Chapter 3 PROJECT ALTERNATIVES

1. What alternatives are evaluated in this EIS?

This section describes in detail the various alternatives evaluated for responding to the erosion threat along the northern 3.8 km (2.4 mi) of Figure Eight Island. These alternatives include:

- Alternative 1 – No Action
- Alternative 2 – Abandon/Retreat
- Alternative 3 – Rich Inlet Management with Beach Fill
- Alternative 4 – Beach Nourishment without Inlet Management
- Alternative 5A – Terminal Groin with Beach Fill from Nixon Channel and a New Connector Channel
- Alternative 5B – Terminal Groin with Beach Fill from Nixon Channel and Other Sources
- Alternative 5C – Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and a New Connector Channel
- Alternative 5D – Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and Other Sources

The primary tools used to evaluate the effectiveness of the various alternatives in meeting the needs and objectives included:

- Delft3D
- GENESIS
- Geomorphic analysis of Rich Inlet and the influence the inlet has on the shorelines of Figure Eight Island and Hutaff Island

These tools were used to help assess and determine the differences between the alternatives and were not intended to represent predictions of what changes to expect in the future. Accurate future predictions for large-scale and long-term coastal changes are too difficult to make due to the absence of the necessary capabilities for those predictions (Barter, Burgess, and Hosking, 2003). With the dynamic nature and complexity of coastal inlets, there remain some processes that are not fully understood and can be difficult for quantitative predictions in estimating short- and long-term migration trends, collective morphologic evolution, and cycles of inlets and the interactions among inlets, adjacent beaches, bays, and estuaries (Demirbilek and Rosati, 2011). There continues to be limitations on modeling for predicting future long-term coastal changes, but numerical models are valid for qualitative comparisons (Beck, pers. comm. 2014).

Delft3D. Delft3D was the primary modeling package used for evaluating this project. The model simulates flows, sediment transport, and bathymetric changes by using advanced sediment transport formulations that respond to forcing functions that include waves, tides, winds, and density gradients. The model takes into account the movement of sediment along the bottom (bedload transport) as well as sediment transported in the water column (suspended transport). Details of the application of the Delft3D model are provided in Appendix B.

The evaluation of the more northerly location of the terminal groin associated with Alternatives 5C and 5D necessitated a new round of model tests since these two options were not included in the initial model runs shown in the 2012 Draft EIS. The model setup for the new round of tests included some modification in the model grids used in the early model runs as well as some minor corrections in depths over portions of the model domain. In order to maintain the same relative comparison of potential impacts from one alternative to another, all the alternatives were re-run using a revised model setup, the 2006 conditions of the inlet and adjacent shorelines, and the same input parameters (tides, waves, wind, etc.). The model was also run for Alternatives 2, 3, 4, and 5D using 2012 inlet and shoreline conditions. Alternatives 5A and 5B were not modeled using the 2012 conditions (Table 3.1) since this position of the terminal groin was not favored by a majority of the northernmost property owners and would not likely be approved by the Figure "8" Beach HOA. Alternative 5C was also excluded from the 2012 model setup due to the Figure "8" Beach HOA designating Alternative 5D as its preferred alternative prior to the initiation of the 2012 model simulations. Although not modeled using 2012 conditions, quantities and cost estimates to construct these three alternatives, given the 2012 conditions, were computed using actual 2012 survey data.

Table 3.1 Model conditions utilized for each Alternative

Alternative	2006 Conditions	2012 Conditions
2	Yes	Yes
3	Yes	Yes
4	Yes	Yes
5A	Yes	No
5B	Yes	No
5C	Yes	No
5D	Yes	Yes

The Delft3D model responds to prescribed or predetermined input conditions including waves, tides, winds, etc. The model results are by no means intended to represent predictions of what changes to expect in the future as this would require an ability to predict future weather and oceanic conditions. Rather, the Delft3D model results for Alternative 2, the abandon/retreat alternative where absolutely no shoreline stabilization measures are implemented, were used as a basis for comparing relative changes in Rich Inlet and the adjacent shorelines that could be attributable to physical changes in the system associated with each alternative.

<u>GENESIS</u>. GENESIS is a shoreline response model developed by the USACE. It is classified as an “on-line” model since model output is limited to changes in a specified contour (for example mean high water). The model can incorporate the effects of groins, revetments, seawalls, breakwaters, and offshore bathymetry. GENESIS was used to develop a “second opinion” with regard to shoreline changes that could result from the channel modifications and a terminal groin. GENESIS results are reported in Appendix B.

<u>Rich Inlet Geomorphic Analysis</u>. Dr. William J. Cleary, formerly with the University of North Carolina Wilmington, was contracted by the Figure "8" Beach HOA to evaluate the impact of the changes that Rich Inlet had on the shorelines of Figure Eight Island as well as Hutaff Island. The results of Dr. Cleary’s analysis are provided in Sub-Appendix A of Appendix B.

Dr. Cleary's assessment indicated that the condition of the shoreline along the north end of Figure Eight Island is linked to the orientation of the channel crossing through the ebb tide delta of Rich Inlet (ocean bar channel). Dr. Cleary's report, which provides a history of the ocean bar channel orientation and its relationship to the shoreline response on both the north end of Figure Eight Island and the south end of Hutaff Island since 1938, is provided in Sub Appendix A of Appendix B. Based on this history, when the ocean bar channel of Rich Inlet is orientated toward Figure Eight Island, the north end of the island tends to accrete. When the channel orientation shifts toward Hutaff Island, the south end of Hutaff Island generally accretes while the north end of Figure Eight Island erodes.

Based on Dr. Cleary's assessment, since 1938, the ocean bar channel of Rich Inlet has been oriented toward Figure Eight Island at least five (5) times over periods ranging from 2 years to about 9.5 years (see Figure 8 in Sub Appendix A). Similarly, the ocean bar channel was also oriented toward Hutaff Island during five (5) time periods with the durations ranging from 3.5 years to approximately 14 years.

During the early part of 1994, the ocean bar channel of Rich Inlet breached the ebb tide delta resulting in an almost instantaneous reorientation of the channel toward Hutaff Island. Following this breach, shoreline on the north end of the island, which had experienced a relatively long period of accretion, began to erode at accelerated rates. The erosion became so severe that the 20 homes were eventually deemed imminently threatened which allowed the owners to install temporary sandbags. In this regard, the definition of imminently threatened, as used by the State of North Carolina, refers to a condition in which the erosion scarp encroaches within 20 feet of its foundation. When this condition occurs, the property owners can employ temporary erosion response measures, such as the installation of sandbag revetments, to protect their property until such time the threat no longer exists or the structure is moved and/or abandoned.

One of the threatened homes was moved off the ocean shoreline in 2010 leaving 19 homes imminently threatened. The condition of the shoreline that existed following this channel breach prompted the Figure "8" Beach HOA to initiate the evaluation of shoreline protection measures that would provide long-term protection to the threatened homes. This effort was initiated in 2006.

Beginning around October 2010, the Rich Inlet ocean bar channel again assumed an orientation toward Figure Eight Island and that orientation persists today. As the result of the latest shift in the channel orientation, the north end of Figure Eight Island has experienced a period of accretion which has temporarily removed the imminently threatened status of the previously threatened 19 homes. However, as has been shown by the past behavior of Rich Inlet, the present configuration of the inlet bar channel and associated ebb tide delta is expected to again undergo changes that will result in a renewed period of erosion on the north end of Figure Eight Island.

A description of each alternative is provided below which includes detailed discussions of what each alternative entails and how it was formulated. An assessment of the economic impact of each alternative on the existing island development and infrastructure, developed by Dr. Peter W.

Schuhmann, Professor of Economic, University of North Carolina Wilmington, is provided in Appendix G.

Alternative 1: No Action

Sandbag revetments along the northern portion of Figure Eight Island

Description. Under Alternative 1, the Figure "8" Beach HOA and individual property owners would continue to respond to erosion threats in the same manner as in the past. These measures, which involve obtaining Federal and/or State authorizations to allow beach scraping (bulldozing) to create and/or repair damaged dunes, intermittent beach nourishment, and the deployment of sandbags. These erosion response measures become increasingly necessary when the ocean bar channel of Rich Inlet shifts to a more northeasterly alignment, as was the case beginning in 1993 and extending to 2010 (Cleary, 2009). When the bar channel shifts to a more northeasterly alignment, the south side of the inlet's ebb tide delta also migrates to the north exposing the north end of Figure Eight Island to wave attack. As an example, when the bar channel was oriented toward Hutaff Island between 1993 and 2010, extensive erosion occurred along the northern 1,400 m (4,500 ft) of the Island, with a maximum of 150 m (500 ft) of shoreline retreat. During this time, sandbag revetments were installed around 20 homes on the north end of Figure Eight Island. Even so, one of the homes, located at 13 Comber Road, was relocated landward in 2010 leaving 19 homes along the north end of the island with sandbag revetments. In one home along the Nixon Channel, the shoreline is imminently threated and is protected by a sandbag revetment.

With the shift of the ocean bar channel to an orientation toward Figure Eight Island in 2010, the shoreline on the north end of Figure Eight Island north of the intersection Comber Road and Dunes Point Road (approximately baseline station 80+00) has accreted considerably. For example, the shoreline at station 90+00 has accreted approximately 165 feet seaward between July 2006 and January 2013 while the shoreline at station 95+00 moved 350 feet seaward during this same time interval. Under the present condition (March 2015), none of the oceanfront structures located between Surf Court and Rich Inlet, including the 19 structures presently protected by temporary sandbag revetments, are in imminently threatened status as defined by the State Coastal Resources Commission (CRC). Based on the rules adopted by the CRC, a structure is deemed to be imminently threatened when the erosion scarp (or some other erosion indicator) encroaches within 20 feet of the structures foundation. The recent accretion along the north end of Figure Eight Island has not changed the condition along Nixon Channel as the one structure protected by a sandbag revetment remains imminently threatened. In general, the imminently threatened status is used by the CRC to determine when temporary erosion response measures, such as the installation of sand bag revetment, can be permitted.

During periods when the bar channel of Rich Inlet is oriented toward Hutaff Island, the Figure "8" Beach HOA has utilized beach nourishment to counter the erosion threat. In general, the beach nourishment operations were carried out about every three to four years. A summary of past beach nourishment activities is provided in Table 1.1.

Past nourishment activities along the north end of the island consisted of depositing dredged material from maintenance of a previously permitted navigation channel and boat basin located in Nixon Channel. This previously permitted area is shown on Figure 3.1. Dredging in Nixon Channel was initiated in 1983 with the first maintenance event occurring in 1988. The permitted depth for these first two events was -1.8 m (-6 ft MLW) [-2.6 m (-8.4 ft) NAVD]. The area permitted in Nixon Channel was modified in 1993, covering the area shown on Figure 3.1. The modification increased the authorized depth to -2.7 m (-9 ft) MLW (or -3.5 m (-11.4 ft) NAVD). The modified area was initially dredged in 1993-94 with subsequent maintenance dredging in 1997, 2001, 2005, 2009 and 2011 (see Table 2.1 in Chapter 2). The volume of material deposited along the north end from the Nixon Channel permit area since 1993 has ranged from 90,000 cy to 350,000 cy, per event, with densities ranging from 26 cy/linear foot to 133 cy/linear foot. Since 1993, the total volume of material removed from Nixon Channel and deposited along the north end of Figure Eight Island north of Bridge Road totals approximately 1.75 million cy or an average of approximately 291,000 cy for each event (Appendix B).

