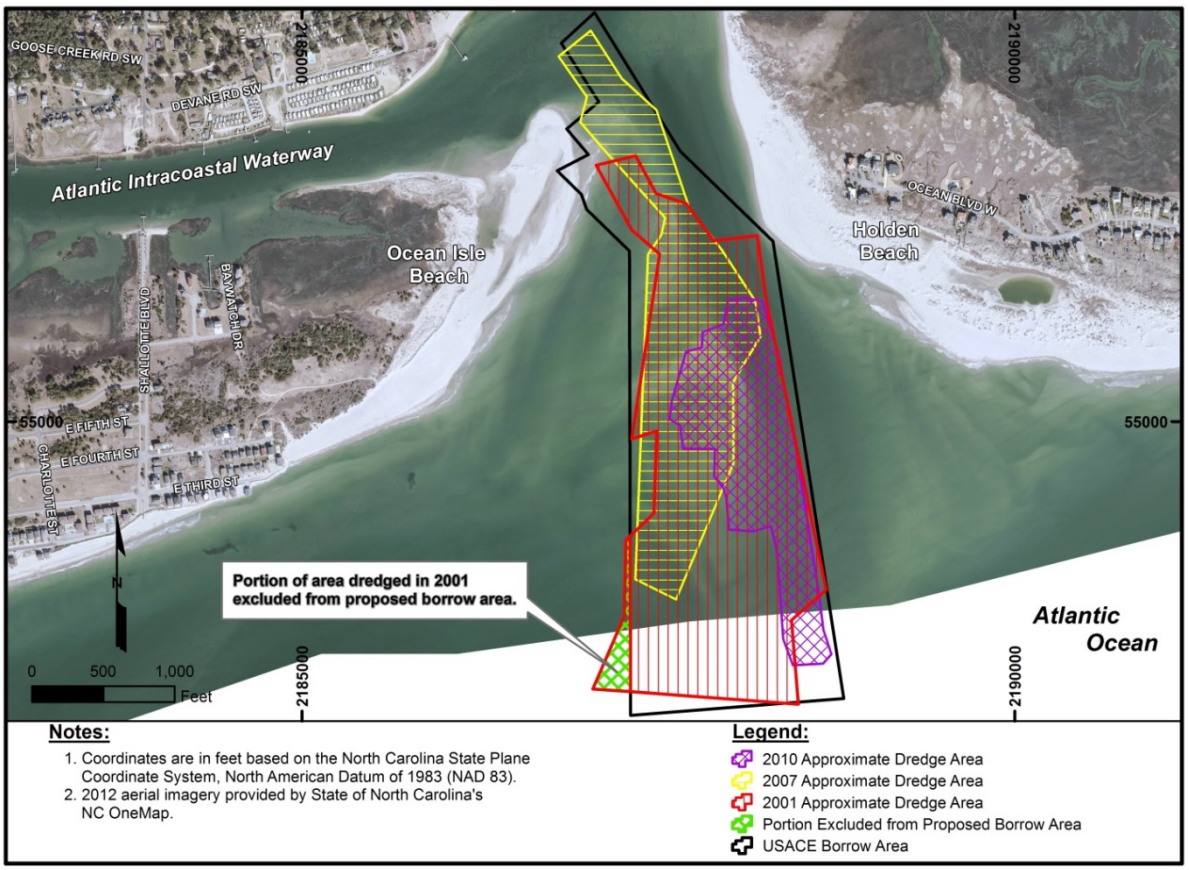


Figure 3. Map showing location of USACE approved borrow area within Shallotte Inlet and approximate locations of previously dredged areas during initial construction and maintenance events.

2.2 Beach Fill at East End

In addition to the federal storm damage reduction project, the USACE has periodically deposited material on the east end of Ocean Isle Beach from maintenance of the Atlantic Intracoastal Waterway (AIWW) at the intersection with Shallotte Inlet. An estimated 300,000 to 400,000 cubic yards of navigation maintenance material has been placed on the east end of Ocean Isle Beach since 2001. All of this material has been deposited generally within the area fronting the development east of Shallotte Boulevard (i.e., outside the limits of the federal project). The material removed from the AIWW and placed within this area has eroded quickly and has been generally ineffective in slowing the rate of erosion in the area east of Shallotte Boulevard.

Additional measures undertaken by the Town and private interests on the east end include placement of a sandbag revetment along 1,400 feet of shoreline, beginning at a point west of Shallotte Boulevard and extending east to the end of development. This revetment was installed around 2005. The sandbag revetment has recently been extended 400 feet to the west or just past Charlotte Street. Some of the recent sandbag placement was accomplished by NCDOT in an attempt to protect the eastern end of 2nd Street. The cost of erosion damages incurred by the Town since 2004, as well as the cost of erosion response measures, is estimated at $5,086,200.

Despite the previous efforts to stem the erosion along the Town's east end, since 2005, five (5) homes have been lost, and between 20 and 25 parcels have become unbuildable due to the inability to meet building setback requirements as dictated by the rules established by the NC

Coastal Resources Commission (CRC). The estimated appraised value of the lost homes and parcels since 2005 totals approximately $1.6 million.

2.3 Terminal Groin with Beach Fill

Since 2012, the Town has been pursuing a terminal groin/beach fill project to accomplish two goals: 1) mitigate inlet induced erosion that threatens development along the east end of the island, and 2) improve the performance of the federal project. The currently proposed project design includes construction of a 1,050-foot long terminal groin consisting of a 750-foot rubble mound section on the seaward end and a 300-foot long sheet pile shore anchorage section on the landward end. The terminal groin would be positioned just east of the last development on the island (Figure 3). Groin installation will be accompanied by a beach fill to create an accretion fillet immediately west of the terminal groin (Figure 4). The structure and associated fillet will be designed to provide storm damage reduction for the area east of Shallotte Boulevard and will enhance project performance along the east end of the federal project. The plan calls for a 30-year permit to be issued for the terminal groin and associated beach fill.

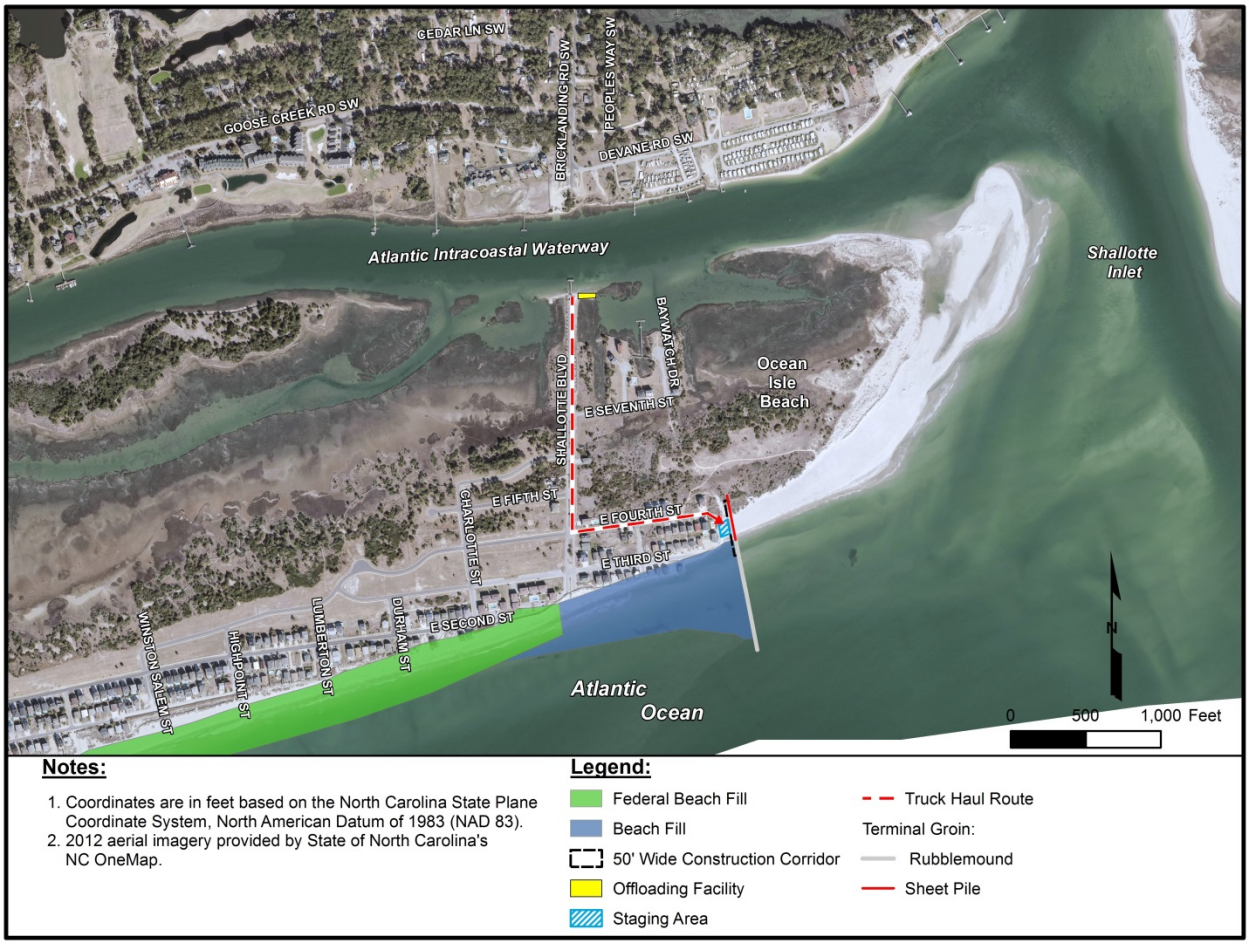


Figure 4. Location of the proposed terminal groin and associated beach fill located on the eastern portion of Ocean Isle Beach

2.4 West End of Ocean Isle Beach

The western most 9,400 feet of the Ocean Isle Beach shoreline has not been included in the federal project and is not currently managed. The presence of a stable dune system has maintained an adequate level of storm damage reduction, thereby excluding this portion of the island from nourishment needs. This study included engineering analyses of island-wide shoreline and volume change rates, which have been used to determine long-term beach nourishment needs for the foreseeable future. Essentially, these analyses establish thresholds of shoreline and volume change that would trigger the need for nourishment in order to provide an acceptable level of erosion and storm damage mitigation.

2.5 Static Line Exception

In accordance with 15A NCAC 07H .0305 (North Carolina Administrative Code), a static vegetation line was established by the Division of Coastal Management following the initial construction of the federal storm damage reduction project in 2001. A pre-construction survey of the vegetation line, made in 1999, was used to define the static vegetation line within the project area for the Ocean Isle Beach federal project as described above. In 2009, the NC Legislature amended the Coastal Area Management Act (CAMA) to allow communities with static vegetation lines to apply for a static vegetation line exception. An application for a static vegetation line exception must include: (a) documented performance of the project over at least a 5 year period prior to applying for the exception, (b) engineering design documents for the projects, (c) availability of borrow material needed to maintain the projects, (d) and a financial plan demonstrating the ability to continue maintenance of the projects for at least 25 years after the establishment of the static vegetation line exception. The Coastal Resources Commission approved a request by the Town for a static vegetation line exception on January 13, 2010. As part of the rules governing the static line exception, an applicant is required to provide a progress report to the CRC every 5 years (15A NCAC 07J .1204). This exception was extended an additional 5 years in late 2014.

2.6 Beach Monitoring

Historically, the USACE has conducted beach profile surveys along the portion of the Town included within the federal project. Initially these surveys were conducted annually; however, in recent years survey frequency has been reduced due to federal funding shortfalls. Recent survey frequency has been limited to a pre-construction survey every 3 to 4 years to allow for the design of periodic nourishment events. In 2013, the Town contracted with McKim & Creed to collect beach profile data along the portions of the Town outside of the federal project. These data have assisted CPE-NC with the design and alternative analysis associated with the terminal groin project. In addition, data collected along the western portion of the Town was used by CPE-NC in this study to determine changes occurring along this portion of the Town in an effort to better understand the shoreline change and volume change taking place west of the federal project.

3.0 Engineering Analysis

3.1 Development of Design Beach Fill Template

The beach fill for the federal storm damage reduction project between baseline stations 70+00 (just east of Southport St.) and 181+00 has performed extremely well since its initial construction in March-May 2001. While this section of the federal project has experience some

losses, the losses have not compromised the level of protection provided by the beach fill design template. As a result, this 11,100-foot section of the federal project has not required any periodic nourishment since initial construction nor has this section of the shoreline sustained any damage due to coastal storms both tropical and extra-tropical. Based on this performance, this section of the federal project was used as a guide in developing the design beach fill template for the west end of Ocean Isle Beach that is not included in the federal project. The goal of the design is to increase the level of storm protection along the west end of the island to a level comparable to that provided by the federal project.

As a first step, the volume of material on the existing profiles within the federal storm damage reduction project between station 70+00 and 180+00 was computed. The volume computations extended from the back or landward toe of the dune seaward to the -18-foot NAVD88 depth contour. An example of this area is shown in Figure 5. For this analysis, the existing profiles were based on a beach profile survey taken in 2013 by the engineering firm McKim & Creed. The volume between the back toe of the dune and the -18-foot depth contour on the existing profiles between 70+00 and 180+00 averaged 511.3 cubic yards/foot of shoreline (cy/ft.) with the volume ranging from a minimum of 474.6 cy/ft. to a maximum of 554.8 cy/ft.

Similar computations were made for the profiles along the west end of Ocean Isle beach between baseline stations 185+00 and 270+00 and the volume on those profiles compared to the average volume on the profiles within the federal project. The results are provided in Table 1.