With the Rich Inlet bar channel presently oriented toward Hutaff Island, beach nourishment is not needed to protect the development on the extreme north end of the island. However, future shifts of the channel to an alignment toward Hutaff Island will likely result in a need to resume beach nourishment along the north end of the island. As noted above, an October 2014 aerial photograph of the inlet, provided on Google Earth, indicates a shift of the channel to an alignment toward Hutaff Island has already begun. If this shift in channel alignment continues, erosion rates along the north end of Figure Eight Island are expected to accelerate and attain rates comparable to those measured between 1993 and 2007. Given the variable and unpredictable nature of the behavior of Rich Inlet, the need to periodically maintain the previously permitted area in Nixon Channel with disposal of the dredged material along the north end of Figure Eight Island will probably continue indefinitely.

With the expected pending shift of the channel back toward Hutaff Island, the cost to implement Alternative 1 was determined using conditions that existed in 2006 (considered to be a worst case) and 2012. For the 2006 condition, the economic assessment assumed the shoreline would erode into the existing development at rates comparable to those measured between 1999 and 2007. The implementation costs for Alternative 1 include the value of homes that would be lost to erosion, the value of land that would be lost, the cost for installation of temporary erosion response measures, and the cost for continued beach nourishment over the 30-year evaluation period.

A similar cost evaluation was made for the 2012 condition, however, as noted above, the shoreline north of baseline station 80+00 was positioned somewhat seaward of the 2006 shoreline position, therefore, the damages and implementation cost along this northernmost portion of Figure Eight Island, given the accreted shoreline condition, would occur later in the 30-year evaluation period.

Over time, the continuation of the long term erosion south of baseline station 80+00 would also affect homes located along Surf Court and portions of Beach Road North just south of Surf Court. This will result in additional homes becoming imminently threatened which could result in the placement of additional temporary sandbag revetments.

Implementation Cost-2006 Eroded Condition. Alternative 1 includes the demolition and/or relocation of some of the threatened homes. With regard to whether the threatened homes would be demolished or relocated to a new lot, there is no definitive way to make this determination as such a decision depends primarily on the desires of the individual property owners as well as the availability of suitable building lots on the island. Therefore, the implementation costs for Alternative 1 was based on the assumption ten (10) of the threatened homes would be relocated and thirty (30) homes demolished.

The ten (10) structures that were assumed to be relocated to another lot on Figure Eight Island have an appraised value of $6.5 million with their value assumed to remain the same even though they would no longer be on an oceanfront lot. However, the land on which they were situated would eventually be lost. The lost value of these ten (10) lots is included in the total land loss value. See Appendix B and Appendix G for more information regarding cost.

Over the thirty year analysis period, the total implementation cost associated with Alternative 1, given the 2006 eroded shoreline condition would be about $92.5 million. This includes $16.9 million for the value of 30 structures that would be demolished, $1.4 million to demolish the structures, $2.4 million to relocate 10 structures, $38.3 million for the loss of land, $1.2 million for temporary sandbag revetments, $3.3 million for damages to roads and infrastructure on the north end of Figure Eight, and $29.0 million for eleven (11) beach nourishment events that would take place approximately every three years beginning in year 0 of the 30-year evaluation period.

The equivalent annual cost for implementation of Alternative 1 given the 2006 eroded shoreline condition, computed using an interest rate of 6% and a 30-year amortization period is $3,191,000/year.

Implementation Cost-2012/13 Accreted Condition. Over the thirty year analysis period, the total implementation cost associated with Alternative 1, given the 2012/2013 accreted shoreline condition, would be about $84.6 million. This includes $16.9 million for the value of 30 structures that would be demolished, $1.4 million to demolish the structures, $2.4 million to relocate 10 structures, $38.3 million for the loss of land, $1.2 million for temporary sandbag revetments, $3.3 million for damages to roads and infrastructure on the north end of Figure Eight, and $21.1 for eight (8) beach nourishment events that would take place approximately every three years beginning in year 9 of the 30-year evaluation period.

The equivalent annual cost for implementation of Alternative 1 given the 2006 eroded shoreline condition, computed using an interest rate of 6% and a 30-year amortization period is $3,122,000/year.

Figure 3.1. Previously permitted dredge area in Nixon Channel.

Alternative 2: Abandon/Retreat

Description. For Alternative 2, the Figure "8" Beach HOA and the individual property owners would not take any action to slow erosion. Furthermore, no Federal and/or State authorization would be sought to conduct stabilization measures such as the installation of new sandbags, beach scraping/bulldozing, or other stabilization measures described above in Alternative 1. Also, the Figure "8" Beach HOA would not make any effort to pursue a long-term beach nourishment project or inlet channel relocation project. Once the existing temporary sandbag revetments fail or have to be removed upon reaching the end of their permit period, the affected structures would either be abandoned (demolished) or moved to another lot on the island.

At the present time (2015), the shoreline along the north end of Figure Eight Island is responding positively to the orientation of the ocean bar channel of Rich Inlet and as long at the channel maintains this favorable orientation, immediate efforts to abandon and/or relocate structures from the ocean shoreline will not be necessary. In this regard, the position of the shoreline north of the intersection of Comber Road and Dunes Point Road (approximately baseline station 80+00) are now between 160 and 350 feet seaward of the 2006 shoreline position.

An October 2014 aerial photograph of Rich Inlet provided on Google Earth indicates the bar channel of Rich Inlet has already begun to swing to an alignment toward Hutaff Island. As a result, shoreline erosion rates along the north end of Figure Eight Island are expected to accelerate with erosion rates approaching rates observed between 1993 and 2007. As shoreline conditions deteriorate as the result of a change in the orientation of the ocean bar channel toward Hutaff Island, some oceanfront structures may have to be either abandoned (i.e., demolished) or moved to another lot somewhere on Figure Eight Island.

With regard to the relocation option, twenty-three (23) oceanfront homes located on Surf Court, Comber Road, and Inlet Hook Road fall into this category and would have to eventually be demolished or moved within the next five (5) years. If erosion rates continue at their current level, nine (9) homes on Beach Road North located immediately south of Surf Court are expected to become threatened within the next ten (10) years with an additional eight (8) homes on Beach Road North threatened within the next 25 years. Thus, over the 30-year analysis period used for the evaluation of the project alternatives, forty (40) oceanfront homes on the extreme north end of Figure Eight Island would either be demolished or moved. After the loss of these homes, it is presumed that no future homes will be built upon these lots. There are currently, eighty (80) undeveloped residential lots on the island. The vast majority of these lots are located on the waterfront; either on the ocean or sound side. Of these undeveloped lots, thirty-one (31) are located directly on the oceanfront. A total of forty-five (45) undeveloped lots are located on the sound side shoreline. Even though there appears to be a sufficient number of vacant lots to accommodate the relocation of oceanfront structures that may again become imminently threatened, the number of homes that would actually be relocated cannot be predicted with any degree of certainty as this decision would be made by each affected property owner. Also, owners of the existing vacant lots would have to be willing to sell the lots.

Given the wide range of possible shoreline conditions along the north end of Figure Eight Island as dictated by conditions of the ocean bar channel of Rich Inlet, implementation costs for

Alternative 2 were evaluated for the 2006 eroded shoreline condition and the 2012/2013 accreted condition.

Implementation Cost-2006 Eroded Condition. Over the 30-year analysis period, the total implementation cost associated with Alternative 2, given the 2006 eroded shoreline condition would be about $63.7 million. This total cost includes $16.9 million for the value of thirty (30) structures that would be demolished, $1.4 million to demolish the structures, $2.4 million to relocate ten (10) structures, $4.7 million for damages to roads and infrastructure on the north end of Figure Eight, and $38.3 million for the loss of land. The value of the land for the ten (10) homes that would be relocated to another lot on Figure Eight Island is included in the total land loss amount. However, the value of the ten (10) structures was assumed to remain the same even though they would no longer be situated on an oceanfront lot.

The equivalent annual cost for implementation of Alternative 2 given the 2006 eroded shoreline condition, computed using an interest rate of 6% and a 30-year amortization period is $2,610,000/year.

Implementation Cost-2012/13 Accreted Condition. Over the 30-year analysis period, the total implementation cost associated with Alternative 2, given the 2012/13 eroded shoreline condition would be about $63.7 million which is the same as under the 2006 eroded condition. However, on an equivalent average annual cost basis, the annual cost under the 2012/13 shoreline condition would be less than the 2006 shoreline condition due to actions such as abandoned and/or moving homes would occur later in the analysis period.

The equivalent annual cost for implementation of Alternative 2 given the 2012/13 accreted shoreline condition, computed using an interest rate of 6% and a 30-year amortization period is $2,503,000/year.

Alternative 3: Rich Inlet Management with Beach Fill

Description. The main bar channel of Rich Inlet, also referred to as the entrance channel, would be maintained in a positon closer to the north end of Figure Eight Island and along an alignment essentially perpendicular to the adjacent shorelines. The establishment of a preferred location of the ocean bar channel would be accompanied by new channels connecting the bar channel with Nixon Channel and Green Channel (Figure 3.2). Material removed to maintain the preferred location of the bar channel and construct the new connecting channels would be used to construct a closure dike across the existing ebb channel located next to Hutaff Island, provide beach fill along 426.8 m (1,400 ft) of the Nixon Channel shoreline just south of Rich Inlet, and nourish 3,810 m (12,500 ft) of ocean shoreline extending from Rich Inlet south to Bridge Road. The purpose of the closure dike would be to concentrate most of the tidal flow through the preferred channel.