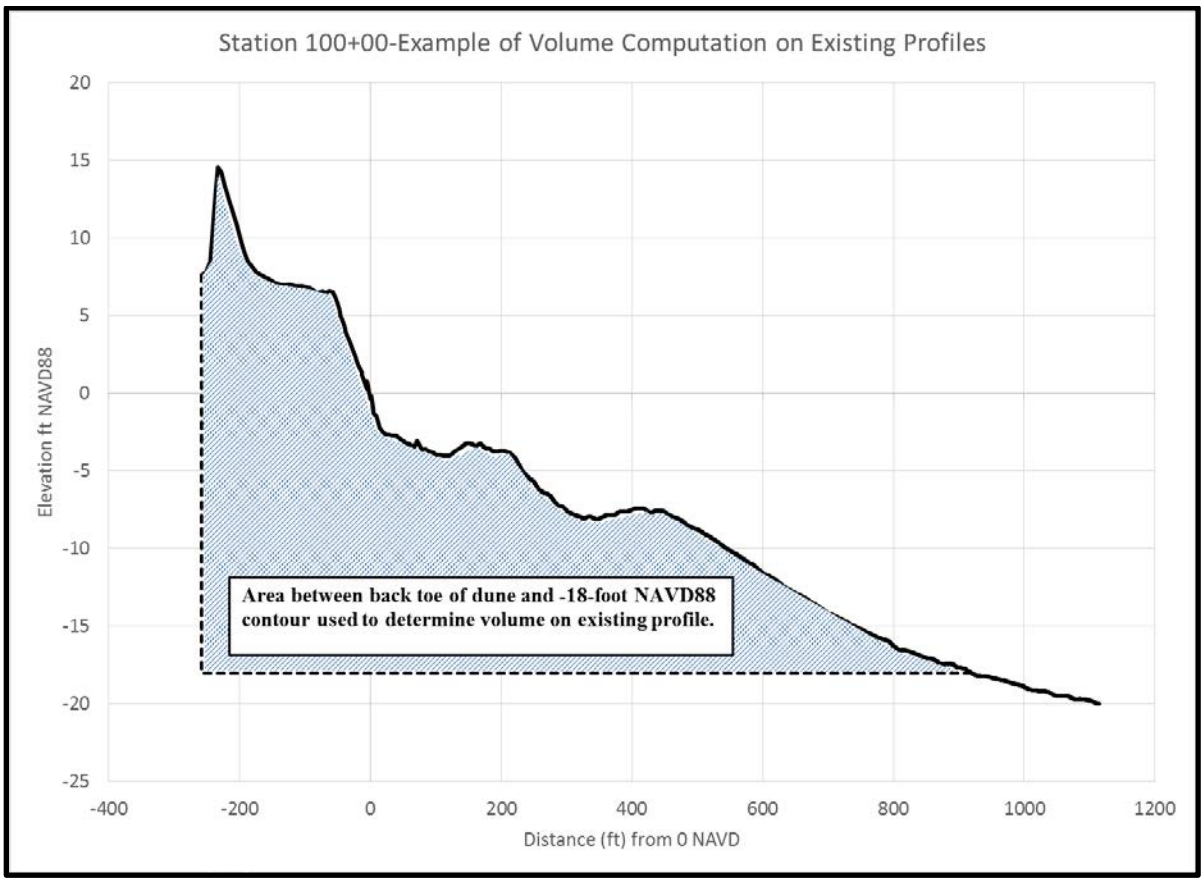


Figure 5. Example of area used to compute volume of material on the existing profiles between station 70+00 and 120+00 (Example shown is station 100+00).

For the shoreline segment between the west end of the federal project (station 181+00) and station 245+00 (baseline stationing shown on Figure 7), the difference in the volume of material on the profiles along the west end of Ocean Isle Beach and the volume within the federal project was fairly consistent, averaging a little over 34 cy/ft. (Table 1). West of station 245+00 to station 260+00, the volume of material on the profiles was approximately equal to the volume within the federal project. West of station 260+00 to station 270+00 (located near the east shoulder of Tubbs Inlet), the volume of material on the profile exceeded the volume on the profiles within the federal project. This westernmost 1000-foot segment of Ocean Isle Beach is influenced by the orientation of the ocean bar channel of Tubbs Inlet and the associated configuration of the ebb tide delta of the inlet. A discussion of the influence of Tubbs Inlet on the behavior of the extreme west end of Ocean Isle Beach is provided below.

Table 2. Difference in volume on the existing west end profiles (June 2013 survey) and the average volume on the profiles of the federal project between stations 70+00 and 180+00.

Station	Cross Street Name	Volume (cy/ft.) on existing profile	Volume Difference-federal project and west end (cy/ft.)[1]
185+00	Isle Plaza	470.2	-41.1[2]
190+00	220 ft. west of Driftwood Dr.	470.3	-41.0
195+00	Starboard St.	496.2	-15.1
200+00	200 ft. east of Beaufort St.	462.6	-48.7
205+00	305 feet west of Beaufort St.	477.0	-34.3
210+00	Ocean Isle Villas	475.6	-35.6
215+00	N/A	475.3	-36.0
220+00	210 ft. east Via Dolorsosa Dr.	479.1	-32.2
225+00	290 ft. west Via Dolorsosa Dr.	473.8	-37.5
230+00	65 ft. east entrance to Island Park Cottages	468.7	-42.6
235+00	165 ft. east Harbor Dr.	476.0	-35.3
240+00	230 east of Schooner Dr.	496.4	-14.8
245+00	140 ft. west of Schooner Dr.	481.9	-29.4
250+00	Near Coggeshall Dr.	510.1	-1.2
255+00	Gate to Private Development	510.1	-1.1
260+00	N/A	505.7	-5.5
265+00	N/A	589.8	78.5
270+00	480 ft. east of the end of Ocean Isle W. Blvd.	666.6	155.3

[1]Average within federal project is 511.3 cy/ft.
[2]Negative values indicate a deficit, positive values indicate a surplus.

Based on the comparison of the volume material on the existing profiles within the limits of the federal project to the volume of material on the profiles located west of the federal project, a design beach fill template was developed that would provide the volume of material on each west end profile that would be comparable to the volume of material residing on the profiles within the federal project between baseline stations 70+00 and 180+00. The design profile, which is shown on Figure 5, consists of a 10-foot wide dune at elevation +12.5 feet NAVD88 fronted by a 40-foot wide berm at elevation +6.0 feet NAVD88. The back or landward slope of the dune would be 1V:5H (1 Vertical to 5 Horizontal) and the front or seaward slope 1V:10H.

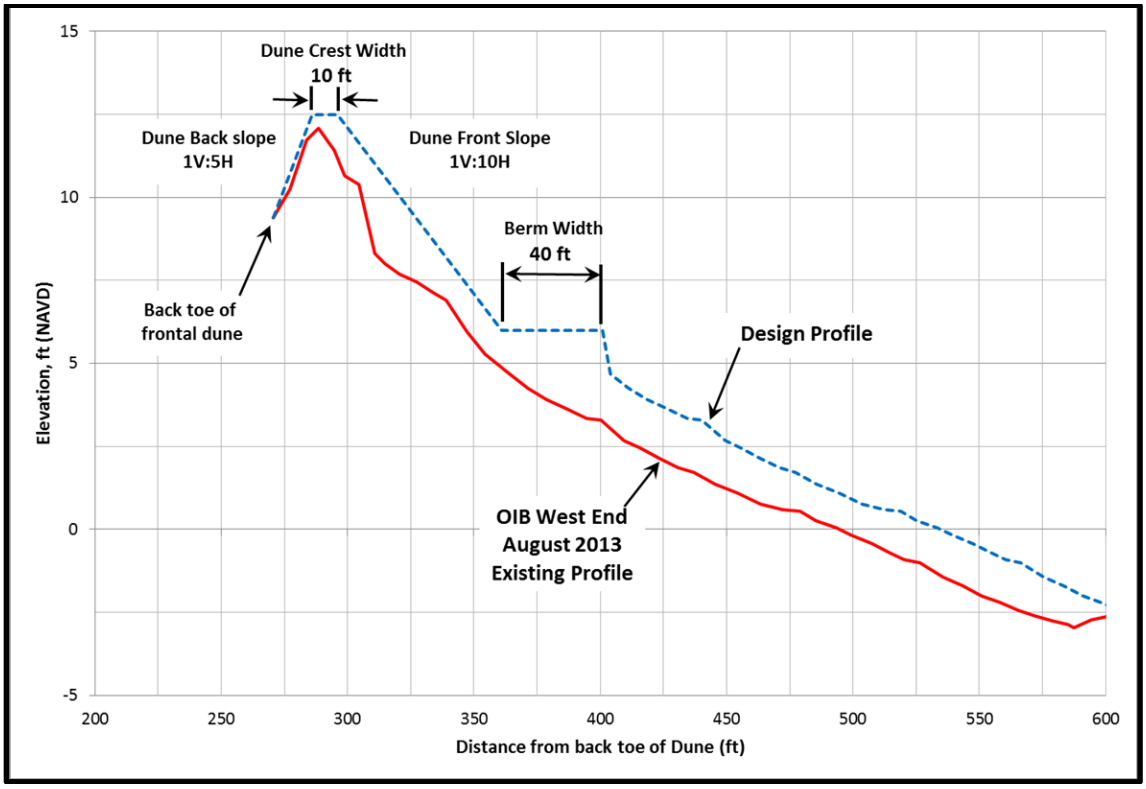
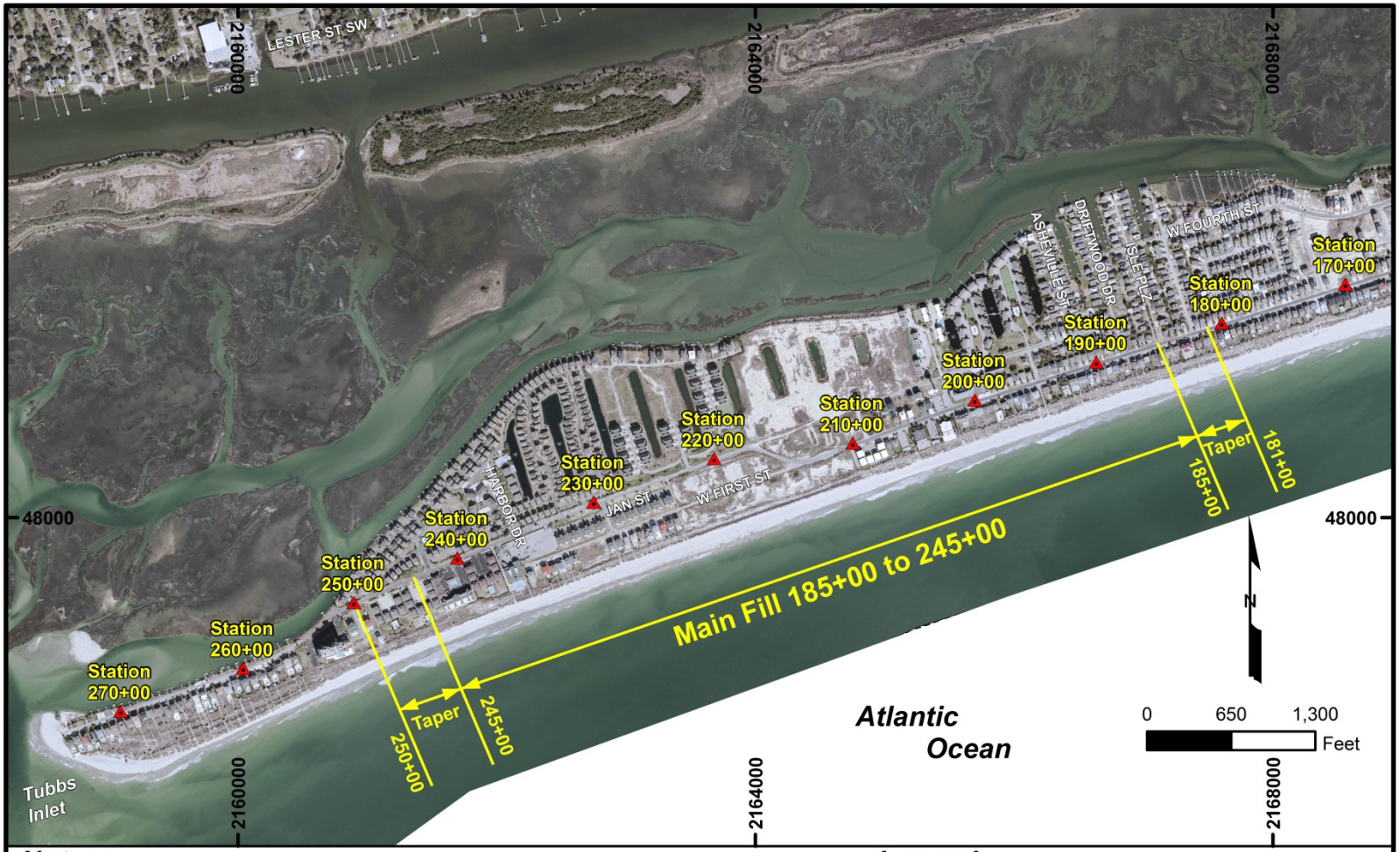


Figure 6. Recommended beach fill design template for the west end of Ocean Isle Beach.

The beach fill for the west end of Ocean Isle Beach would begin at the west end of the federal project, located at station 181+00. A 400-foot transition would be constructed between station 181+00 and 185+00 with the full design template, shown in Figure 6, extending between station 185+00 and 245+00. A 500-foot transition would be constructed on the west end between station 245+00 and 250+00 in order to merge the beach fill shoreline with the existing shoreline. A plan view showing the limits of the proposed beach fill is provided on Figure 7.

The volume of material needed to construct the design beach fill template, including the two taper sections, totals approximately 262,000 cubic yards based on the June 2013 survey. In addition to the initial construction volume, a volume of material designated as advanced nourishment should be placed seaward of the design template to account for anticipated volume losses during the time interval between completion of initial construction and the first scheduled periodic nourishment operation. Periodic nourishment requirements for the west end project are discussed below.

While the shoreline west of station 250+00 is not presently included in the beach fill estimate, the shoreline along the west end of Ocean Isle Beach is subject to rapid changes due to the influence of Tubbs Inlet, which is discussed below. In anticipation of possible future beach erosion response measures in this area, the permitting actions recommended in this report for the west end of Ocean Isle Beach include the entire shoreline west of baseline station 181+00.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2012 aerial photography provided by NC Onemap.

Legend:

▲ Profile Station

Figure 7. Baseline stationing and limits of proposed beach fill on west end of Ocean Isle Beach.

3.2 Influence of Tubbs Inlet

The orientation of the ebb tide channel running across the ocean bar of Tubbs Inlet and the associated configuration of the ebb tide delta has a significant influence on the behavior of the shoreline on the extreme west end of Ocean Isle Beach. Google Earth aerial photos of Tubbs Inlet dated from September 2006 to December 2012 are shown on Figure 8 and Figure 9. As shown on Figure 8a, the bar channel of Tubbs Inlet was oriented toward the west end of Ocean Isle Beach in September 2006. As a result of this bar channel orientation, the extreme west end of Ocean Isle Beach experienced a significant accumulation of sediment, particularly in offshore portions of the profiles west of station 260+00. Examples of this build-up of material in the offshore area are given on Figure 10 which shows comparative plots for profile stations 260+00 and 270+00, respectively, for the February 2001, April 2007 and June 2013 profile surveys.

Sometime between September 2006 and October 2007 the bar channel assumed an alignment perpendicular to the orientation of the adjacent shorelines with this orientation persisting until about October 2009. During this time, the offshore portions of the profiles east of Tubbs Inlet to about station 250+00 began to lose material as is evident on Figure 8a and b. The bar channel alignment shifted toward Sunset Beach between October 2009 and March 2011 and that alignment persist today. With the bar channel aligned toward Sunset Beach, the offshore portions of the beach profiles along the west end of Ocean Isle Beach is likely to continue to experience some erosion, however, as of June 2013, the volume of material on the profiles west of station 250+00 still exceeded the volume within the federal project by a considerable margin (Table 1). Therefore, the extreme western end of Ocean Isle Beach between station 250+00 and Tubbs Inlet does not need nourishment at this time.

The extreme west end of Ocean Isle Beach should continue to be monitored and if shoreline conditions deteriorate in the future, consideration for remedial measures along this section of the town's shoreline may be in order. While the use of beach fill alone may prove problematic given the dynamic influence Tubbs Inlet has on the west end of the island, if the Town elects to move forward with the permitting process for a project along the west end of town, the shoreline between 250+00 and Tubbs Inlet should be included in the permit application. This would allow the town to place beach fill in this area should future conditions warrant. If beach fill is placed west of station 250+00, the performance of the fill would be tracked by the monitoring surveys. If the results of the beach fill monitoring surveys along the extreme west end of the island indicate poor beach fill performance, the data collected would help in the formulation of possible alternative shoreline management measures for this area.

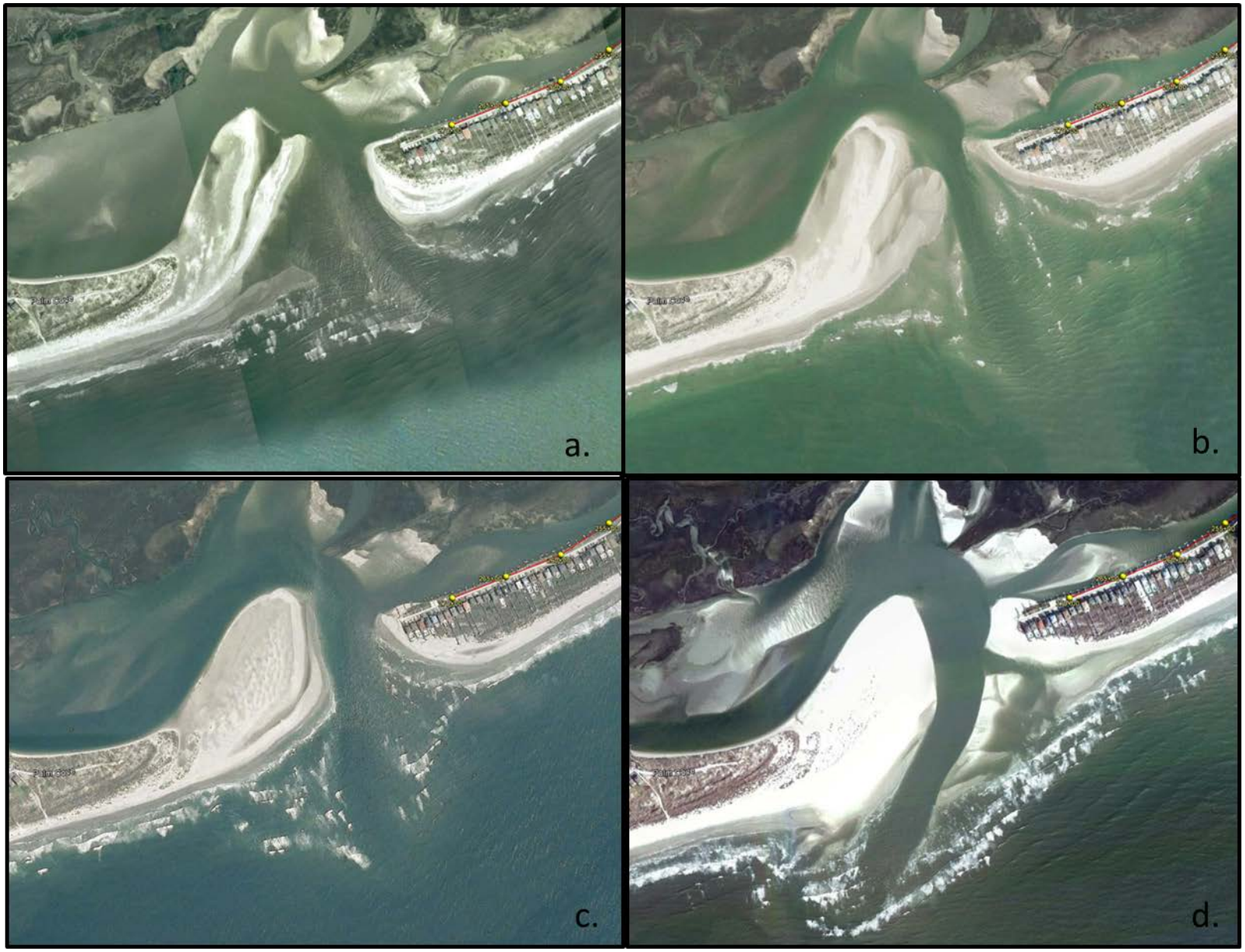


Figure 8. Google Earth images of Tubbs inlet during (a) September 2006 (b) October 2007, (c) October 2009, and (d) March 2011

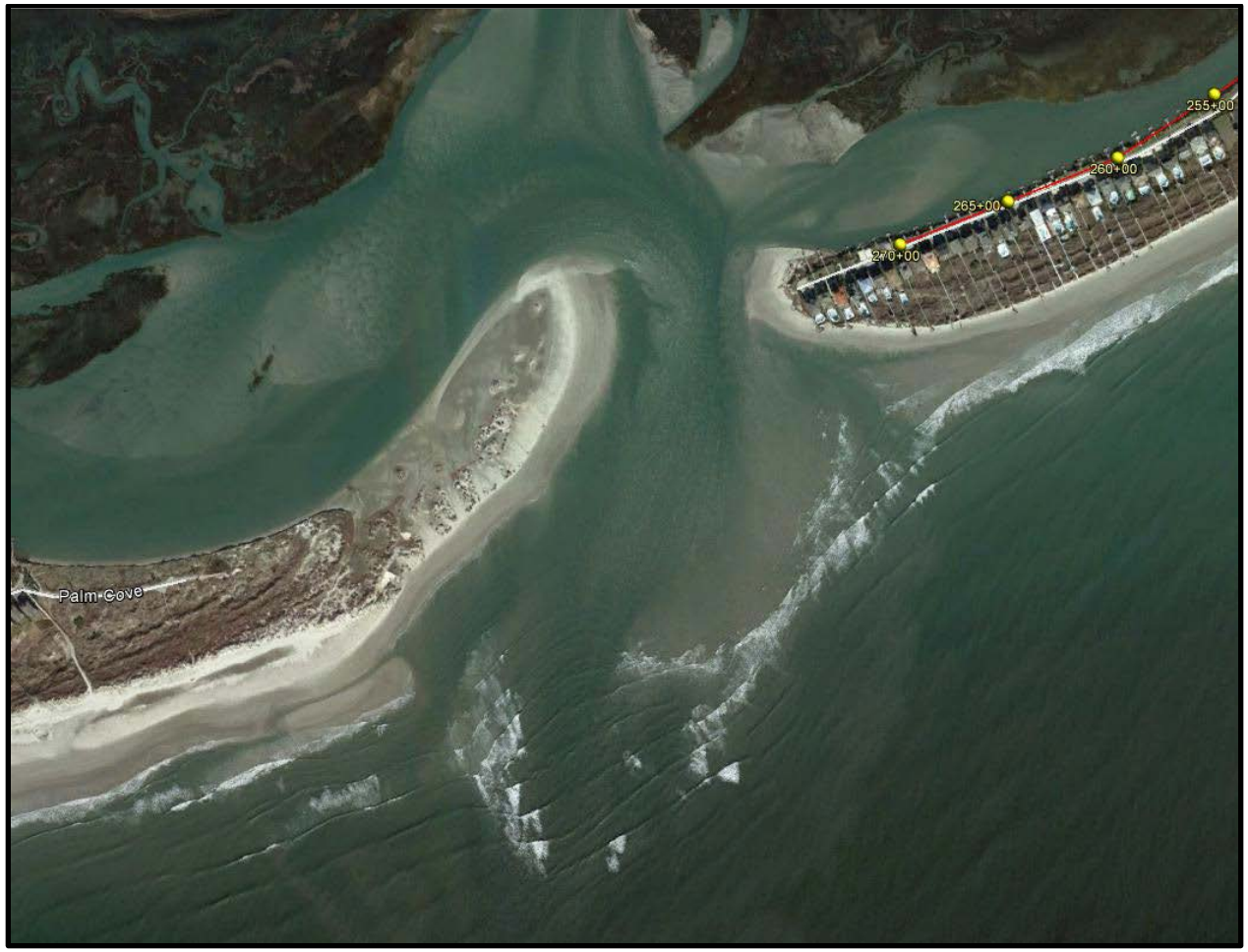


Figure 9. Most recent Google Earth image of Tubbs Inlet – December 2012.

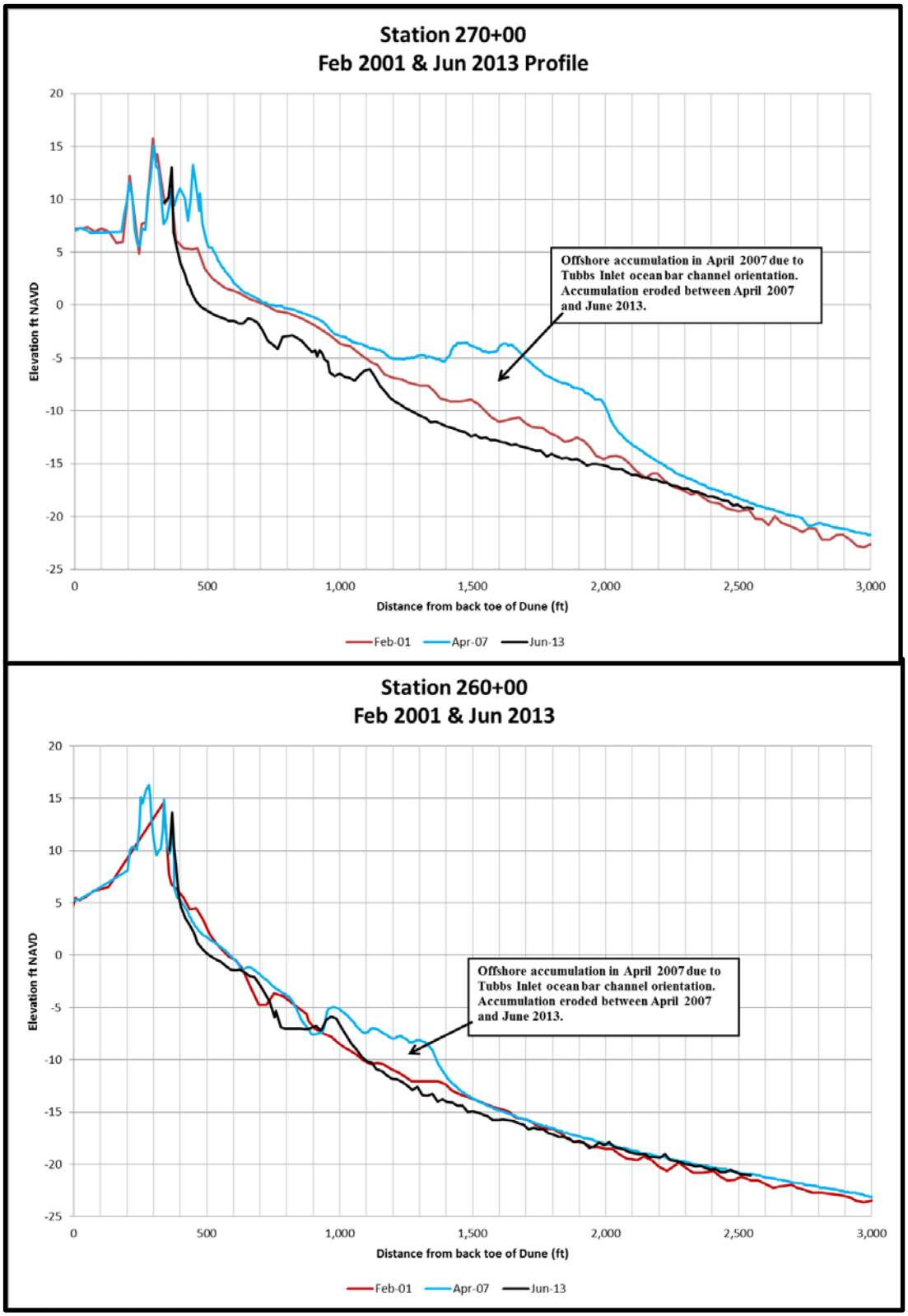


Figure 10. Comparison of February 2001, April 2007, and June 2013 profile surveys for (top) station 260+00 and (bottom) station 270+00.

3.3 Behavior of West End Shoreline.

Cumulative volumetric changes along the west end of Ocean Isle Beach were determined from 13 beach profile surveys taken between May 2002 and August 2013. As in the previous analyses, the volume of material on each profile was measured between the landward toe of the dune and the -18-foot NAVD88 depth contour. The May 2002 starting date for the analysis, which was approximately one year after the completion of the initial construction of the federal storm damage reduction project, was selected to allow time for the federal beach fill to equilibrate. The cumulative volume changes were determined for each 1,000-foot baseline station between 170+00 and 270+00. Plots of the cumulative volume changes for stations 170+00 to 240+00 are given on Figure 11 while cumulative volume changes for stations 250+00 and 260+00 are given on Figure 12. A plot of the cumulative changes for station 270+00 is not shown due to the erratic behavior and wide swings in volume caused by the influence of the ocean bar of Tubbs Inlet.

All of the profiles along the west end of Ocean Isle Beach experienced relatively rapid accretion between the May 2013 and August 2013 surveys. However, the phenomenon is believed to be temporary and not unlike similar upticks in the shoreline change trends measured over the years. For example, similar upticks in the shoreline response occurred at most profile stations between April and May 2007. Therefore, the apparent accretion during the last month of the record is not considered to be significant.