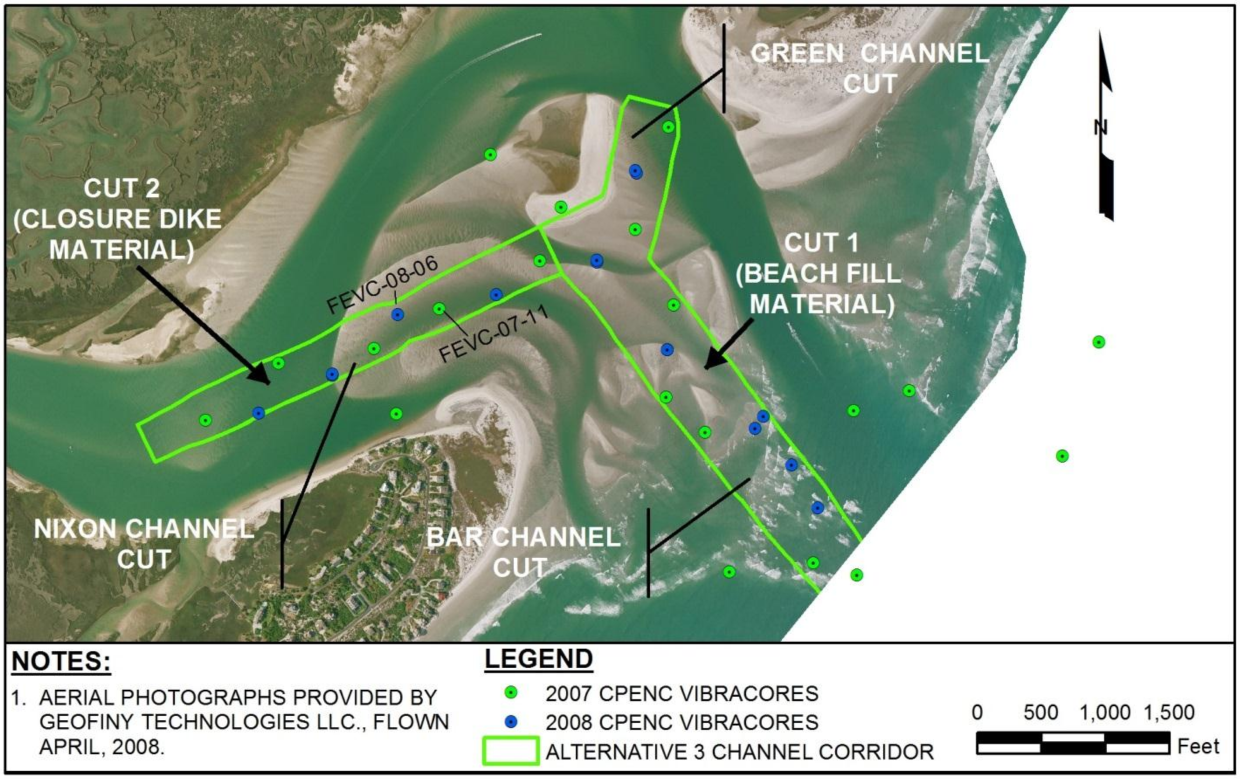

Figure 3.2. Map depicting the two different cuts designed for the Alternative 3 channel corridor. Note the locations of two vibracores (FEVC-07-11 and FEVC-08-06) in which clay material was found.

The performance of Alternative 3, as well as the other alternatives, was based on the results of a numerical model known as Delft3D. Delft3D simulates changes in hydrodynamics, sediment transport, and the morphology of the inlet and nearshore environments in response to changes imposed by project alternatives over a 5 year period. Details of the Delft3D model simulations are provided in Appendix B and Chapter 5 with summary discussions provided below.

The preferred bar channel position would be periodically maintained with maintenance episodes dictated by shoaling of the channel and/or natural shifts in the channel position outside the preferred channel corridor. Based on the results of the Delft3D model simulations, maintenance of the new channels connecting to both Nixon Channel and Green Channel will probably not have to be maintained on a regular basis. All the material removed to maintain the channel(s) would be distributed along the Figure Eight shoreline between Rich Inlet and Bridge Road and along the 426.8 m (1,400 ft) shoreline segment in Nixon Channel. Dredging associated with the construction and maintenance of the new channels would be performed by a cutter-suction pipeline dredge (pipeline dredge).

Plan Formulation. The major factor affecting shoreline stability along the extreme north end of Figure Eight Island is associated with the uncontrolled movement in the position and orientation of the main bar channel passing through Rich Inlet. At the time the Figure "8" Beach HOA initiated efforts to develop a shoreline and inlet management plan for the north end of the island the ocean bar channel of Rich Inlet was oriented toward Hutaff Island and the north end of Figure

Eight Island was experiencing extremely high rates of erosion. The high rate of erosion was impacting several homes on the extreme north end of the island.

As previously mentioned, the ocean bar channel of Rich Inlet assumed an alignment toward Figure Eight Island around 2010 and since that time the north end of Figure Eight Island has been accreting. With the ocean bar channel continuing to occupy a position and alignment favorable to the north end of Figure Eight Island, implementation of a project involving the establishment and maintenance of a channel along in a preferred position would not be needed in the immediate future. However, as has been the case in the past, the present condition of the ocean bar channel is not expected to last in perpetuity. Based on historic trend of periodic changes in the ocean bar, the present bar channel condition may only last another 3 to 5 years. When the channel does eventually swing back toward Hutaff Island, the channel project developed under Alternative 3 could be considered as an option to respond to the renewed erosion threat.

Under Alternative 3, the main ocean bar channel would be maintained in a position and along an alignment that would produce favorable shoreline changes on the extreme north end of Figure Eight Island. The preferred bar channel would be accompanied by new channel connections to Nixon Channel and toward the mouth of Green Channel and the construction of a closure dike across the existing entrance channel. The purpose of the closure dike would be to force most of the tidal flow through the inlet into the preferred bar channel.

The development of the preferred channel modifications/inlet management plan for Rich Inlet involved a screening process utilizing Delft3D model runs in which various options for Nixon Channel, Green Channel, and the main entrance channel were evaluated. Simulations were also performed excluding the closure dike. The results of all screening runs are provided in Appendix B.

All the screening runs included a bar channel with a 152.4 m (500 ft) bottom width at a depth of 5.2 m (-17 ft) NAVD and 1V:5H (1 Vertical to 5 Horizontal) side slopes and various options with regard to the length of the interior channel cuts connecting the inlet throat with Nixon and Green Channels. The screening runs were conducted with a closure dike extending off the south end of Hutaff Island to close the entrance channel and interior channel depths of 5.2 m (-17 ft) NAVD, or the same depth as the inlet bar channel. The screening runs were conducted for the 2006-07 conditions which represent a worst-case with regard to the impacts of the bar channel on the behavior of the north end of Figure Eight Island. Selection of a preferred position and alignment for the bar channel, in terms of its impacts on Figure Eight Island, was based on historic morphological changes in the inlet and the accompanying impact of the inlet changes on the adjacent shorelines of Figure Eight Island and Hutaff Island. The morphologic history of Rich Inlet was developed by Dr. William Cleary formerly with the University of North Carolina at Wilmington. Dr. Cleary's complete report is included as Sub-Appendix A in Appendix B.

One other consideration for the location of the channel is the presence of the civil war era shipwreck, the *Wild Dayrell*. Geotechnical and geophysical investigations were conducted within Rich Inlet to determine its location. These targeted submerged cultural resource investigations were conducted to accurately map its location and allow for proper design and planning of a channel that would avoid adverse impacts to the wreck (Appendix C and Appendix D).

Optimal Channel Modifications. The recommended channel modifications for the preferred channel include a 1,158.2 m (3,800 ft) long cut within Nixon Channel and a 426.7 m (1,400 ft) long cut extending into Green Channel.

While all of the screening runs were performed with a channel depth of -5.2 m (-17 ft) NAVD, a review of cutter-suction pipeline dredge capabilities available from three dredging companies (Great Lakes Dredge & Dock, Weeks Marine, and Norfolk Dredging) found dredge plant capable of working in an ocean/inlet environment have minimum digging depths ranging from 4.3 m (14.0 ft) to -5.3 m (17.5 ft). If a dredge is to work continually throughout a complete tidal cycle, the minimum digging depths would be measured at mean low water. With mean low water in the project area being approximately -0.8 m (2.5 ft) below NAVD, the minimum digging depths for the available dredge plant would range from -5.0 m (-16.5 ft) NAVD to -5.9 m (-19.5 feet) NAVD. In order to assure competitive bidding and providing some margin of safety to allow for the turbulent nature of the inlet environment, the recommended design depth for the Alternative 3 channels was increased to -5.8 m (-19.0 feet) NAVD.

A similar channel relocation project was recently completed for New River Inlet and had a design depth of -5.5 m (-18.0 ft) NAVD. A comparison of wave hindcast data was generated by the USACE Wave Information Study (WIS) for two stations, one located seaward of Rich Inlet and the other seaward of New River Inlet (see Appendix B). Data results found that the average wave heights in the vicinity of Rich Inlet were slightly greater than the waves off New River Inlet. The WIS station 63297 located seaward of Rich Inlet has a 20-year (1980 to 1999) average wave height of 1.12 m (3.68 ft) compared to an average wave height for WIS station 63290 off New River Inlet of 1.04 m (3.40 ft). While the average wave height difference is relatively small, it would be magnified in the inlet environment when incoming waves interact with ebbing tidal currents; hence a larger margin of safety was adopted for Rich Inlet.

The increase of the channel depth to -5.8 m (-19 ft) NAVD was accompanied by a 50-foot reduction in the width of the main entrance channel to maintain the same flow carrying capacity as the -5.2 m (-17 ft) NAVD channel. Other channel modifications from those considered during the initial screening included a reduction in the width of the Nixon Channel cut from 83.8 m (275 ft) to 73.2 m (240 ft) and an increase in the width of the Green Channel cut from 68.6 m (225 ft) to 91.4 m (300 ft) (see Appendix B). The reduced width of the Nixon Channel cut was based on maintaining the same flow carrying capacity as the -17-foot NAVD channel while the increased width of the Green Channel cut was to accommodate possible increased shoaling associated with erosion of the closure dike across the exiting channel next to the south end of Hutaff Island.

Summary of Channel Modifications. The modifications to Rich Inlet for oceanfront shoreline stability and protection under Alternative 3 would move the channel approximately 304.8 m (1,000 ft) to the southwest of its present location and would consist of the following:

All new channel depths = -5.8 m (-19 ft) NAVD + 1-foot overdepth

Channel widths and lengths:

- Entrance (Bar) Channel = 137.2 m (450 ft) wide from inlet throat to -5.8 m (-19 ft) NAVD depth contour in the ocean
- Nixon Channel = 73.2 m (240 ft) x 1,154.8 m (3,800 ft)
- Green Channel = 91.4 m (300 ft) x 426.7 m (1,400 ft)

Channel Dredge Volumes:

April 2006 Survey:
1,773,300 cy + 150,400 cy overdepth = 1,923,700 cy

March 2012 Survey:
1,786,500 cy + 156,400 cy overdepth = total 1,942,900 cy

Closure Dike:

- Crest Elevation = +1.8 m (+6 ft) NAVD
- Crest Width = 137.2 m (450 ft)
- Side Slopes = 1 vertical on 20 horizontal (assumed)
- Volumes:
  April 2006 Survey: 513,700 cy
  March 2012 Survey: 393,000 cy

Beach Fill Design.

The beach fill along the ocean shoreline would cover the area from a point opposite the intersection of Bridge Road and Beachbay Lane (station F90+00) to Rich Inlet (station 105+00), a total distance of 3,810 m (12,500 ft) as shown in Figures 3.4a and 3.4b. The fill would include a 1,000-foot transition or taper section on the south end between stations F90+00 and F100+00 and a 500-foot taper on the north end between stations 100+00 and 105+00. The southern limit of the ocean beach fill area (F90+00) corresponds to the northern limit of the beach disposal area associated with the Mason Inlet Relocation Project.