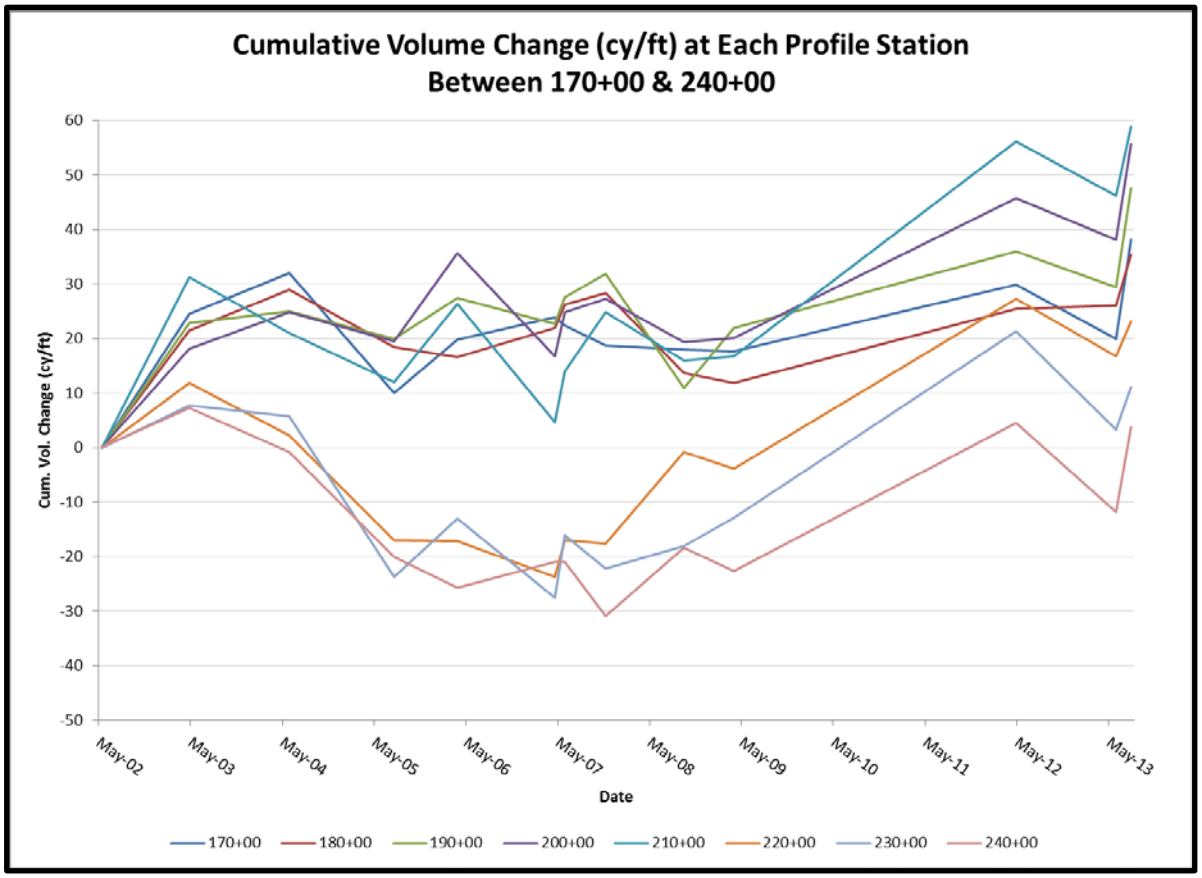


Figure 11. Cumulative volume changes between station 170+00 and 240+00 – May 2002 to June 2013.

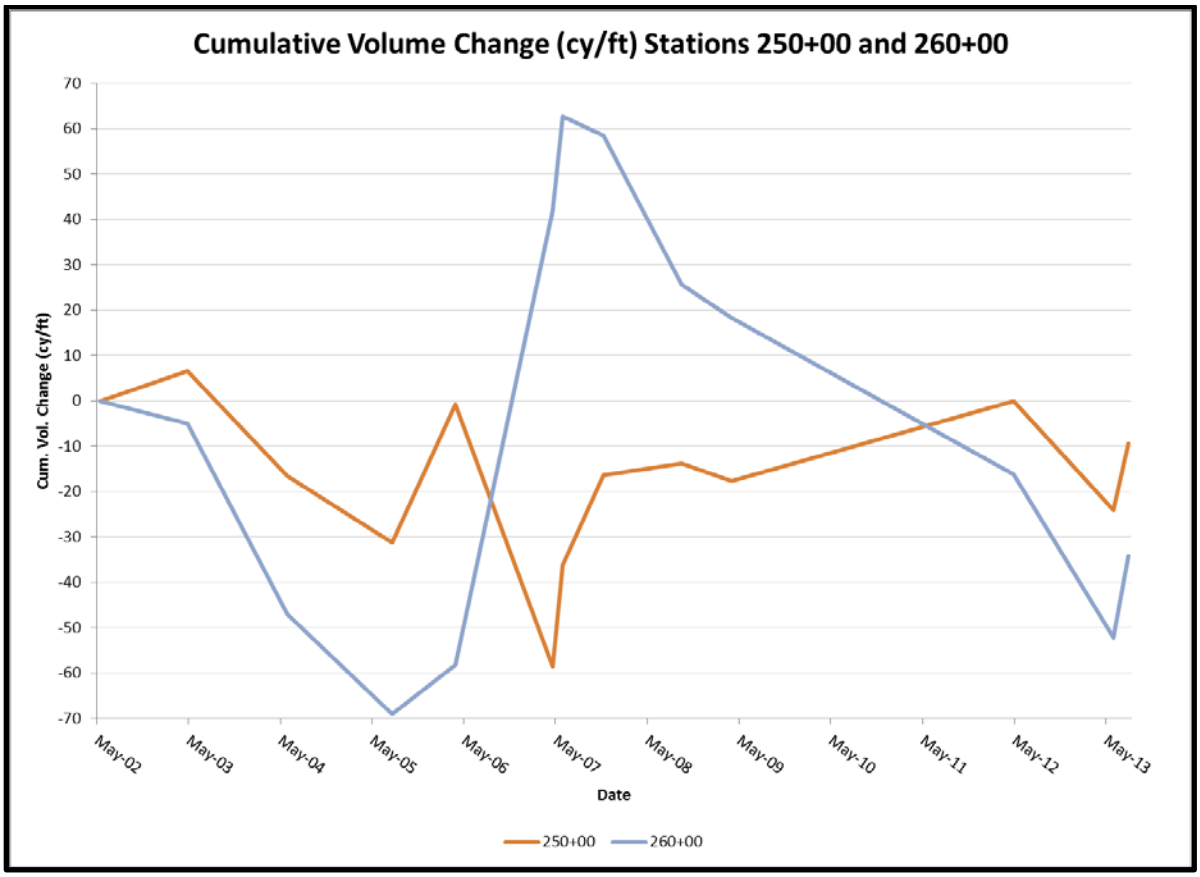


Figure 12. Cumulative volume changes stations 250+00 and 260+00 – May 2002 to June 2013.

The cumulative volume changes for stations 170+00 to 210+00 appeared to follow similar trends. Therefore, the changes between each profile survey were averaged for these stations to produce one cumulative volume change curve applicable to the shoreline between 170+00 and 210+00. This average curve is shown on Figure 11. Cumulative changes for stations 220+00 to 240+00 also appeared to follow similar trends and were averaged to produce the average cumulative volume change plot also shown on Figure 11. The cumulative volume change curves for stations 250+00 and 260+00 as well as station 270+00 (not shown) were radically different due to the influence of Tubbs Inlet and were not combined into an average curve.

As discussed above, changes in the orientation of the ocean bar channel of Tubbs Inlet and the associated impacts the channel has on the configuration of the ebb tide delta has a significant impact on the behavior of beach profiles east of Tubbs Inlet to about station 250+00. This influence is clearly demonstrated by the cumulative volume change curve for station 260+00 (Figure 12) in which the volume of material on the profile increased between July 2005 and May 2007, a time when the ocean bar channel oriented toward the west end of Ocean Isle Beach, and then rapidly decreased following the shift of the channel toward Sunset Beach in 2007. The volume of material on profile 250+00 was influenced to some extent by Tubbs Inlet but the impact was much less than that observed at station 260+00.

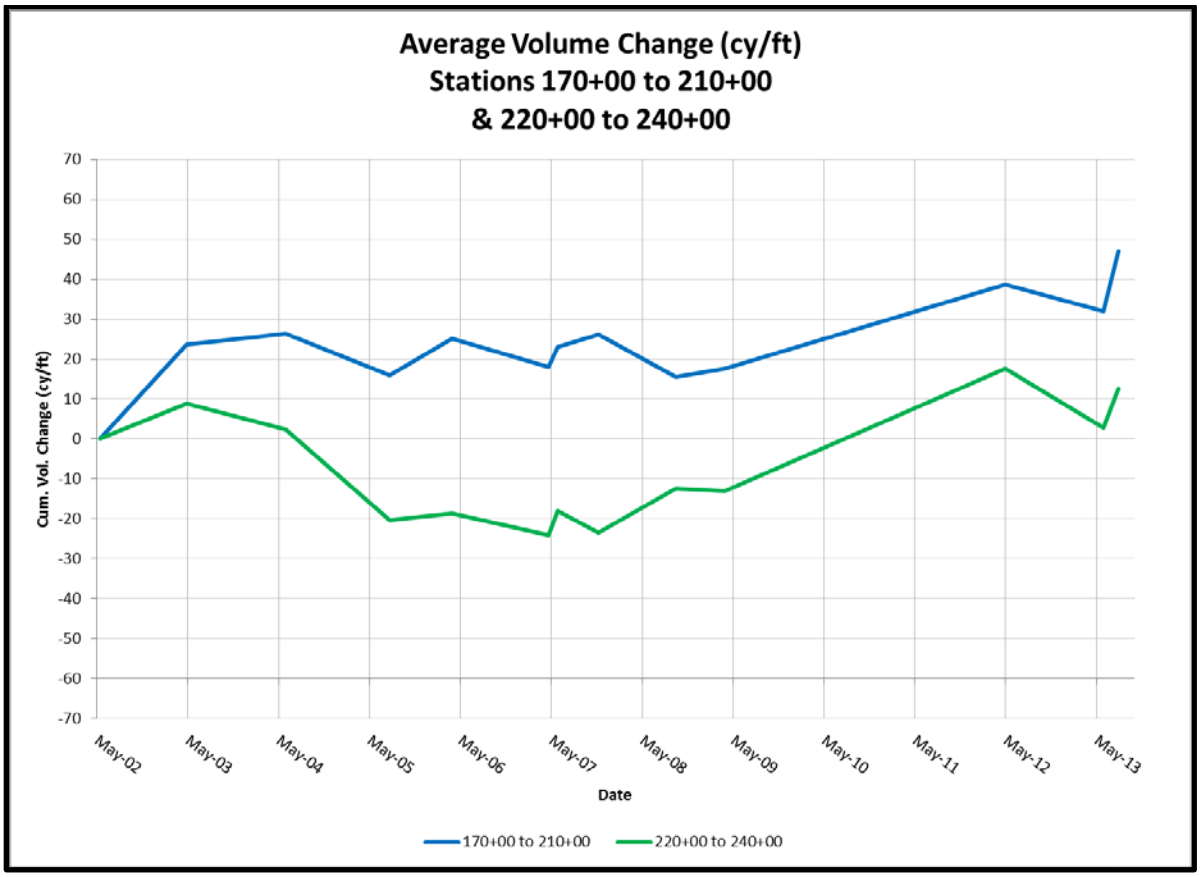


Figure 11. Average cumulative volume changes stations 170+00 to 210+00 and 220+00 to 240+00 between May 2002 and June 2013.

Since about July 2005, all of the profiles west of the federal project have experienced a cumulative increase in the volume of material residing between the landward toe of the dune and the -18-foot NAVD88 contour. Some of this accretion, particularly between stations 181+00 and 210+00, which lie outside or west of the federal project, could be due to the westward spreading of material from the federal storm damage reduction project. In this regard, the volume of material on the profiles between 181+00 and 210+00 appeared to increase significantly till about April 2003 with the volume stabilizing till around September 2008. A slightly smaller increase was observed between stations 220+00 and 240+00 which are located farther from the west end of the federal project. Beginning around November 2007, both areas began to experience gradual but significant gains. The reason for this latter trend is not clear. Some of the gains, particularly on the far west end (stations 220+00 to 240+00) could have been due to the onshore migration of some of the ebb tide delta material of Tubbs Inlet following the movement of the bar channel toward Sunset Beach; however, the extent of this impact are less likely to be attributed to gains observed along the eastern portion of this shoreline segment.

3.4 West End Beach Periodic Nourishment Requirements.

The west end of Ocean Isle Beach, situated between baseline stations 181+00 and 240+00, has been relatively stable since 2002. Even so, the placement of a beach fill along the west end of Ocean Isle Beach to enhance the level of storm damage protection would still be expected to

experience some volume losses. Losses from the beach fill would occur primarily as spreading or diffusion losses. In this regard, the placement of the beach fill would move the shoreline seaward in the placement area relative to the adjacent areas thus creating somewhat of a bulge in the planform shape. This seaward protuberance would focus more wave energy on the ends of the fill resulting in increased rates of sediment transport out of the fill area compared to sediment transport rates along the natural shoreline alignment.

An estimate of the possible losses from a fill on the west end of Ocean Isle Beach was obtained from an analysis of the behavior of the federal project between baseline stations 60+00 and 120+00. Prior to the construction of the federal project, the shoreline between station 60+00 and 120+00 was behaving in a manner similar to the west end with shoreline change rates varying from +0.3 ft./yr. to -0.4 ft./yr. Therefore, the post-construction behavior of this section of the federal project was used as proxy to develop possible periodic beach nourishment requirements for a beach fill project constructed along the west end of Ocean Isle Beach.

An average cumulative volume change curve developed for the area between baseline station 60+00 and 120+00 is provided on Figure 13. As noted on this figure, the beach project was initially constructed at the beginning of 2001 and nourished in 2006-07 and 2010.