The design for Alternative 3 focused on optimizing the distribution of the material removed to reposition the ocean bar channel and construct the new channel connectors into Nixon and Green Channels along the ocean shoreline between Rich Inlet and Bridge Road. To that end, the design widths of the beach fill along various sections of Figure Eight Island north of Bridge Road were based on maximum shoreline recession rates observed during the period from 1999 to 2007 and an assumed 5-year design life (Table 6.1 in Appendix B). In this regard, the design recession rate used for the area between stations 50+00 and 105+00 was -8.7 m (-24.8 ft)/year with a recession rate of -2.8 m (-9.2 ft)/year used for the area from Bridge Road (station F90+00) to station 40+00. The beach fill would be constructed to an elevation of 1.8 m (6.0 ft) NAVD and would have the placement rates and design berm widths shown in Table 3.2.

Table 3.2. Alternative 3 beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)*	Placement Volume (cy/lf)	Design Berm Width (ft)
F90+00 to F100+00 (transition)	0 to 53.5	0 to 46.2
F100+00 to 40+00	53.5	46.2
40+00 to 50+00 (transition)	53.5 to 143.6	46.2 to 123.8
50+00 to 100+00	143.6	123.8
100+00 to 105+00 (transition)	143.6 to 0	123.8 to 0

*Refer to Figures 3.4a and 3.4b for station locations

A dune with a crest elevation of 4.6 m (15.0 ft.) NAVD would be provided in the area from baseline stations 77+50 to 95+00 or in the area presently devoid of a dune and where homes are protected by sandbag revetments. Based on the April 2006 survey, the total volume of beach fill along the ocean shoreline, including 29,900 cy used to construct the dune, would be 1,152,300 cy. For the March 2012 survey, the total volume of beach fill along the ocean shoreline, including 43,800 cy used to construct the dune, would be 1,190,700 cy. If required by permit conditions, once the beach fill is in place, the sandbags could be removed by manually tearing the fabric and utilizing heavy machinery to extract the bag leaving the sand in place. If removed, the site will be shaped, planted with dune vegetation, and sand fences installed for further stabilization.

The width of the Nixon Channel beach fill was based on shoreline recession rates observed between 1999 and 2005 and an assumed 5 year design life. The fill would consist of a 122.0 m (400 ft) long main section constructed to a width of approximately 50 feet and at an elevation of 1.8 m (6.0 ft) NAVD and two 152.4 m (500 ft) transitions on each end of the main fill. The estimated volume of material needed for the Nixon Channel beach fill is 57,000 cy.

The length of the beach fill along the Nixon Channel shoreline was reduced by 122.0 m (400 ft) from that presented in the DEIS to avoid impacts on the mouth of a small tidal finger that drains the marsh area on the extreme north end of Figure Eight Island. The reduced length of the Nixon Channel fill lowers the fill volume from 65,000 cy presented in the DEIS to 57,000 cy presented above.

Beach Fill Material Compatibility. In April 2008, the North Carolina Coastal Resources Commission (CRC) adopted State Sediment Criteria Rule (15A NCAC 07H .0312) which sets State standards for borrow material aimed at preventing the disposal of incompatible material on the beach. The new rule limits the amount of material by weight in the borrow area with a diameter equal to or greater than 4.76 mm and less than 76 mm (gravel), between 4.76 mm and 2.0 mm (granular), and less than 0.0625 mm (fines) to no more than 5% above that which exists on the native beach. Several beach nourishment operations have taken place along the north end of Figure Eight Island since 1983 and as a result, the NC DCM requested native beach samples be collected on both Figure Eight Island and Hutaff Island to establish a “native” value. The locations of the native beach sampling transects on both Figure Eight Island and Hutaff Island are shown on Figure 3.3.

The results of the characterization of both Figure Eight and Hutaff Island are provided below in Table 3.2. The native beach material on Hutaff Island is slightly coarser (mean grain size of 0.21

mm) than the material found on Figure Eight Island (mean grain size of 0.18 mm) and is comprised of more carbonate (shell) and granular material. The material on both beaches has essentially the same silt content. Given the absence of artificial beach nourishment on Hutaff Island, the characteristics of the beach material on Hutaff Island were adopted as a proxy to represent the native beach material on Figure Eight Island.

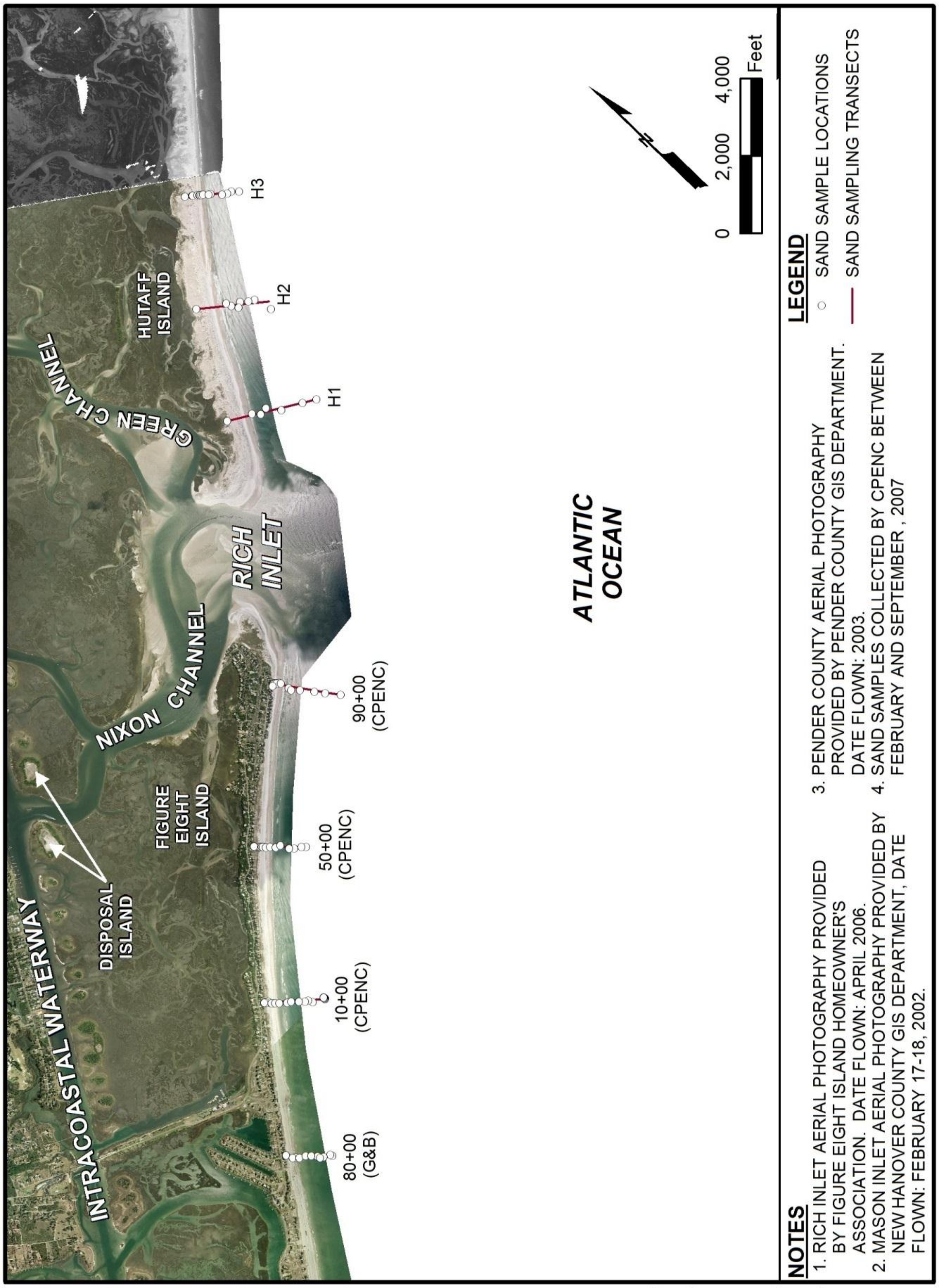

Figure 3.3. Map depicting the locations of sand samples collected on Figure Eight and Hutaff Island.

The performance of a beach fill along Figure Eight Island will depend on how closely the material removed to relocate the inlet bar channel and construct the two channel connectors matches the native beach material, or in this case, the native material on Hutaff Island. In general, borrow area material (channel material in this case) that is finer than the native material will generally form flatter slopes and require more fill to achieve a certain design template. Finer material also tends to erode faster which would require more periodic nourishment to maintain the desired beach profile configuration.

The geotechnical investigations conducted to characterize the material within the proposed new channels included two vibracores (FEVC-07-11 and FEVC-08-06) located in Nixon Channel that contained a layer of clay material at a depth of about -16 ft NAVD which is not compatible with the native beach. As a result, two separate cuts (Cut 1 and Cut 2) were designed (Figure 3.2) with material from Cut 1 to be placed along the ocean shoreline of Figure Eight Island and along the Nixon Channel shoreline while material from Cut 2 will be used to construct the closure dike. An estimated 29,700 cy of clay material that would be removed from Cut 2 would be deposited in an upland disposal area located on the south side of Nixon Channel at the intersection of Nixon Channel with the AIWW (Figure 3.3). With the exception of the 29,700 cy of material to be disposed of in an upland site, the material to be removed to construct the new channels meets all of the requirements for compatibility as stipulated in the State of North Carolina sand compatibility standards. From an engineering or performance standpoint, comparison of the channel material to the native beach material on Hutaff Island resulted in an overfill factor of 1.04, meaning only 4% of the material placed along the ocean shoreline could be lost from the active beach profile, which extends seaward to a depth of -24 feet NAVD, as a result of natural sorting and winnowing of the fill in response to wave and tidal action.

The composite characteristics of the material that would be removed from Cut 1 and Cut 2 (exclusive of the clay) are provided in Table 3.3 and include the silt, granular, gravel, and carbonate percentages for material in each cut. Material from Cuts 1 and 2 have mean grain sizes of 0.25 mm and 0.22 mm, respectively (Table 3.3) both of which are coarser than the native beach material. The characteristics of the material in both cuts (again exclusive of the clay in Cut 2) are well within the silt, carbonate, granular, and gravel contents allowed by the State Sediment Criteria.

Table 3.3- Characteristics of the Native Beach and Rich Inlet Channel Material.

	% Silt	% Carbonate	% Granular	% Gravel	Mean Grain Size (mm)
State Standard Allowance[(1)]	5	15	5	5	
Figure Eight Native Beach	1.04	6.0	0.26	0.05	0.18
State Standard Cutoff	6.04	21.0	5.26	5.05	
Hutaff Island Native Beach[(2)]	1.00	9.9	1.15	0.33	0.21
State Standard Limit	**6.00**	**24.9**	**6.15**	**5.33**	
Rich Inlet Borrow Area Cut 1	1.13	11.28	1.39	0.80	0.25
Rich Inlet Borrow Area Cut 2	1.25	8.12	0.77	0.52	0.22

[(1)] Refer to Figures 3.4a-d for station locations; allowances above native beach material.
[(2)] Characteristics of the native beach material on Hutaff Island adopted as representative of the native beach material on Figure Eight Island.

The channel modifications, closure dike, and general layout of the beach fills for Alternative 3 are shown in Figures 3.4a-d. The following depicts the approximate amount of dredged material that would be placed at each location based on both the April 2006 and March 2012 surveys:

April 2006 Survey	
Ocean Shoreline Beach Fill	1,152,300 cy
Nixon Channel Beach Fill	57,000 cy
Closure Dike	513,700 cy
Upland Disposal (clay material)	42,300 cy
TOTAL	1,765,300 cy

March 2012 Survey	
Ocean Shoreline Beach Fill	1,190,700 cy
Nixon Channel Beach Fill	57,000 cy
Closure Dike	393,000 cy
Upland Disposal (clay material)	29,700 cy
TOTAL	1,670,400 cy

The total volume of material that would be removed to construct the new bar channel and the connector channels in Nixon and Green Channels based on the April 2006 survey exceeds the disposal volumes to construct the dike and beach fills by 8,000 cy whereas the dredged volume based on the 2012 survey exceeds the disposal volume by 272,500 cy or roughly 14%. Since removal of 100% of the available volume from each of the channel areas is unlikely, the small difference in dredge and placement volumes for both surveys will account for some of the inefficiencies associated with the dredging operation.

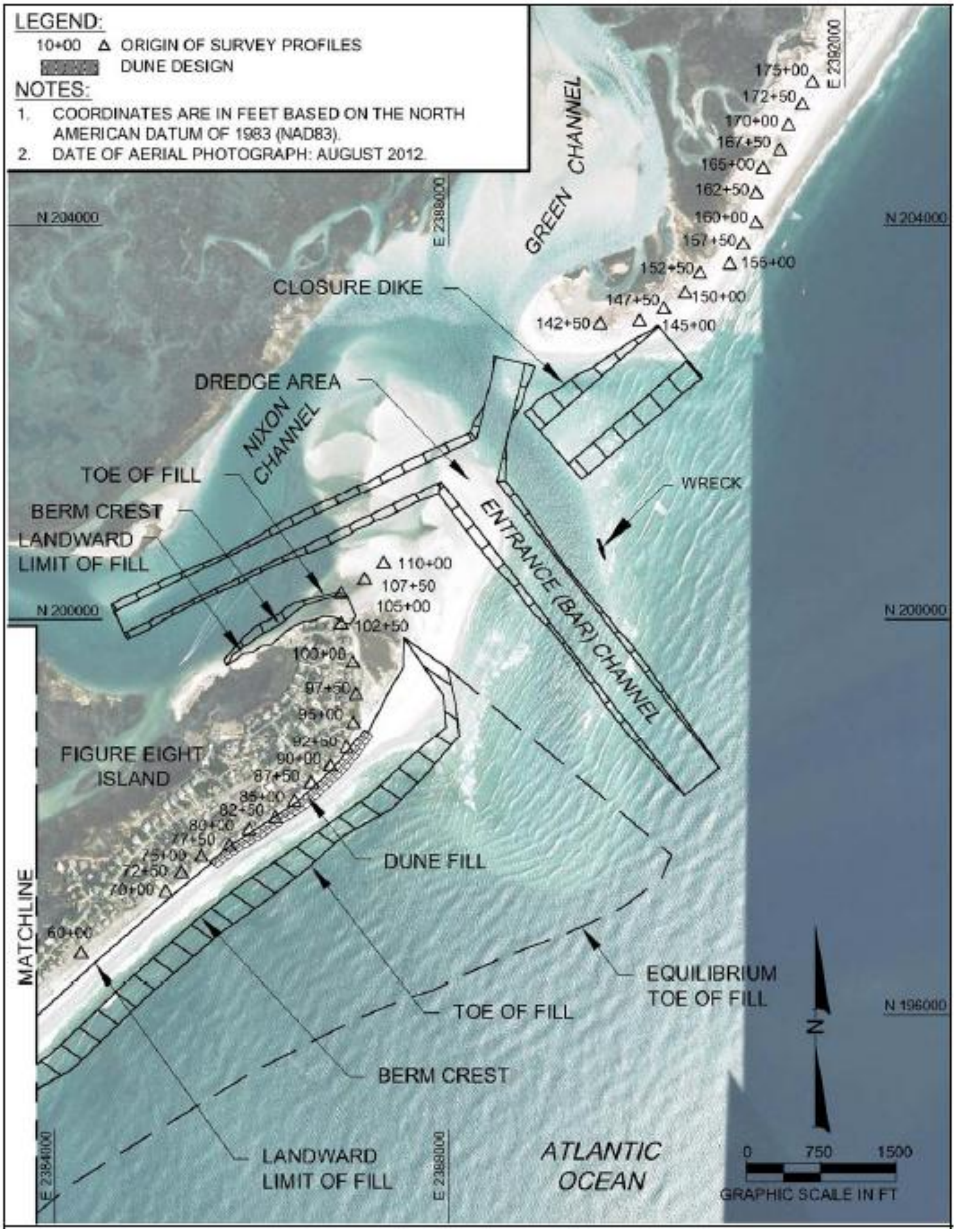

Figure 3.4a. Alternative 3: Optimal channel design, closure dike, and northern portion of beach fill; 2012 shoreline conditions.

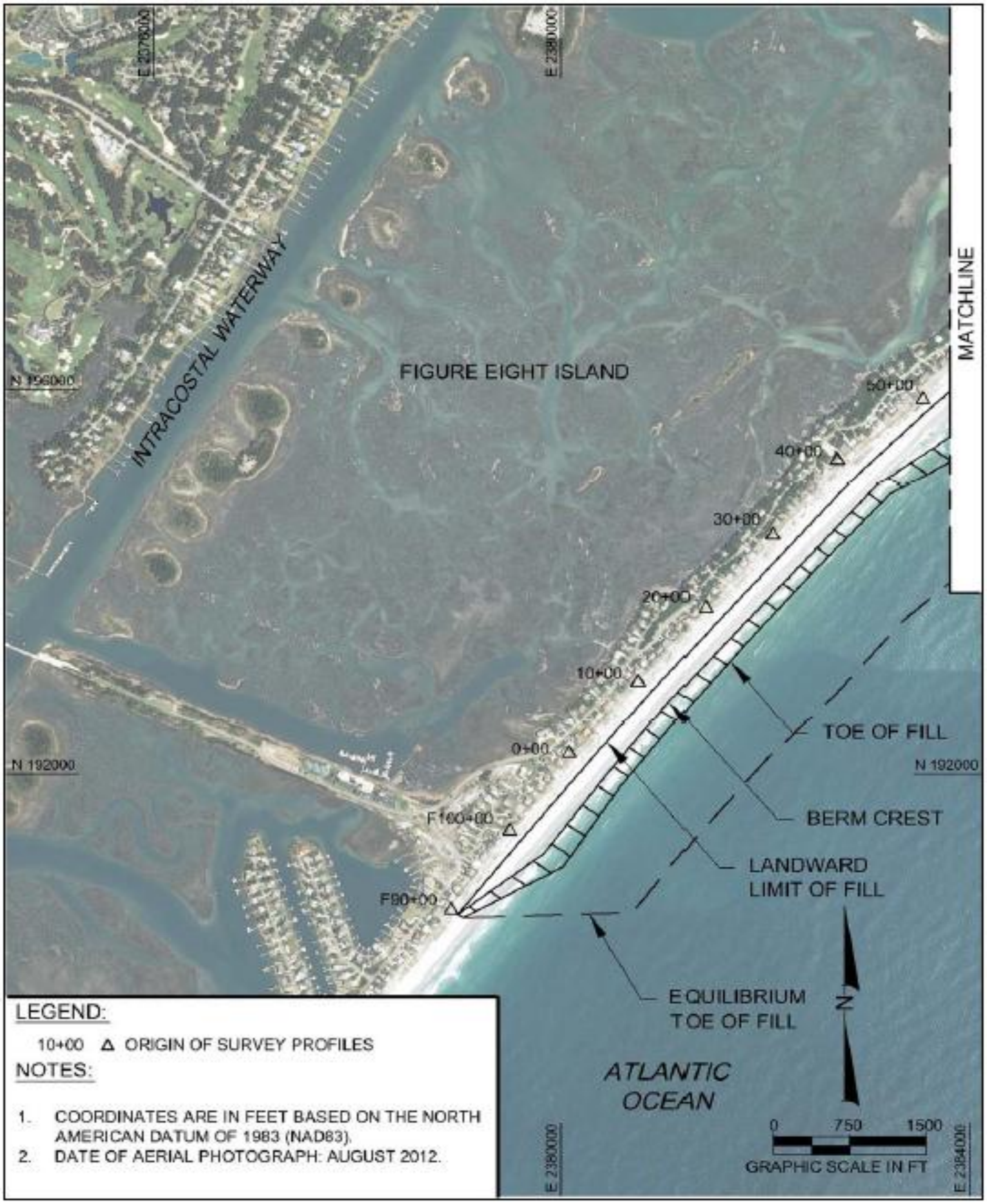

Figure 3.4b. Alternative 3: Southern portion of beach fill; 2012 shoreline conditions.