Following initial construction, the section of the federal project between station 60+00 and 120+00 experienced an initial gain of material which lasted till around April 2003 (Figure 13). Following this initial response, this section of the project began to erode. The rate of loss from this section of the project between April 2003 and May 2006 (time period noted by green oval on Figure 13 averaged -11.4 cubic yards/foot of beach/year (cy/ft./yr.). Some of the initial gain of material between December 2001 and April 2003 was probably derived from portions of the federal project located east of station 60+00 which experienced some rather high initial rates of volume loss (CPE-NC, 2015).

Following the first periodic nourishment operation, which was completed in April 2007, the beach fill experienced an initial period of relatively rapid loss that persisted until September 2008 (Figure 13). Following this initial loss and prior to the second renourishment operation in 2010, no additional losses occurred. The rate of volume change during the initial post-nourishment period between April 2007 and September 2008 was -7.4 cy/ft./yr. The third periodic nourishment was completed in May 2010. Since that time, the volume of material between station 60+00 and 120+00 has actually accreted at a rate of 0.9 cy/ft./yr. The average rate of volume change for the three post-nourishment periods is a loss of 6.0 cy/ft./yr.

Even though the beach fill between station 60+00 and 120+00 experience a wide range of post-nourishment response, the average rate of volume change of -6.0 cy/ft./yr. was used to estimate possible periodic beach nourishment requirements for the west end of Ocean Isle Beach. This rate of volume change may be pessimistically high given the varied response of the federal project and the relative stability of the west end of the island, however, for planning purposes, particularly with respect to beach nourishment projects, a high estimate should allow the town to safely budget for future nourishment operations.

Using a periodic nourishment rate of 6.0 cy/lf/yr. and a total project length of 6,900 feet, which includes the main fill and the two taper sections, the nourishment requirement for the west end project would be 37,000 cubic yards/year.

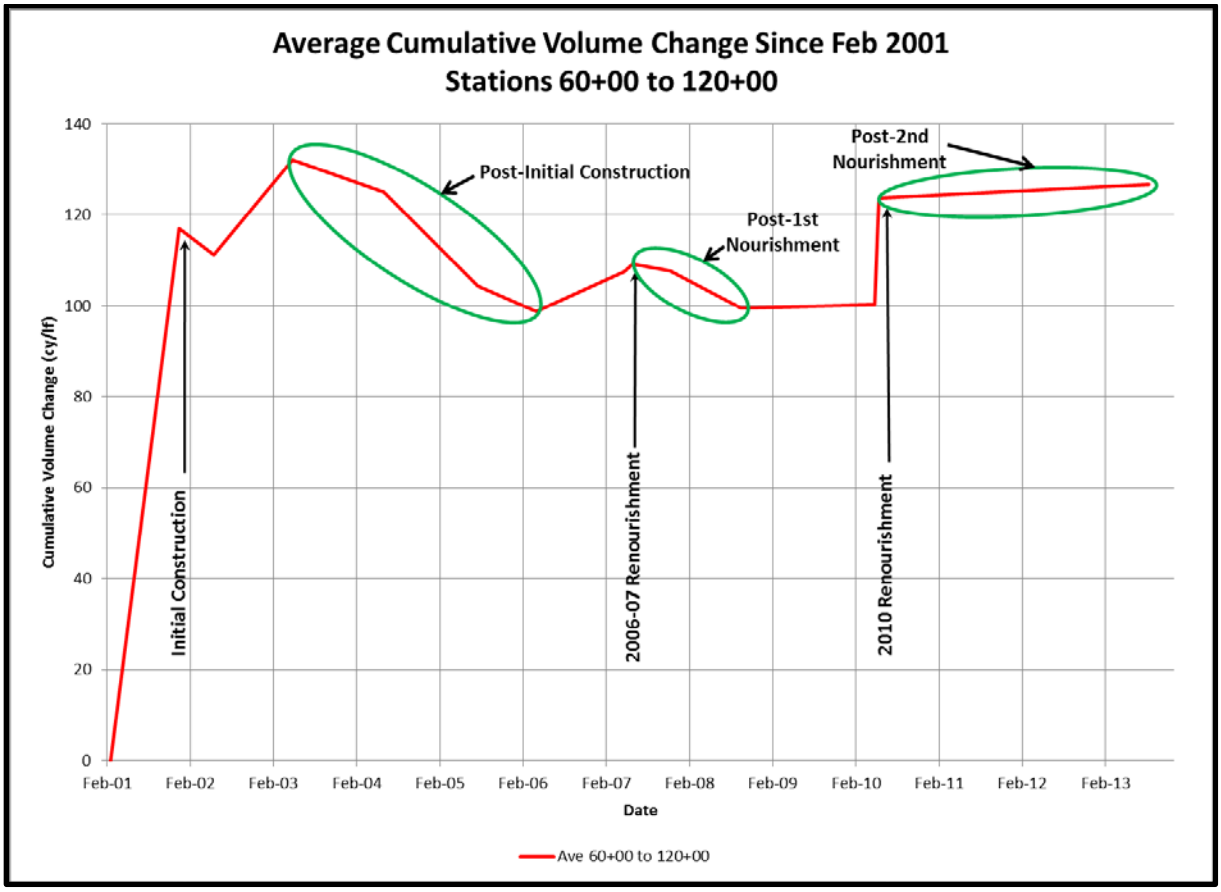


Figure 13. Average cumulative volume change for stations 60+00 to 120+00 since initial construction of the federal project in 2001.

3.5 Island-wide Periodic Nourishment Requirements.

If the Town elects to implement a beach nourishment project on the west end of the island, periodic nourishment of the west end project would be accomplished in conjunction with periodic nourishment of the federal project and possibly the Town's east end project that includes a terminal groin and beach fill. Based on the evaluation of the east end project that would include a terminal groin near the west shoulder of Shallotte Inlet, periodic nourishment of the area west of the proposed terminal groin to station 120+00 of the federal project would require 80,000 cubic yards/year (CPE-NC, 2015).

The portion of the federal project between station 120+00 and 181+00 has not required any periodic nourishment since construction and periodic nourishment of this section of the federal project is not anticipated in the near future (CPE-NC, 2015). In any event, given the possibility the area could be impacted by a severe coastal storm, for planning purposes, a nominal nourishment requirement of 2 cy/ft./yr. for this section of the federal project is recommended for

planning purposes. Therefore, periodic nourishment of this portion of the federal project could require an average of about 12,000 cubic yards/year.

Based on the assessment of the impacts of the proposed terminal groin on the shoreline of Ocean Isle Beach and the associated reduction in periodic nourishment requirements required for the federal project as well as the extreme east end of the island, a five (5) year periodic nourishment interval was recommended in the DEIS. Adopting a 5-year nourishment interval for the west end project as well, the 5-year periodic nourishment requirements needed to maintain the entire ocean shoreline of Ocean Isle Beach following the implementation of the east and west end projects, is summarized below.

Five Year Periodic Nourishment Requirements for the Town of Ocean Isle Beach:

Proposed Terminal Groin to Station 120+00	**400,000 cy**
Contingency Volume Station 120+00 to 181+00	**60,000 cy**
West End from Station 181+00 to 250+00	**185,000 cy**
Total	**645,000 cy**

The borrow source that would be used to provide material to nourish all of the segments along Ocean Isle Beach would be the existing sediment trap/borrow area located in Shallotte Inlet. This particular borrow area was originally approved for use with the federal storm damage reduction project. The inlet borrow area is also being proposed for the east end project. A discussion of the Shallotte Inlet borrow area as well as other potential borrow areas near Ocean Isle Beach is provided below in the Geotechnical Section (Section 4.0).

3.6 Implementation Schedule for a West End Project.

Implementation of a beach fill project along the west end of the Town of Ocean Isle Beach would require both federal and state permits as well as other environmental clearances (See Section 5.0 below). If the town begins the permitting process for a west end project by April 2015, the permitting process, which is discussed below, could take between 12 and 16 months to complete. Assuming 16 months as a worst case, the Town should have the necessary permits in hand by August 2016. Based on this schedule, the earliest the town could construct a project on the west end of the island would be during the 2016-2017 environmental dredging window.

Ideally, construction of a project on the west end should be done at the same time as construction of the east end project and periodic nourishment of the federal project in order to limit the cost of mobilization and demobilization of the dredge and ancillary equipment to one operation. However, the condition of the beach on the east end of Ocean Isle Beach has reached a critical point in terms of threats to existing development and infrastructure and the Town of Ocean Isle Beach is pressing to have the east end project constructed during the next environmental dredging widow that extends between November 16, 2015 and April 30, 2016. If the east end project is constructed during the 2015-2016 environmental window, construction of the west end project at the same time as the east end project would not be possible, and, due to relatively low erosion rates along the west end of the island, may not be needed.

With regard to the federal project, periodic nourishment is normally scheduled every three years. With the last nourishment operation being completed in the spring of 2014, the next scheduled periodic nourishment operation for the federal project would likely occur during the 2016-2017 environmental window. Therefore, construction of a project along the west end of Ocean Isle Beach could possibly occur in conjunction with the next nourishment of the federal project. However, due to the historical performance of the west end and the storm protection provided by the relatively healthy existing dune in this area, implementation of a beach fill project along the west end of the island should not be needed prior to the 2020-2021 environmental dredging window. The recommended schedule for implementing the various components of the island-wide shoreline management plan for the Town of Ocean Isle Beach and the estimated volume of material associated with each component are summarized in Table.

Table 3. Implementation schedule and volumes of beach nourishment projects along Ocean Isle Beach

Environmental Dredging Window	Project	Permitted Beach Fill Volume (CY)
2015-2016	**East End – Beach Fill for Terminal Groin including 5-Years of Advanced Nourishment**	**264,000**
2016-2017	**Nourish Federal Project with 4-yr volume advanced nourishment volume[(1)]**	**320,000**
2020-2021	**Periodic Nourishment Federal Project**	**400,000**
	Contingency Beach Fill Station 120+00 to 181+00 (Optional)	**60,000[(2)]**
	Initial Construction of West End Project	
	(a) Construct Design Template	262,000[(3)]
	(b) 5-Years Advanced Nourishment	185,000
	TOTAL West End Project	**447,000**

[(1)]In order to place each component of the management plan on a 5-year nourishment cycle.
[(2)]On an as-needed basis.
[(3)]Based on June 2013 survey data.

3.7 Initial Construction Cost for West End Project.

Based on the above discussion, construction of a beach fill project along the west end of Ocean Isle Beach was assumed to occur during the 2020-2021 environmental dredging window with construction of the project occurring at the same time as periodic nourishment of the federal and east end projects resulting in one island-wide nourishment operation. Based off historical erosion rates and nourishment performance, the periodic renourishment would be projected to be once every five (5) years (CPE-NC, 2015). The total volume of beach fill to be placed on the west end of Ocean Isle Beach if construction is accomplished in 2020-2021would consists of 262,000 cubic yards for construction of the design template (June 2013 survey) and 185,000 cy of advanced fill for a total of 447,000 cubic yards.

Normally, the USACE is not allowed to combine a federal project with a non-federal component. However, a non-federal entity can negotiate a separate contract with USACE selected dredging company. This was done in during the 2006-07 periodic nourishment operation in which the Town contracted directly with the company performing periodic nourishment of the federal project. Under this scenario, the Town would probably only be required to pay a negotiated unit cost to pump the material needed for the west end project the additional distance measured from the west end of the nourished portion of the federal project to the west end of the west end project. The Town would also be responsible for additional mobilization and demobilization cost associated with the longer pipeline.

Using the cost for the 2014 periodic nourishment operation as a guide, the unit cost for pumping material the additional distance to construct the west end project during the 2020-2021 environmental dredging window would be $8.14/cubic yard (Table 4). The additional cost to lay and remove the pipeline from the federal project to the west end of Ocean Isle Beach would be approximately $239,000. These costs have been inflated to reflect 2016-17 price levels. Using these adjusted costs, the estimated cost for constructing the initial fill along the west end of Ocean Isle Beach would be as presented in Table 4. Table 5 depicts the anticipated project costs for each component of the island-wide beach management plan.

Table 4. Cost Estimate for West End Project – Ocean Isle Beach

Item	Quantity	Unit Cost	Cost
Mobilization & Demobilization	1 Job	Lump Sum	$239,000
Dredging	447,00 cy	$8.14	$3,637,000
Contingency			$581,000
Engineering & Design	1 Job	Lump Sum	$110,000
Construction Observations	1 Job	Lump Sum	$120,000
TOTAL			**$4,687,000**

Table 5. Estimated project costs.

Environmental Window (Years)	Project	Estimated Non-Federal Cost
2015-2016	Initial Construction-Terminal Groin & Fill-East End	$4,941,000
2016-2017	Nourish Fed Project (non-Federal Share)	$2,049,000
2020-2021	Nourish Fed Project (non-Federal Share)	$2,481,000
2020-2021	Construct West End Project	$4,687,000
	TOTAL NON-FED COST 2020-2021	$7,168,000
2025-2026[(1)]	Nourish Federal Project (non-Federal Share)	$2,739,000
	Nourish West End Project	$2,424,000
	TOTAL NON-FED COST 2020-2021	$5,163,000

[(1)] **Nourishment cost could increase 10 to 15 percent every 5 years after 2025-2026.**

3.8 Periodic Nourishment Cost for West End Project.

Periodic nourishment of the west end project, which would be accomplished every 5 years in conjunction with the periodic nourishment operations for the other sections of the Town's shoreline, would cost approximately $2,424,000 in 2025-2026 assuming the unit cost and additional mobilization and demobilization costs inflate at a rate of 2% per year.

4.0 Geotechnical Services

As part of this study, CPE-NC conducted an assessment of sand resources available to the Town for use over the course of a long-term 30 year management program. An extensive amount of data regarding sediment resources in the vicinity of Ocean Isle Beach has been collected by the USACE. Since the 1990's, at least seven (7) geotechnical and geophysical investigations have been conducted in an attempt to identify beach compatible sand for beach nourishment projects in the vicinity of Ocean Isle Beach. These investigations include:

- Ocean Isle 1994 Borings – Shallotte Inlet and area between 1 and 3 miles offshore of Ocean Isle Beach investigated. 46 vibracore borings performed by the USACE vessel SNELL. Designated OI-1-94 through OI-46-94.
- Ocean Isle Offshore 1994 (200 Series) Borings – Sub-area of the area between 1 and 3 miles offshore investigated earlier that year. 27 additional vibracore borings performed by the USACE vessel SNELL. Designated OI-200-94 through OI-226-94.

- Tubbs Inlet 1994 Borings – 17 splitspoon borings taken in Tubbs Inlet throat and feeder channels behind Ocean Isle Beach. Designated TI-1-94 through TI-17-94
- 1994 C&C Offshore Geophysical Survey – Performed offshore Ocean Isle and Holden Beach in an area 19 miles long and 2 miles wide. Utilized Odom Echotrac Bathymetric Sustem, O.R.E 3.5 kHz Subbottom Profiler and a GeoPulse "Boomer" Profiler. Trackline spacing varied from 2,000 to 3,750.
- Shallotte Inlet 1998 Borings – 13 vibracore borings performed in the vicinity of Shallotte Inlet. Designated SHI – 1 through SHI – 16.
- Shallotte Inlet 2005 Borings – 10 vibracore borings performed in the vicinity of Shallotte Inlet. Designated OI-05-03 through OI-05-13.
- Shallotte Inlet 2009 Borings – 17 vibracore borings performed in the vicinity of Shallotte Inlet. Designated SHI-V-09-01 through SHI-V-09-17.

Sand resources previously considered for the Town include Shallotte Inlet to the east, Tubbs Inlet to the west, and portions of the inner continental shelf in the vicinity of Ocean Isle Beach. The cost of a beach nourishment project is in large part driven by the proximity of the sand resource to the project area. Although other sand sources are known to exist regionally, those sources should only be considered if an insufficient quantity of beach quality sand exists within the adjacent inlets and directly offshore of the project location.

4.1 Shallotte Inlet

Thus far the borrow area developed by the USACE in Shallotte Inlet has supplied sufficient sand for the initial construction of the project in 2001, and each of the subsequent maintenance events. This is in large part due to the ability of the borrow area to "re-charge" or re-fill due to natural sediment transport processes that occur between maintenance events. Historic surveys of Shallotte Inlet were used to determine the amount of material available for beach nourishment. As previously mentioned, the initial construction of the project in 2001 involved the placement of 1,866,000 cubic yards of material obtained from Shallotte Inlet. Figure 2 shows a map of Shallotte inlet with the approved USACE borrow area delineated (Black), along with the approximate boundary of dredging that occurred during the 2001 initial construction (Red).

Since the initial construction, Ocean Isle Beach has been nourished three times. The first periodic nourishment which included the placement of 449,400 cy of sand by the USACE and an additional 155,000 cy by the Town of Ocean Isle Beach, occurred between December 2006 and January 2007. The second periodic nourishments, which placed 509,600 cy of sand on the beach, occurred between April and May 2010. Figure 2 shows the approximate boundaries of the 2006/2007 and 2010 maintenance dredging in Shallotte Inlet. The third periodic nourishment was completed in April 2014, with the placement of approximately 800,000 cubic yards of material.

As part of the process of designing and developing environmental documents for the Ocean Isle Beach terminal groin project, a borrow area within Shallotte Inlet was proposed for use to provide sand to fill the fillet of the terminal groin. The borrow area proposed for that project was designed to be confined to the footprint of both the federally authorized borrow area 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 was limited to -15 ft. MLW (-17.97

NAVD88). An evaluation of vibracores collected in Shallotte Inlet in 1994, 1998, 2005, and 2009 showed that material is compatible and meet all required state criteria as established by rule 15A NCAC 07H.0312. Specifically the material contained in the proposed borrow area has a mean grain size of 0.36 mm and a percent by weight of fine-grained (less than 0.0625 millimeters) material of 1.95% (CPE-NC, 2014). 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).

Remaining volume left in the proposed borrow area designed for the terminal groin project was computed based on comparing the post-construction surveys for the three maintenance events to the borrow area design. Following the placement of approximately 604,000 cy of sand from Shallotte Inlet between December 2006 and January 2007, approximately 780,000 cy of sand remained in the proposed borrow area. Following the placement of approximately 550,000 cy of sand from Shallotte Inlet in 2010, approximately 591,000 cy of sand remained in the proposed borrow area. Following the placement of approximately 800,000 cy of sand from Shallotte Inlet in 2014, approximately 916,000 cy of sand remained in the proposed borrow area. The variability of these numbers reflects both the dynamic nature of the inlet and the fact that dredging by the USACE has not been completely confined to the proposed borrow area.

4.2 Tubbs Inlet

In 1994, the USACE collected 17 split spoon cores from within the inlet and back bay area of Tubbs Inlet (Figure 13). Borings TI-5-94, TI-7-94, TI-8-94, TI-11-94, TI-13-94 and TI-16-94 are located in the back bay area, approximately 500 ft. to 1500 ft. east of Tubbs Inlet. Based on comparing imagery from 1994 through 2014, sediment and vegetation have accumulated in these areas. Permitting of such sand sources could be difficult due to environmental concerns; therefore, a thorough evaluation of these borings was not conducted.

The remaining cores within the inlet contain potentially compatible material, based on the available sediment data. Borings TI-1-94, TI-2-94, TI-3-94, TI-4-94, TI-6-94, TI-9-94, TI-10-94, TI-12-94, TI-14-94, TI-15-94 and TI-17-94 (located within the green line boundary in Figure 14 have thicknesses that range from 20 ft. to 21 ft. The composite mean grain sizes for these borings range from 0.18 mm to 0.30 mm, with a majority of the borings ranging from 0.20 mm to 0.23 mm.

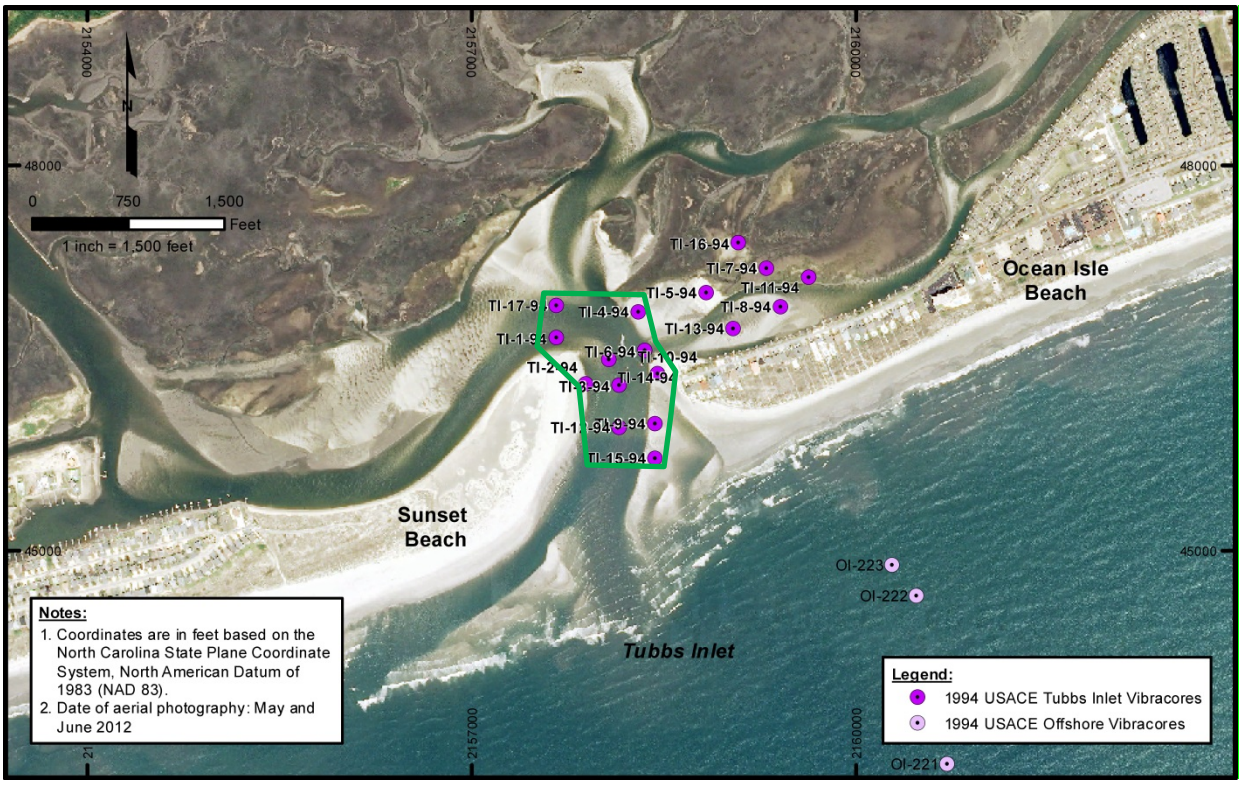


Figure 14. Tubbs Inlet boring locations.

4.3 Offshore Ocean Isle Beach

Over the course of 2 separate operations, the USACE collected approximately sixty-three borings from about 7,000 ft. to 17,000 ft. offshore Ocean Isle Beach in 1994 (Figure 15). Core logs were provided by the USACE, which were used to evaluate offshore sand resources. Three of these borings, OI-221, OI-222 and OI-223 were collected just outside of Tubbs Inlet, about 1,500 ft. to 3,000 ft. southeast of the inlet. Based on written descriptions of the cores, these borings may contain between 3 ft. to 14 ft. of compatible material. In order to verify specific sediment characteristics, additional borings would be required.

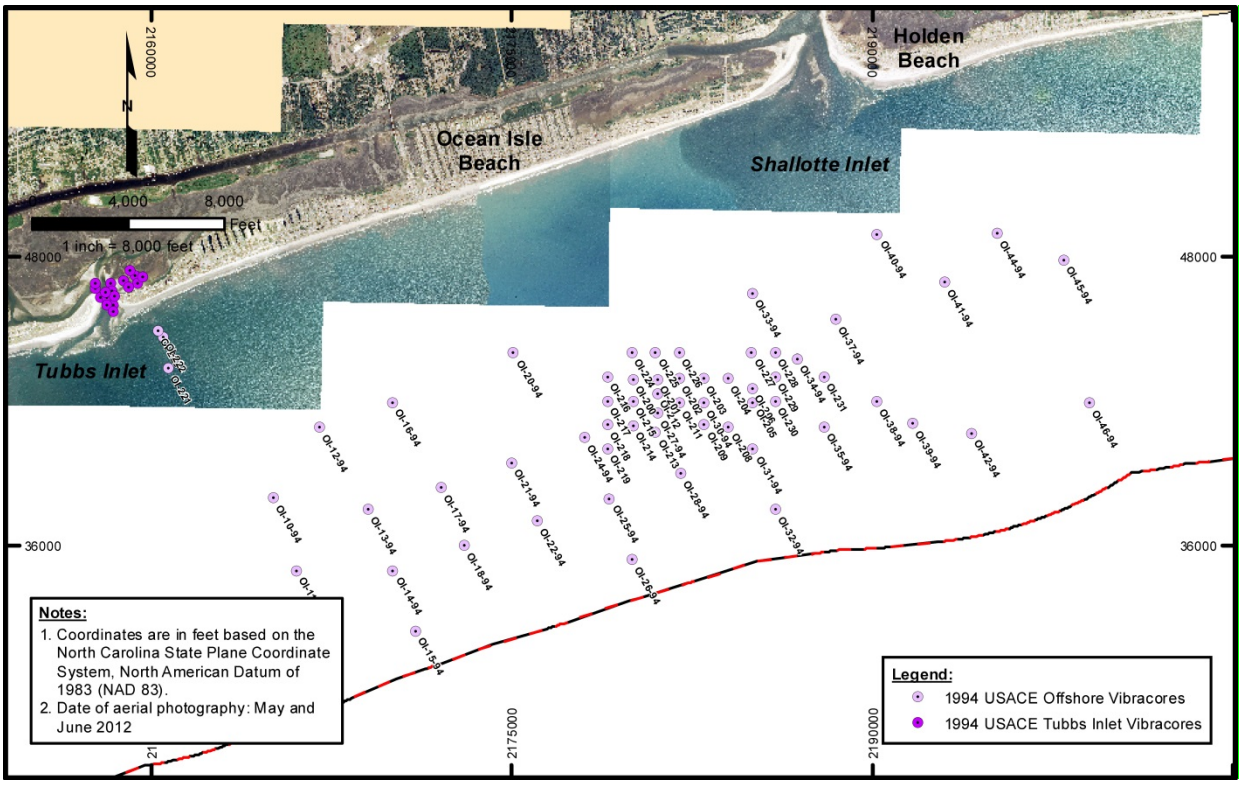


Figure 15. Ocean Isle Beach offshore boring locations.

Core logs for the remaining offshore borings were reviewed. Cores were color coded (green and red) based on an interpretation of the quality of the material. Green indicated potentially beach compatible material in sufficient thicknesses to be dredged and red indicated non-compatible material or thin deposits of compatible material not easily dredgeable (Figure 16). The offshore borings show minimal promise for potential sand resources offshore Ocean Isle Beach. The majority of the borings (red) contained materials that were a majority of clay, silt, gravel, rock, and mixtures of these components, with thin surficial sand layers, if any. The extent of this non-compatible material could be mapped seismically to determine the continuity of this material that should be avoided during future investigations.

Those borings that show some promise (green) had sand layers that ranged in thickness from 4.5 ft. to 13.0 ft. Vibracore logs describe the material as gray to dark gray in color, fine to medium to coarse sand. Some description include slightly silty or trace silt as well as traces of shell fragments. Borings OI-30-94, OI-38-94, OI-200, OI-202, and OI-227 are isolated and appear to be surrounded by borings containing incompatible material (Figure 16). Given their proximity to non-compatible material, these areas do not demonstrate a high degree of potential for borrow area development; however, the potential that they are indicative of a channel deposit containing beach compatible material exists. Although a sub-bottom profile and boomer survey were conducted by the USACE in the 1990's, records were not available from the USACE at the time this analysis was conducted. If these records exist, they may be able to provide some insight into the nature of the sand deposits.

Borings OI-27-94, OI-213 and OI-214 form a small cluster together, and are located approximately 800 ft. to 1,100 ft. apart (Figure 16). They have sand thicknesses of 5.8', 11.5' and 4.5' respectively. Vibracore logs describe the material as light gray to gray in color, fine to medium to coarse grained, poorly graded sand. Some description include silty or slightly silty as well as an indication of the presence of shells and shell fragments. Approximately 400,000 cy of sand may be available in the vicinity of these three borings. This was determined by estimating a volume for the individual borings, using an estimated sand thickness (with a two foot buffer applied above non-compatible material or the bottom of the boring), and estimated area of influence around each boring. Further detailed investigations would be needed to confirm these potential sand volumes.