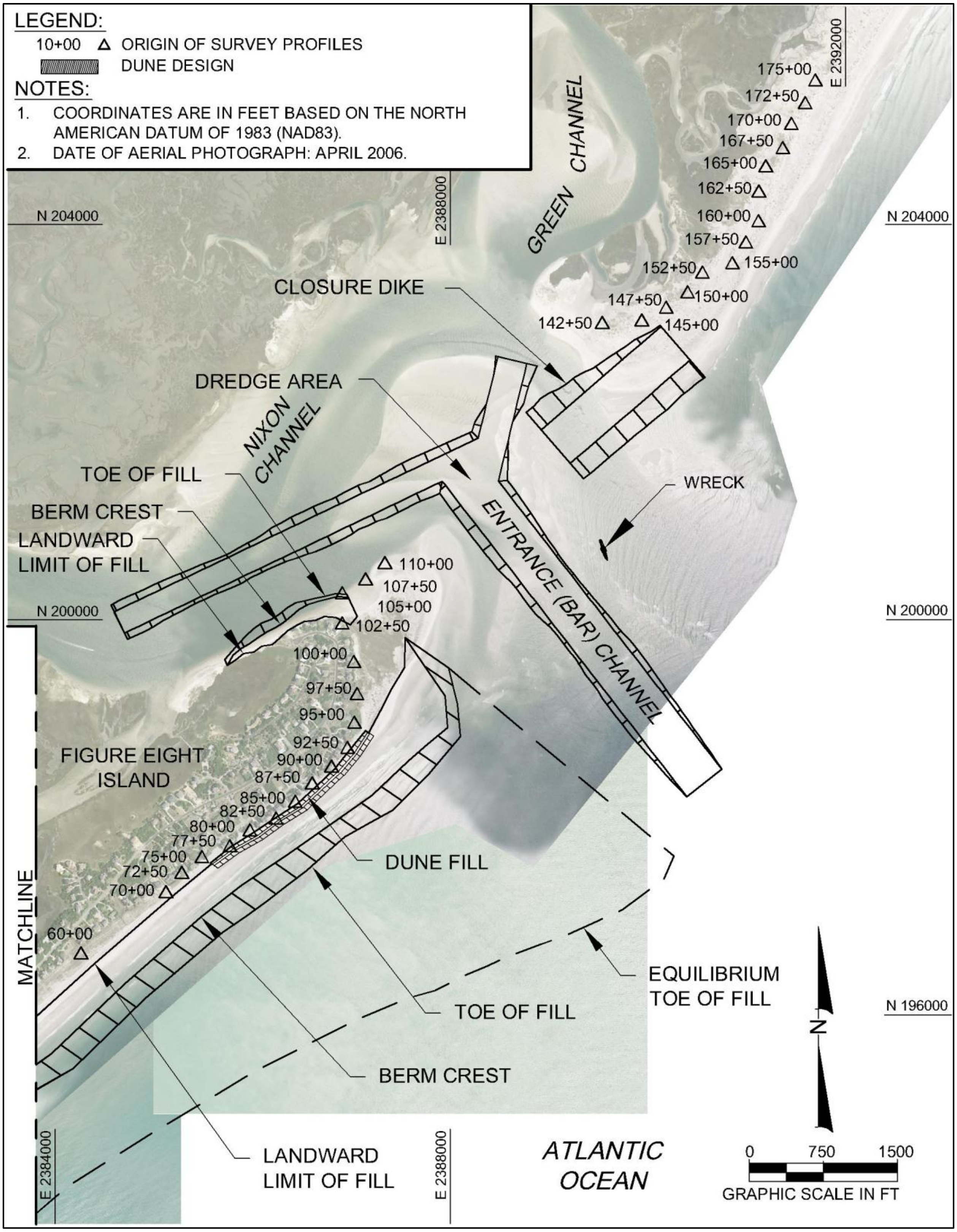

Figure 3.4c. Alternative 3: Optimal channel design, closure dike, and northern portion of beach fill; 2006 shoreline conditions.

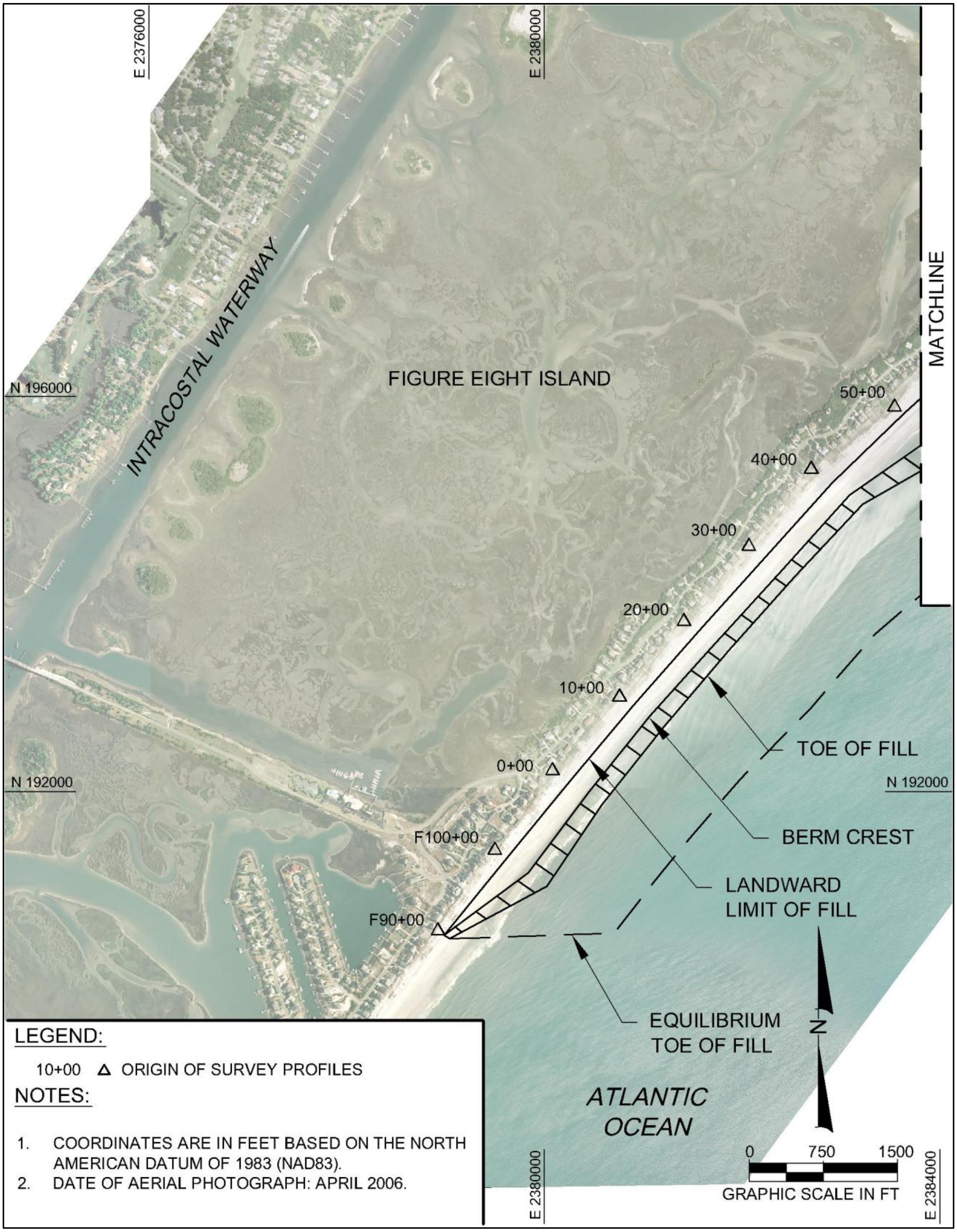

Figure 3.4d. Alternative 3: Southern portion of beach fill; 2006 shoreline conditions.

Channel Maintenance Requirements

Alternative 3 will likely require periodic maintenance of the new inlet bar channel to maintain its preferred position and alignment. While some maintenance may be needed for the Nixon and Green Channel connectors, as discussed below, future maintenance of these two channels would be deferred until conditions indicate maintenance would be desirable. The need to maintain the new bar channel would be evaluated when one of the following two thresholds is exceeded:

> Shoaling Threshold. Channel maintenance could be performed once the shoal volume in the new bar channel totals 60% of the initial construction volume.
>
> Bar Channel Position/Alignment Threshold. Channel maintenance could be performed if the thalweg of the new bar channel migrates toward Hutaff Island and 50% of the channel thalweg is located outside the 450-foot channel corridor established during initial construction. Shifts in the channel orientation toward Figure Eight Island would have a beneficial impact on the north end of Figure Eight Island and would not necessarily trigger the realignment threshold unless the landward portion of the channel moved to a position that threatened the integrity of homes located on the north end of the island.

As previously mentioned, maintenance of the new channels would be performed by the same type of equipment, i.e., cutter-suction pipeline dredge, used for initial construction.

Shoaling rates in the three new channel segments over the 5-year simulation period derived from the results of the Delft3D simulations are presented in Table 3.4a for the 2006 conditions and in Table 3.4b for the 2012 conditions. A plot of the cumulative shoal volume in each channel, expressed as a percent of the initial construction volume, is shown on Figure 3.5 for both the 2006 (dashed lines) and 2012 (solid lines) conditions. The initial construction volumes for the three channels (excluding overdepth allowances) are estimated to be 909,000 cy for the bar channel, 599,400 cy for Nixon Channel, and 264,900 cy for Green Channel (April 2006 survey data). For the 2012 survey, the initial construction volumes (excluding overdepth allowances) for the three channels are estimated to be 931,800 cy for the bar channel, 654,700 cy for Nixon Channel, and 200,000 cy for Green Channel (2012 survey data).

Table 3.4a. Estimated cumulative shoal volumes in each channel over the 5-year simulation for Alternative 3 (2006 Conditions).

Year	Channel Shoal Volume (cy)			
	Bar	Nixon	Green	Total
0	0	0	0	0
1	190,000	18,000	12,000	220,000
2	298,000	27,000	143,000	468,000
3	437,000	28,000	145,000	610,000
4	611,000	51,000	169,000	831,000
5	629,000	88,000	178,000	895,000

Table 3.4b. Estimated cumulative shoal volumes in each channel over the 5-year simulation for Alternative 3 (2012 Conditions).

Year	Channel Shoal Volume (cy)			
	Bar	Nixon	Green	Total
0	0	0	0	0
1	202,000	10,000	72,000	284,000
2	430,000	20,000	173,000	623,000
3	571,000	70,000	142,000	783,000
4	641,000	103,000	132,000	876,000
5	666,000	121,000	140,000	927,000

The initial size of all three channels was based on stability requirements and the need to initially capture flow in and out of the inlet. Once this flow pattern is established, restoration of the two connector channels to the original design dimensions may not be necessary as long as the flow through Nixon Channel does not induce erosion along the back side of Figure Eight Island and the flow distribution into Green Channel is comparable to existing conditions. However, since maintenance of the position and alignment of the bar channel is critical to the success of Alternative 3, the shoaling and migration of the bar channel derived from the results of the Delft3D model was used to formulate future maintenance requirements for Alternative 3.