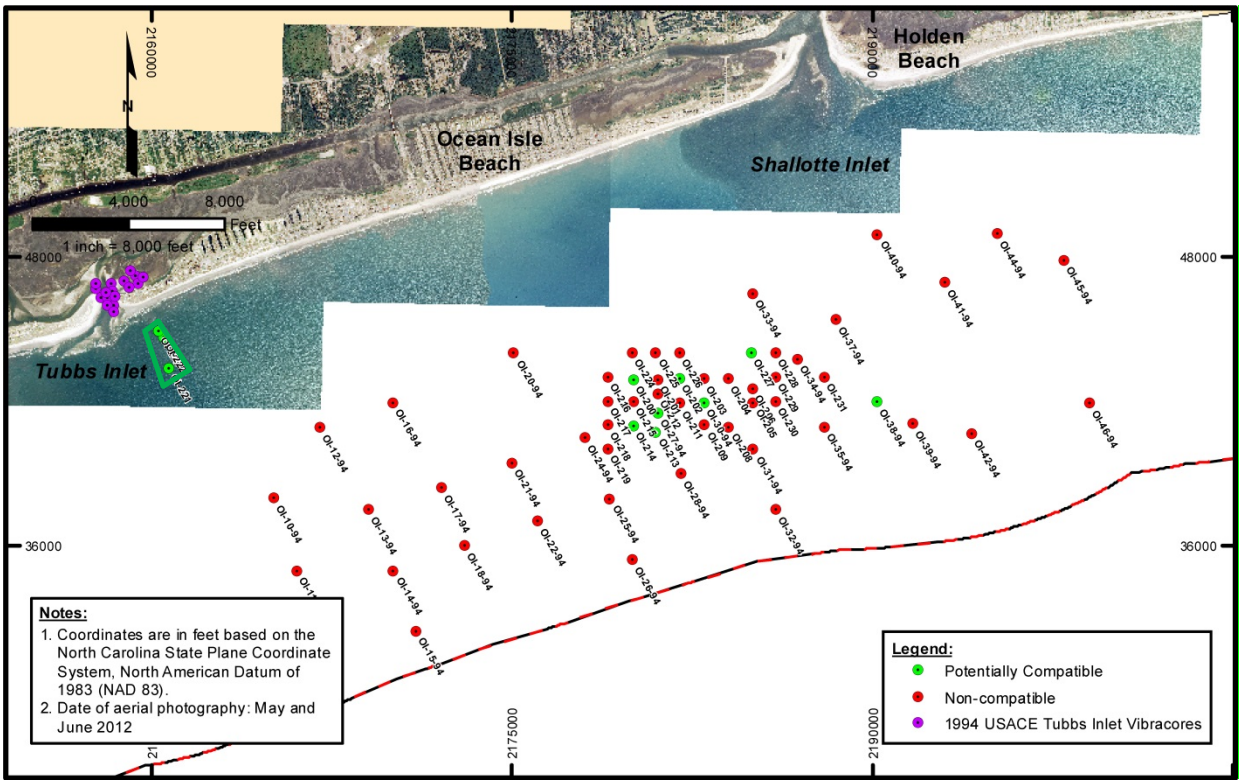


Figure 16. Ocean Isle Beach offshore boring locations color coded to indicate beach compatibility.

4.4 Cost Comparisons for Utilizing Alternate Borrow Areas

The cost estimate presented above for the west end project was based on using the Shallotte Inlet borrow area and constructing the project during the same time periodic nourishment is performed for the federal storm damage reduction project. This scenario has several advantages. First, the Shallotte Inlet borrow has already been approved for use with the federal project and will likely be approved as a borrow source for the east end project. Second, by coordinating the construction of the west end project with the periodic nourishment of the federal project, a separate mobilization and demobilization costs for the dredge would not be needed; however, some mobilization and demobilization cost would be incurred for installation and removal of the dredge pipe from the west end of the nourished portion of the federal project to the end of the west end project located near baseline station 250+00. This notwithstanding, the cost for using a potential borrow area in Tubbs Inlet as well as an offshore area were explored as possible cost-

saving measures for the construction and periodic nourishment of a project along the west end of Ocean Isle Beach.

4.4.1 Tubbs Inlet Potential Borrow Area

The area identified in the Tubbs Inlet complex shown on Figure 13 is situated between 4,000 feet and 11,500 feet from the west and east ends of the west end project, respectively. These distances are considerably shorter than the distance from the Shallotte Inlet borrow and therefore would appear to provide a more cost effective borrow area. However, the use of a Tubbs Inlet borrow area would require the dredge to move from Shallotte Inlet to Tubbs Inlet once the dredge had completed work on the federal project. While the distance is relatively short, moving the dredge would entail some cost. Also, a new pipeline would have to be installed from the Tubbs Inlet borrow area to the project shoreline. Assuming the Town would be able to negotiate a contract with the USACE contractor, most of the mobilization and demobilization cost for the dredge and ancillary equipment would be absorbed in the federal project and the Town would presumably only be responsible for the added cost for moving the dredge from Shallotte Inlet to Tubbs Inlet and the installation of the pipeline along the west end of the island.

The additional mobilization cost for moving the dredge from Shallotte Inlet to Tubbs Inlet and mobilization and demobilization of the pipeline on the west end of the island is estimated to be $663,000. The unit cost for dredging material from Tubbs Inlet with deposition along the west end of the island would be about $7.25/cubic yard or about 0.75/cubic yard less than the Shallotte Inlet borrow area. Based on these estimated unit costs, the cost for placing 410,000 cubic yards along the west end of Ocean Isle Beach from Tubbs Inlet, including the cost for engineering and design and construction observations, would be $4,429,000. This is slightly greater than the estimated cost for the Shallotte Inlet borrow area but the difference is not considered to be significant given the variability and uncertainty of dredging costs.

Permitting a borrow area in Tubbs Inlet would require additional geotechnical investigations in order to meet the requirements stipulated in 15A NCAC 07H.0312. The additional investigations would include vibracores, seismic surveys, sidescan surveys, and archeological investigations to supplement information presently available.

4.4.2 Offshore Potential Borrow Areas

Two relatively small potential borrow areas were identified above based on a review of the geotechnical data collected by the USACE, one area is located relatively close to shore just southeast of Tubbs Inlet (Figure 15) while the other is located 10,000 to 12,000 feet directly offshore of baseline station 120+00 (Figure 15).

Both of these potential borrow sources appear to have limited volumes of sediment and would probably not be able to sustain a project along the west end of Ocean Isle Beach for the assumed 30-year life of the project. While both areas would need additional geotechnical investigations in order to be permitted, there are other overriding issues that would tend to eliminate these two sources, at least at the present time.

With regard to the near shore area just southeast of Tubbs Inlet, the material in this area may be residual material associated with previous ebb tide delta configurations of Tubbs Inlet. While this would not necessarily be a deterrent for its eventual use, experience with permitting a similar area off New Topsail Inlet for the Town of Topsail Beach would seem to indicate approval by the various state and federal resource agencies would be contingent on the results of detailed numerical model investigations that would be needed to identify potential positive and negative impacts associated with the removal of material from this area. The type of model investigations needed to obtain approval for use of the area could range from $250,000 to over $500,000. Again, the model investigations would be in addition to the geotechnical investigations needed for approval.

For the area offshore of baseline station 120+00, the preliminary estimate of the volume of material potentially available is only 400,000 cubic yards which is less than the volume needed to initially construct the west end project. Perhaps more detailed geotechnical investigations could identify a potentially larger volume, however, finding enough material to sustain the west end project for 30 years seems unlikely. As a best case, if this offshore area was permitted for use as a source of beach fill material, it could be held in reserve and only used in the event of a catastrophic storm event. Even then, the offshore area would only be used in the absence of other readily available sources.

Since the Shallotte Inlet borrow area appears to provide an economical, reliable, and essentially renewable source of material for nourishment of the entire Ocean Isle Beach shoreline, the Town of Ocean Isle Beach it is recommended that the Town withhold efforts to permit a borrow area in Tubbs Inlet or an offshore borrow area at this time. If conditions with respect to Shallotte Inlet change in the future, the need to permit additional borrow sources could be revisited.

5.0 Environmental Documentation and Permitting Assessment

One of the fundamental aspects of the Town's 30-Year Beach Management Plan is to determine the most efficient permitting procedure that would allow the Town to effectively manage the various nourishment needs along the oceanfront shoreline. Typically, beach nourishment projects require the following individual state and federal approvals:

- National Environmental Policy Act (NEPA) Compliance
- Coastal Area Management Act (CAMA) Major Authorization
- NCDWR 401Certification
- USACE Section 10/404 Permit
- U.S. Fish and Wildlife Service (USFWS) Biological Opinion (BO)
- National Marine Fisheries Service (NMFS) Concurrence
- NC State Historic Preservation Office (SHPO) Concurrence

Federal approvals, including the NEPA Compliance, a BO from USFWS, and the NMFS approval, are obtained as part of the overall federal approval process. This process is typically coordinated through the United States Army Corps of Engineers (USACE). State approvals include the CAMA authorization, Water Quality Certification and SHPO approvals. This process is typically coordinated through the North Carolina Division of Coastal Management (NCDCM).

This section explores the permitting options for sand placement activities for Ocean Isle Beach; the construction of the terminal groin project will be permitted separately and is therefore not considered in the permitting options below. However, the sand volumes required for construction of the filet associated with the terminal groin project will be taken into consideration, as this will affect the amount of beach-quality material available in the Shallotte Inlet borrow area for the remainder of the island. The various permitting approaches for the 30-year Management Plan reviewed in this document include:

- **Option 1: Manage the Town's shoreline protection for the entire oceanfront shoreline under one federal and one state permit for a 30-year period**.

- **Option 2**: **Same as Option 1, with the addition of simultaneously obtaining a General Permit 291 which would allow for the Town to rapidly obtain permits to manage the portion of the oceanfront shoreline currently managed by the Federal project.**

For each proposed approach we provide a detailed assessment of the various environmental documents required for submittal to federal and state environmental resource agencies in support of permit applications. In addition, a timeline for each approach and a cost-estimate that considers any biological monitoring requirements that may be associated with each approach is provided.

5.1 Option 1: One Federal and One State Permit

5.1.1 Permitting Overview

The basis for Option 1 is an approach which would result in the issuance of one set of federal and state permits allowing for nourishment along the entire oceanfront shoreline of Ocean Isle Beach (from station 00+00 to 250+00) over a 30-year period. Although the federal project has already been authorized, this approach will still require the Town to obtain its own USACE Individual Permit (IP). Receipt of a USACE IP will put the Town in a position to provide nourishment along the entire oceanfront shoreline in the event federal funding short-falls occur.

The shoreline would be managed on a threshold basis, in which nourishment needs will be managed according to thresholds tied to the beach fill design established along sections of the beach. In essence, an area will be deemed in need of nourishment once the shoreline has eroded to the point that the design is no longer in place signaling that an adequate level of storm damage reduction is no longer provided.

5.1.2 Environmental Documentation Required

Individual Permits (IP) issued by the USACE are generally reserved for projects with potential for environmental impacts; therefore, the environmental documentation associated with an Individual Permit would include an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). In the case of the Ocean Isle Beach 30-Year Beach Management Plan, an EA would likely suffice with the resultant "Finding of No Significant Impacts" (FONSI). An

interagency meeting with representatives from federal and state resource agencies would be held in the early stages of the permitting process to ensure buy-in on the EA approach. As described in Section 1508.9 of the Council's National Environmental Policy Act (NEPA) regulations, an EA generally includes brief discussions of the following: the need for the proposal; alternatives (when there is an unresolved conflict concerning alternative uses of available resources); the environmental impacts of the proposed action and alternatives; and a listing of agencies and persons consulted. The NEPA process requires a thorough, objective, and scientifically valid definition of existing (baseline) conditions in the areas that could be affected by a beach nourishment project. The EA would be largely developed with information from existing environmental documentation the USACE has issued in support of the existing federal project and the terminal groin project. However, additional baseline information may be needed to fully describe the environmental setting and current baseline conditions. In addition to the EA, it is likely that supplementing environmental documents will need to be drafted. These include an Essential Fish Habitat Report (EFH) and Biological Assessment (BA). Once issued, the IP would allow for the initial nourishment event as well as future maintenance events along the entire oceanfront shoreline of Ocean Isle Beach over the span of the 30-year permit.

Along with the USACE IP, the Town would also need to obtain a CAMA Major Permit through the State of North Carolina. A CAMA Major Permit application requires much of the same information required for the USACE IP application. Although the CAMA Major Permit is typically valid for three to four years, the permit can be extended indefinitely through a permit modification process. The Town would also need to obtain the various other federal and state approvals listed above.

5.1.3 Available Sand Sources

Option 1 would likely utilize the Shallotte Inlet borrow area, which is the same authorized sand source used by the USACE for the federal project on Ocean Isle Beach. As discussed above in Section 4.0, geotechnical analyses of Shallotte Inlet indicate an adequate amount of compatible material exists within the currently authorized borrow area to supply the volumetric needs for the initial construction as well as future maintenance nourishment events for the entire Ocean Isle Beach shoreline.

5.1.4 Anticipated Timeline

The development of an EA in support of the USACE IP, the CAMA Major Permit application for NCDCM, and actual issuance of the permits will require approximately 12 to 16 months (Figure 17). This timeline depends, in part, on the level of environmental information pertaining to the project that is readily available. Much of the environmental information required within the EA and the CAMA Major Permit Application will overlap, thereby reducing the total amount of effort required for environmental documentation.

An interagency meeting involving NCDCM, the USACE, Ocean Isle Beach and other state and federal agencies will be convened early in the permitting process. The state allows up to six weeks for the scheduling of this meeting from initial time of request. During this time, Ocean Isle Beach will coordinate with the USACE regarding the appropriate permitting approach. Assuming that an IP would be recommended as the appropriate permitting vehicle, draft

environmental documents (i.e., EA, BA, and EFH) will be prepared over the course of approximately 180 days. Simultaneously, the CAMA Major Permit application will be prepared. A Public Hearing and Public Notice will be issued, and a commenting period ranging between 75 and 150 days will be provided to federal and state agencies, as well as the public. Upon receipt of public comments for the draft documents, revisions will be made within approximately 45 days, and final documents will be released. A Public Notice of Availability (NOA) of final documents will be published in the Federal Register, allowing for another 30 day commenting period. The revised and finalized CAMA Major Permit application and EA will then result in the issuance of the state 401 Water Quality Certificate, CAMA Major Permit, and the USACE IP approximately 45 days thereafter.