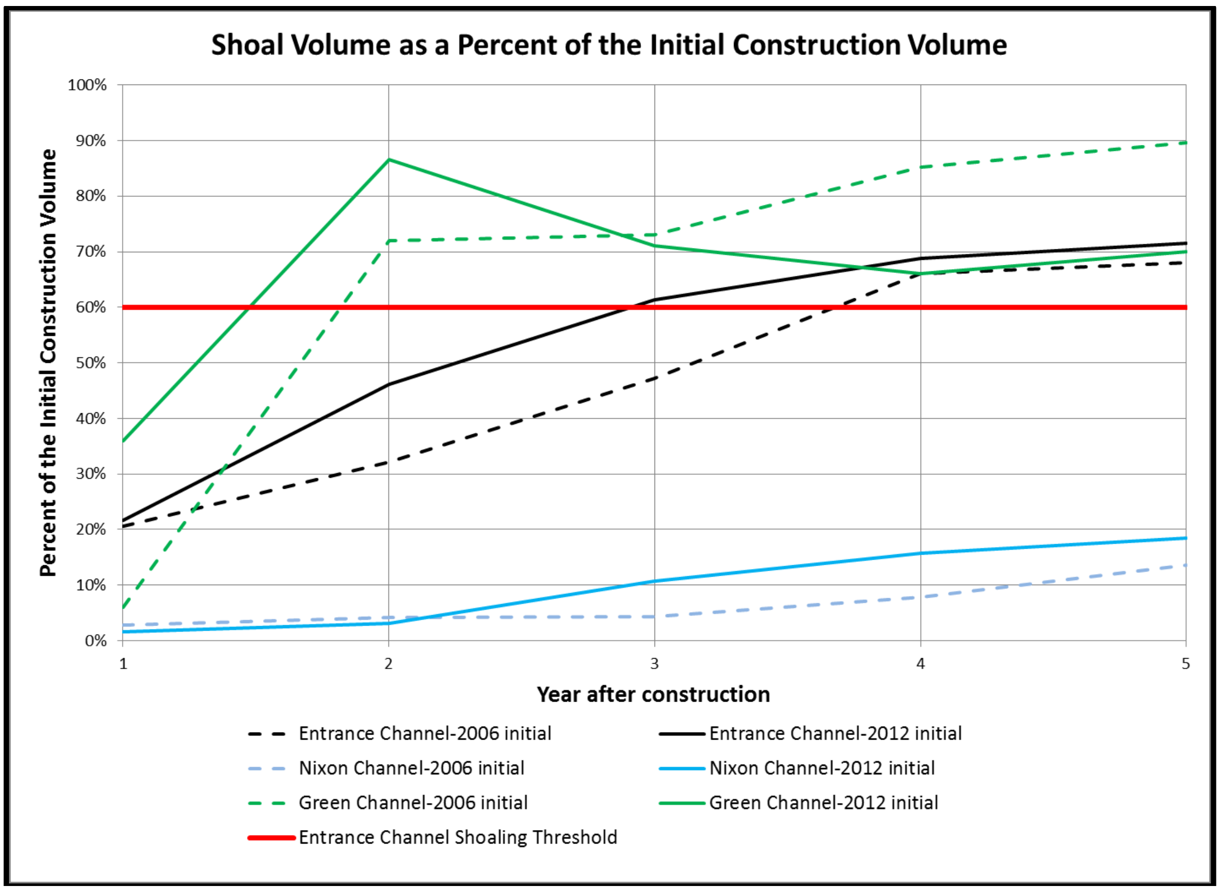

Figure 3.5. Alternative 3 - Cumulative channel shoal volumes over the 5-year model simulation expressed as a percent of the initial construction volume.

Figure 3.5 indicates that based on the 2012 conditions, shoaling of the Entrance Channel would approach the 60% shoaling threshold three years after initial construction. However, the rate of shoaling, expressed as a percentage of the initial volume, moderated after year 3. For the 2006 conditions, the Entrance Channel did not reach the 60% shoaling threshold until almost 4 years. The model also indicated the new bar channel could migrate out of the 450-foot corridor and orient toward Hutaff Island sometime between year 4 and year 5 of the simulation (Appendix B). Therefore, based on the estimated shoaling volumes and modeled behavior of the bar channel, maintenance of the bar channel would be required about every 5 years.

Shoaling of the Green Channel connector occurred rapidly during the first two years of the simulation for both conditions, as shown in Tables 3.3a and 3.3b and on Figure 3.5. This rapid rate of shoaling was associated with erosion of the closure dike as the dike morphed into a recurved sand spit off the south end of Hutaff Island. Once erosion of the sand dike moderated, shoaling of the Green Channel connector stabilized with some slight scour occurring in the channel during years 3 and 4 of the simulation with the 2012 conditions and only moderate shoaling with the 2006 condition. The Nixon Channel connector shoaled at a relatively slow rate throughout the 5-year simulation period with the total shoal volume at the end of year 5 equal to less than 20% of the initial dredge volume for both the 2006 and 2012 conditions. As a result of the slow rate of shoaling, flow through Nixon Channel was concentrated toward the middle of Nixon Channel and away from the back side of Figure Eight Island for both conditions. The slow rate of shoaling in the Nixon Channel connector and the moderation of shoaling in the Green Channel connector after the first couple of years indicated the two channels had achieved some equilibrium and would probably not need to be maintained.

<u>Periodic Nourishment – Alternative 3</u>.

Future maintenance of the channels would be limited to just the bar channel. For the 2006 conditions, the model indicated a 5 year shoal volume of 629,000 cy while the 2012 conditions resulted in a shoal volume of 666,000 cy. Maintenance of the Nixon and Green Channel connectors would be deferred until such time monitoring surveys find maintenance is required to restore flow volumes or in the case of Nixon Channel, divert the flow away from the shoreline in the critically eroding area.

The Delft3D model results for Alternative 3 were used to estimate volumetric changes along the ocean shoreline of Figure Eight Island north of Bridge Road and along the southern 3,000 ft of Hutaff Island. Details of the model results are provided in Appendix B and summarized in Chapter 5. In general, the model indicated favorable performance of the beach fill between baseline stations F90+00 and 60+00 for both the 2006 and 2012 conditions. Over the five year simulation period, the model indicated volume losses between stations F90+00 and 60+00 would only average 2,000 cy/year for the 2006 condition and 10,700 cy/year for the 2012 condition. Based on this performance, periodic nourishment of the fill between stations F90+00 and 60+00 would only be required on an infrequent basis. As a result, the estimated periodic nourishment requirement for the beach fill associated with Alternative 3 was based on nourishing the fill area between baseline stations 60+00 and 105+00 on a regular basis. The future need to nourish the area between stations F90+00 and 60+00, which should not be needed for at least 10 years or more, would be determined from the results of beach profile monitoring surveys.

The annual rate of erosion of the beach fill between stations 60+00 and 105+00 averaged 99,000 cy/year over the 5 year simulation period given the 2006 conditions and 81,000 cy/year for the 2012 condition. Based on the need to reposition the bar channel of Rich Inlet every five years, the five year nourishment requirement for this area would be 495,000 cy under 2006 conditions and 405,000 cy for the 2012 condition. Nourishment of the Nixon Channel area would require about 30,000 cy which brings the total 5-year nourishment requirement to 525,000 cy for the 2006 condition and 435,000 cy for the 2012 condition.

Regardless of the periodic nourishment requirement for the beach fills, the long-term recovery of the beach along the north end of Figure Eight Island is dependent on maintaining the bar channel of Rich Inlet within the preferred inlet corridor. As noted above, the Delft3D model simulation of Alternative 3 indicated the new entrance channel could migrate out of the 450-foot corridor and orient toward Hutaff Island sometime between years 4 and 5 after initial construction. Consequently, the new channels would probably have to be maintained approximately every five years regardless of the nourishment needs along Figure Eight Island. The estimated volume of material that would have to be removed every five years to maintain the entrance channel is 666,000 cy (Table 3.3b). Since the total nourishment requirement for the beach fill between stations 60+00 and 105+00 on the ocean shoreline and beach fill along Nixon Channel is estimated to be between 435,000 cy and 525,000 cy, the apparent excess of channel maintenance material could be used to provide some advanced fill between stations 60+00 and 105+00 or possibly distributed to beach areas south of station 60+00. Regardless, all of the material removed to maintain the entrance channel would be deposited on Figure Eight Island.

<u>Implementation Cost.</u> Over the thirty year planning period, the total implementation cost for Alternative 3, based on the April 2006 survey condition, would be about $61.8 million in current dollars. This total cost includes $17.1 million for initial construction of the new channels, sand dike, and beach fills and $44.7 million for maintaining the channel every 5 years with disposal of the dredged material along both the ocean shoreline of Figure Eight Island north of Bridge Road and along the Nixon Channel shoreline. The initial construction is expected to take approximately 2.5 months.

Over the thirty year planning period, the total implementation cost for Alternative 3, based on the 2012 survey condition, would be about $63.5 million in current dollars. This total cost includes $17.3 million for initial construction of the new channels, sand dike, and beach fills and $46.2 million for maintaining the channel every 5 years with disposal of the dredged material along both the ocean shoreline of Figure Eight Island north of Bridge Road and along the Nixon Channel shoreline. The initial construction is expected to take approximately 2.5 months. See Appendix B and Appendix G for more information regarding cost.

Alternative 4: Beach Nourishment without Inlet Management

This alternative involves the placement of fill material along the oceanfront and Nixon Channel shorelines using several potential borrow sources, however it does not implement any inlet management measures. The model evaluation of the performance of the beach fill under Alternative 3 for both the 2006 and 2012 conditions indicated the volume of material in the initial fill for Alternative 3 exceeded the volume needed to protect upland development. Again, the beach fill volume for Alternative 3 was dictated by the volume of material that would be removed to construct the new bar channel and the connectors into Nixon and Green Channels. Accordingly, the fill density for Alternative 4 was reduced relative to Alternative 3 with the fill densities and design berm widths for Alternative 4 provided in Table 3.5. The layout of the beach fill for Alternative 4 is provided in Figures 3.6a-d.

Table 3.5. Alternative 4 beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
F90+00 to F100+00 (transition)	0 to 20	0 to 17
F100+00 to 20+00	20	17
20+00 to 30+00 (transition)	20 to 50	17 to 43
30+00 to 60+00	50	43
60+00 to 70+00 (transition)	50 to 100	43 to 86
70+00 to 80+00	100	86
80+00 to 82+50 (transition)	100 to 200	86 to 172
82+50 to 100+00	200	172
100+00 to 105+00 (transition)	200 to 0	172 to 0

The reduction in the fill density, particularly north of baseline station 60+00, was aimed at reducing losses from the fill area due to diffusion, i.e., the horizontal spreading or transport of material out of the placement area due to longshore sand transport.

For the April 2006 survey conditions, the total initial beach fill volume along the ocean shoreline from Rich Inlet to just south of Bridge Road (station F90+00) for Alternative 4 would be 864,300 cy which includes 43,800 cy that would be used to construct a dune between stations 77+50 and 95+00 (sandbag area). For the March 2012 survey conditions, the total initial beach fill volume along the ocean shoreline from Rich Inlet to just south of Bridge Road (station F90+00) for Alternative 4 would be 911,300 cy which includes 43,800 cy that would be used to construct a dune between stations 77+50 and 95+00 (sandbag area). If required by permit conditions, once the beach fill is in place, the sandbags could be removed by manually tearing the fabric and utilizing heavy machinery to extract the bag leaving the sand in place.

The beach fill along Nixon Channel would be the same as Alternative 3 or 57,000 cy resulting in a total beach fill volume for Alternative 4 of 921,300 cy based on the 2006 survey conditions and 968,300 cy based on the 2012 survey conditions.