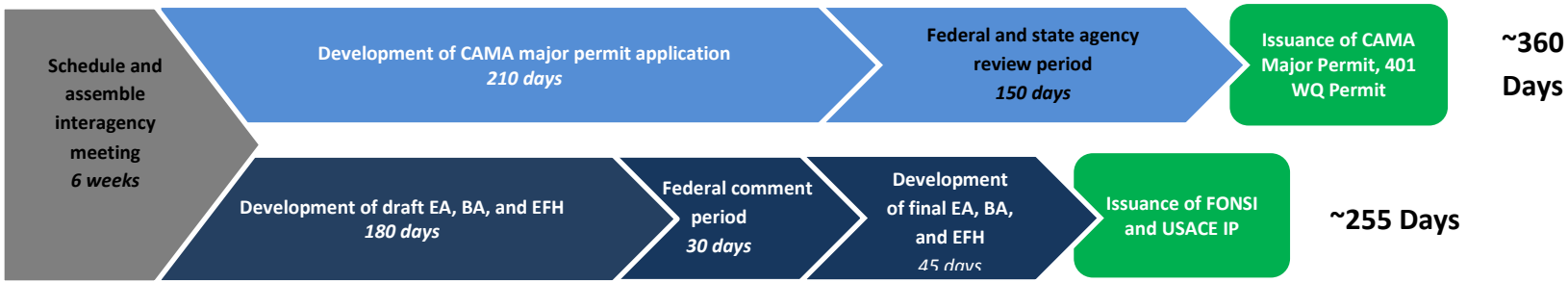


Figure 17. Timeline of events associated with Option 1. The pathway for pursuing the CAMA permit is represented in light blue, and the USACE IP pathway is in dark blue.

5.1.5 Anticipated Cost Estimate

Total cost of Option 1: **$40,000 - $60,000**

5.2 Option 2: Obtain an additional General Permit 291 for the federal project.

5.2.1 Permitting Overview

Under Option 2, the Town would pursue one set of permits to manage the entire oceanfront shoreline as outlined under Option 1. However, in addition, the Town could simultaneously pursue a USACE General Permit 291 (GP 291) that would allow construction of the federal project separately with a different "Purpose and Need" than the island-wide set of permits. The benefit of this option is that the GP 291 permitting process is relatively quicker, and could be obtained before the island-wide IP is issued. In essence, obtaining a GP 291 would serve as an "insurance policy" such that the TOWN would have the option to construct the federal project should the need arise prior to the issuance of the island-wide IP is obtained. Considering the historical performance of the federal project and the fact that it was most recently maintained this past year, it is unlikely that the Town would need to implement this option, however, due to unforeseen circumstances including damaging storms, this option and it's relatively low cost (see below) may be of interest.

5.2.2 Environmental Documentation

Unlike IPs, which entail extensive formal review by the USACE, the use of a GP 291 transfers the majority of review responsibilities from the USACE to the state. Under this arrangement, the USACE coordinates federal agency review of the project and conducts a cursory review itself. The state's decision to issue or deny a CAMA permit is based on application of the appropriate CAMA use standards. Federal authorization pursuant to Section 404, granted under GP 291, occurs only when a CAMA permit has been issued by the state. New Hanover County successfully used this process to obtain local permits for the Carolina Beach Federal beach nourishment project.

Because the majority of review responsibilities would be given the state, the environmental documentation specifically developed in support of the GP 291 would be minimal and entail a brief description of the project and predicted impacts. The state, however, would require the submittal of a CAMA Major Permit application which would involve detailed information regarding the environmental setting and baseline conditions. The GP 291 application would be developed concurrently with the IP described in Option 1, therefore much of the information being developed for the CAMA Major Permit for the island-wide permit could be used in the CAMA Major Permit for the federal project. As with Option 1, a BA and EFH would be required as well.

5.2.3 Available Sand Sources

The sand sources for Option 2 would be the same as described for Option 1.

5.2.4 Anticipated Timeline

The development of the CAMA Major Permit application for DCM and submittal of the General Permit 291 application leading to the eventual issuance of permits will require approximately six to eight months, depending on the level of environmental information readily available by the USACE pertaining to the existing projects (Figure 18). As previously stated, development of the GP 291 and CAMA Major Permit for the federal project would be concurrent with the island-wide IP and CAMA Major Permit. As such, Option 2 would not extend the overall timeline of 12 to 16months suggested under Option 1. Rather, it would increase the amount of effort and overall costs required in that time period. The GP 291 expires after one year, however renewal would not be necessary as the island-wide permit would be obtained by the time the GP 291 expired.

5.2.5 Anticipated Cost Estimate

Total cost of Option 1 + GP 291= **$45,000 - $65,000**

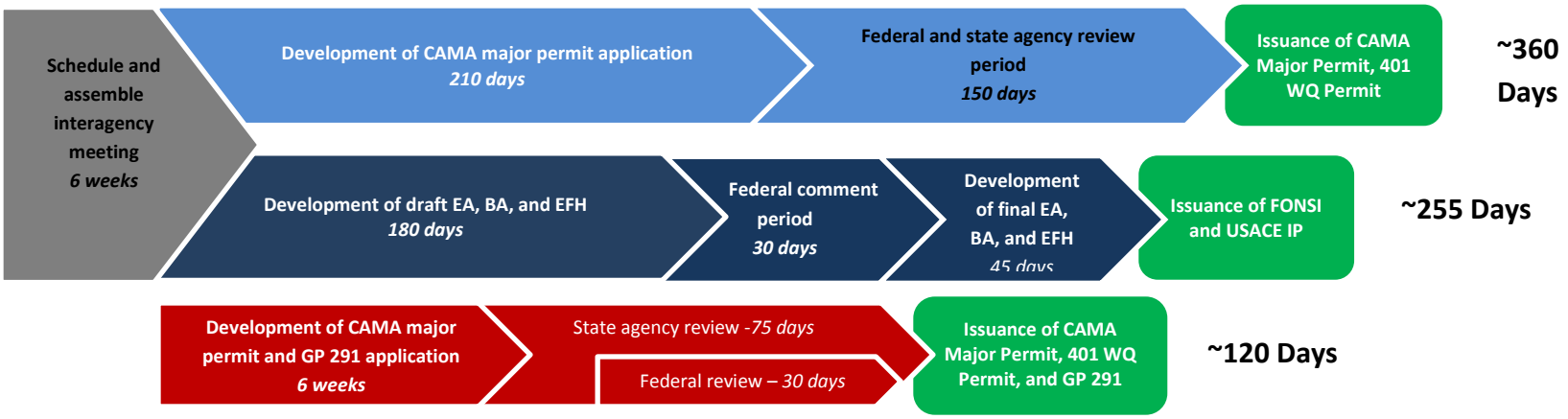


Figure 18. Timeline of events associated with Option 2 in comparison to Option 1. The pathway for pursuing the CAMA permit is represented in light blue, and the USACE IP pathway is in dark blue. The additional pathway for pursuing the USACEGP 291 (Option 2) is shown in red. Note- these timelines are the most aggressive estimates.

5.3 Monitoring Requirements

There are a number of biological and physical monitoring efforts already in effect on Ocean Isle Beach, in association with the federal project and the terminal groin project.

- **Bird Monitoring**
  The North Carolina Wildlife Resource Commission and partners have performed breeding surveys for colonial nesting waterbirds in Ocean Isle Beach on a regular basis since 1977. Specifically, surveys have been conducted along the eastern and western portion of the island in proximity to Tubbs Inlet and Shallotte Inlet. Surveys for breeding piping plovers have been conducted since 1989 at the same locations. Surveys for non-breeding piping plovers have been conducted in more recent years. These surveys include data from breeding and non-breeding seasons for several listed bird species as well as other shorebirds and waterbirds. This monitoring is expected to continue for the foreseeable future.

- **Seabeach Amaranth (*Amaranthus pumilus*)**
  Ocean Isle Beach has been surveyed by the USACE for seabeach amaranth, as part of a larger effort to survey the species along North Carolina Beaches subject to or approved for federal activity. This monitoring will likely continue in the forseeable future.

- **Sea Turtles**
  The Ocean Isle Beach Sea Turtle Patrol has been actively monitoring sea turtle nests along the town's beach since 1984. Currently, the Ocean Isle Beach Sea Turtle Protection Organization provides monitoring along the island. This monitoring is anticipated to continue for the foreseeable future.

- **Biotic Community Delineations**
  The implementation of the terminal groin project may impact biological habitats found within the Shallotte Inlet complex. To determine the size and scale of these impacts, habitat mapping will be implemented to determine a baseline condition of various biological habitats and document any changes that occur post-construction. To do so, pre-construction photographic interpretation of biotic communities utilizing high resolution aerial photography acquired in 2012, and ground-truth investigations within the proposed habitat mapping area, were completed in March 2014. The acquisition of high resolution aerial photographs, ground-truth investigations, and identification of biotic communities will be conducted within the Shallotte Inlet Habitat Mapping Area between 1 September and 30 November in the three (3) years following construction of the proposed project. All surveys will be compared to the pre-construction conditions observed from the 2012 aerial photography.

- **Escarpments**
  For the terminal groin project, visual surveys of escarpments will be made along the beach fill area immediately after construction completion. Escarpments along the newly placed beach fill that exceed 18 inches or greater than 100 ft shall be graded to match adjacent grades on the beach. The decision for escarpment removal will be determined

upon consultation with USACE and NCDCM. Removal of any escarpments during the sea turtle hatching season (May 1 through November 15) shall be coordinated with the North Carolina Wildlife Resources Commission (NCWRC), USFWS, and the USACE – Wilmington District.

In addition to the monitoring efforts discussed above, the Services may require additional monitoring in association with the island-wide permit, including:

- Biotic community delineations at the west end of the island
- Sand compatibility monitoring

It is possible that new environmental regulations and restrictions have increased since the formulation of the federal project, and, as a result, monitoring requirements for future beach projects may also increase. When developing specific permit conditions regarding biological monitoring, the USACE Wilmington District coordinates with other Federal agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). Typically, the USACE Wilmington District and the EPA are concerned with water quality related impacts and impacts to the salt marsh community. The NMFS typically considers impacts to essential fish habitat while the USFWS is mostly concerned with impacts to threatened and endangered species. Additionally, the NCDCM coordinates with other state divisions when developing permit conditions. These divisions include the Division of Marine Fisheries (DMF), Division of Water Quality (DWQ), and the Wildlife Resource Commission (WRC), among others.

5.4 Permitting Recommendations

Based on this assessment of feasible permitting options, the Town of Ocean Isle Beach may benefit from pursuing Option 2. This pathway would achieve obtaining an IP that would allow the Town to manage the entire oceanfront shoreline for 30-years, as well as obtaining a GP 291 that would allow for nourishment of the federal project prior to the issuance of the island-wide permits, should it be needed. Essentially, the GP 291 could be obtained within six months, while the island-wide permit could take a year or more. Additionally, this extra permitting pathway would not require a substantial increase in effort or cost to the overall bottom line. Considering that the east end terminal groin project is slated for construction in 2015/2016, should the Town obtain the GP 291 for the federal project area, both beach fills could occur using the same mobilization.

6.0 FEMA Monitoring and Maintenance Plan Outline

If a locally constructed beach nourishment project is impacted by a presidentially declared disaster or emergency, federal aid is available through the Public Assistance (PA) program administered by Federal Emergency Management Administration (FEMA). Evidence that a maintenance plan has been implemented must be provided to receive federal aid. This stipulation is mandated by 44 CFR 206.226(j)(2), which states:

Work on an improved beach may be eligible under the following conditions:

(i) The beach was constructed by the placement of sand (of proper grain size) to a designed elevation, width, and slope; and,
(ii) A maintenance program involving periodic renourishment of sand must have been established and adhered to by the applicant.

The amount of sand replacement eligible for FEMA funding is limited to the material volume lost as a result of the declared disaster or emergency. Typically, beach profile surveys collected during an annual monitoring are used to determine the pre-storm condition. Following a storm, a post-storm survey should be performed to determine the volume of sand lost.

Using the outline provided below, the Town should develop a maintenance plan that can be implemented upon completion of a locally constructed project as required by 44 CFR 206.226(j)(2) to be eligible for FEMA public assistance.

6.1 FEMA Maintenance Plan Outline

1. Introduction – Describes the Town's overall shoreline management program and the purpose of the maintenance plan.
2. Project Description – Provides a detailed description of each aspect of the non-federal program. Also provides details on the most recent construction events where portions of the project were constructed or maintained.
3. Cost and Volume Requirements – Provides the most up to date information on volume required to construct future projects and costs associated with construction of future projects. This section would also provide information on availability of sand required to maintain the project.
4. Monitoring Protocol – Describes the monitoring protocol employed by the Town to measure project performance and track the amount of sand remaining in the project area.
5. Conclusions – Any conclusive information learned during recent construction or monitoring events. This section could also include any recommended modifications in the program based on monitoring data.

Regardless of whether or not the Town might take on full responsibility of future maintenance of the federal project, it is unknown at this time whether FEMA would provide reimbursement for repairs to portions of the federal project. P.L. 84-99 authorizes the federal government to respond before, during, and after disasters. This includes repair of damaged federally-authorized and constructed coastal storm damage reduction projects. CPE-NC will investigate the eligibility of the federal project to receive funding through FEMA vs. P.L. 84-99 and provide the Town with guidance on planning accordingly in the future.

7.0 Literature Cited

Catlin Engineers and Scientists, 2009. Soil Testing, Compatibility Analysis and Geotechnical Report Ocean Isle Beach Renourishment Project. Letter Report submitted to the USACE Wilmington District for work completed under CATLIN Project No. 209-031

CPE-NC, 2014. Geotechnical Investigation of Ocean Isle Beach & Shallotte Inlet Borrow Area, Ocean Isle Beach Shoreline Management Project. Prepared for the Town of Ocean Isle Beach, NC. 19 pg.

CPE-NC, 2015. Draft Environmental Impact Statement for the Town of Ocean Isle Beach Shoreline Protection Project. Prepared for the US Army Corps of Engineers.

Ivey, Daisy. 2012. Town of Ocean Isle Beach. Town Administrator. Personal communication regarding town property value.

USACE, 1997c Draft General Reevaluation Report and Environmental Assessment for Beach Erosion Control and Hurricane Wave Protection – Brunswick county Beaches, North Carolina, Ocean Isle Beach Portion. *Appendix B Geotechnical Investigation and Sand Compatibility Analysis*. Wilmington Corps District, Wilmington, North Carolina.