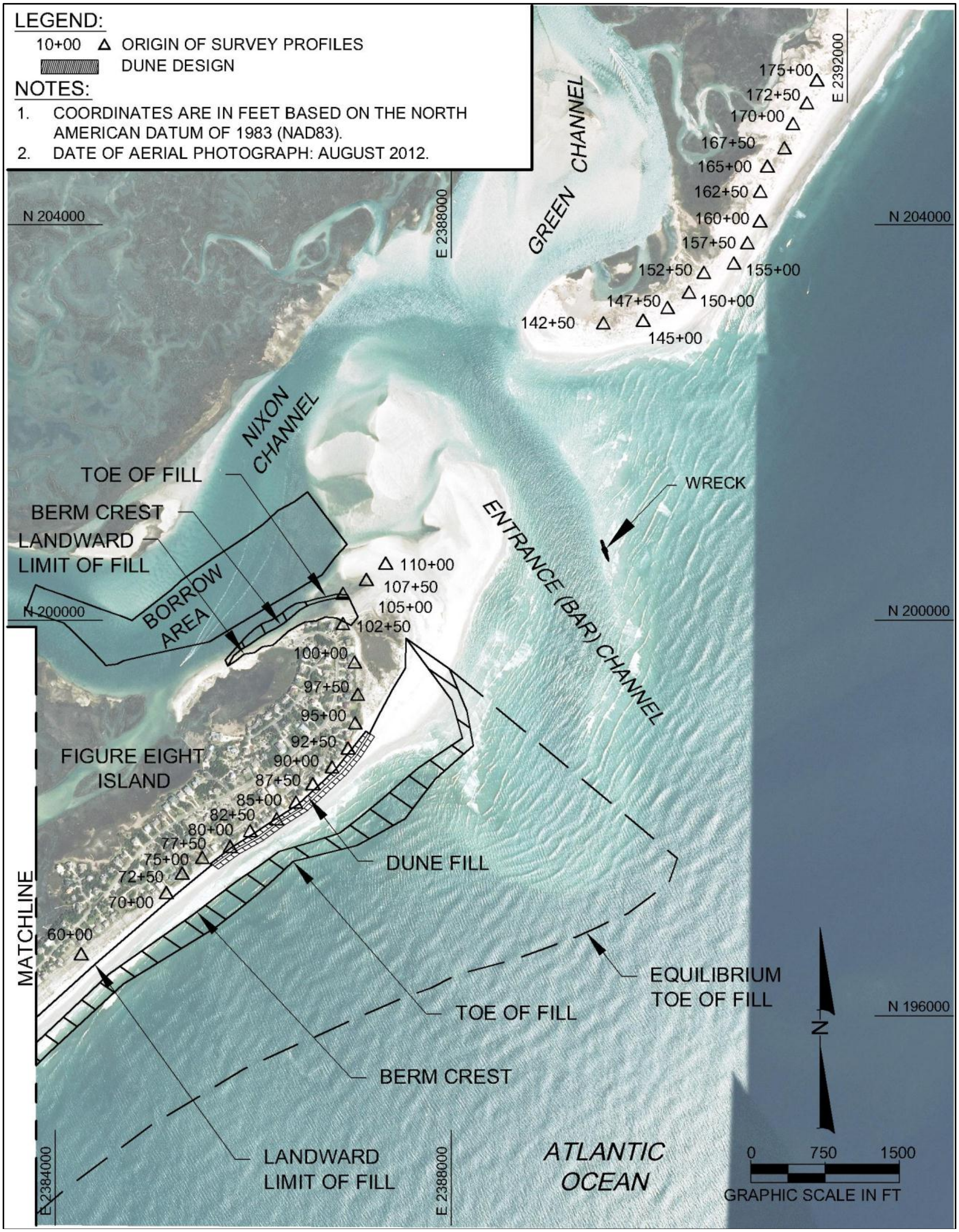

Figure 3.6a Alternative 4: Northern portion of beach fill; 2012 shoreline conditions.

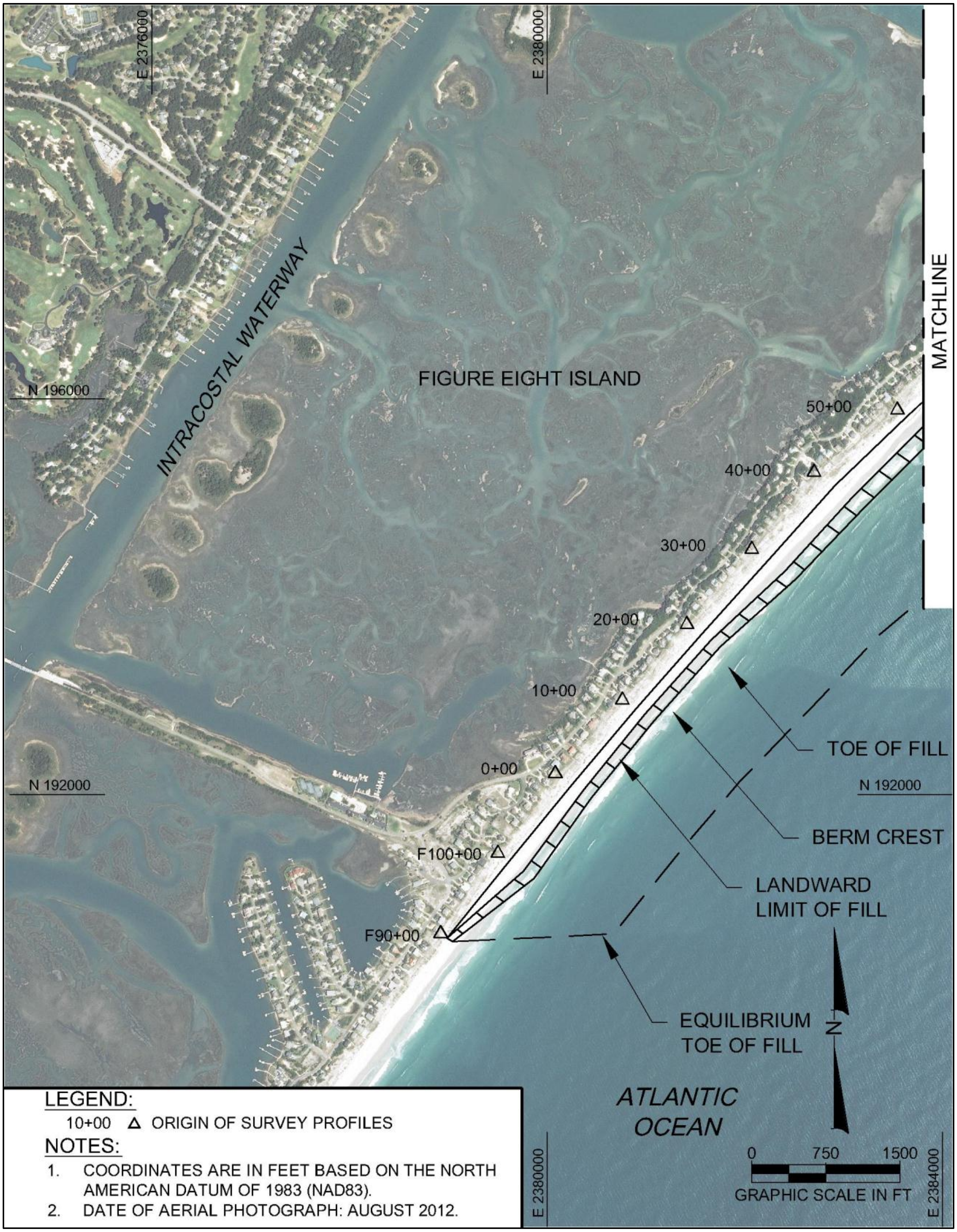

Figure 3.6b Alternative 4: Southern portion of beach fill; 2012 shoreline conditions.

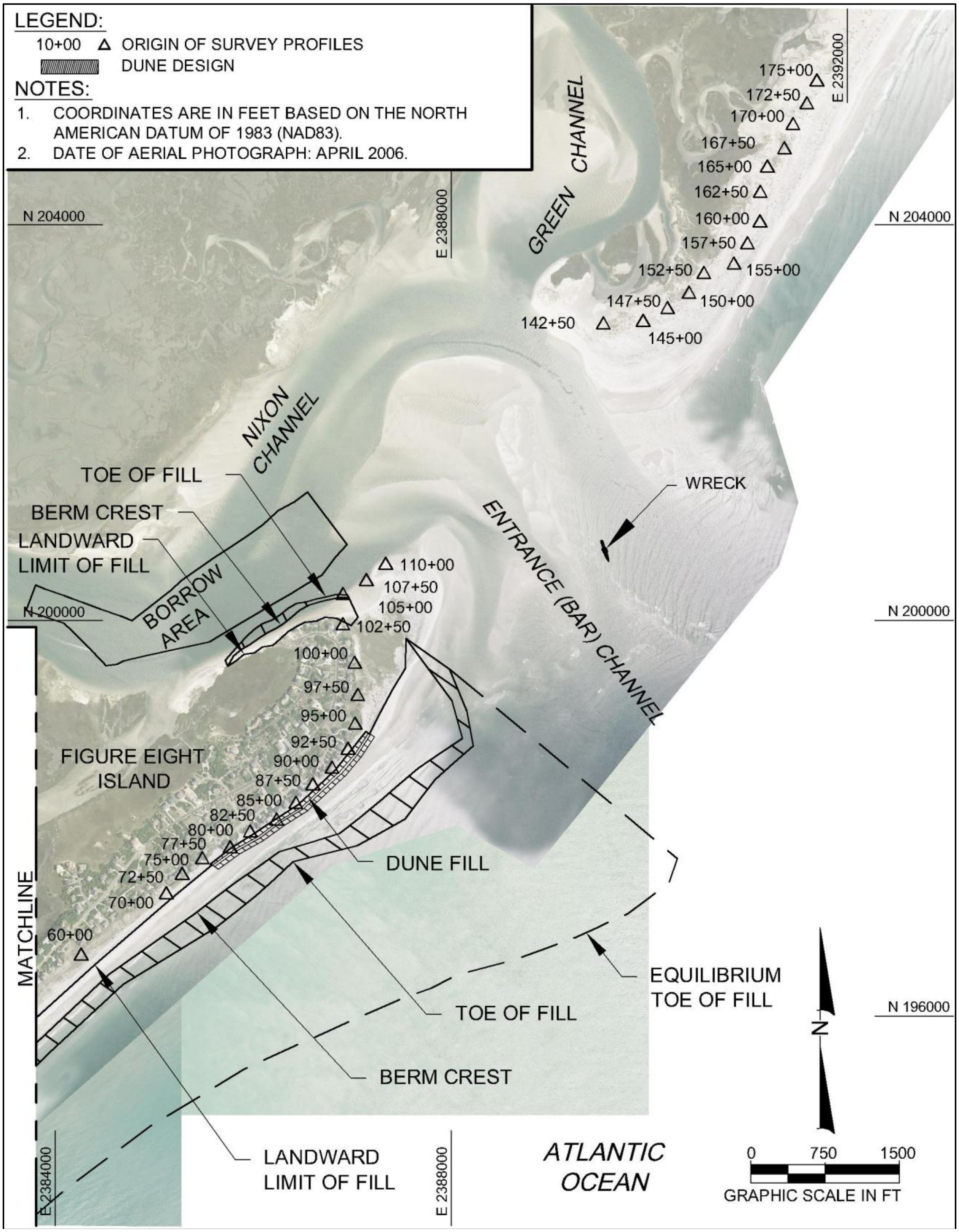

Figure 3.6c Alternative 4: Northern portion of beach fill; 2006 shoreline conditions.

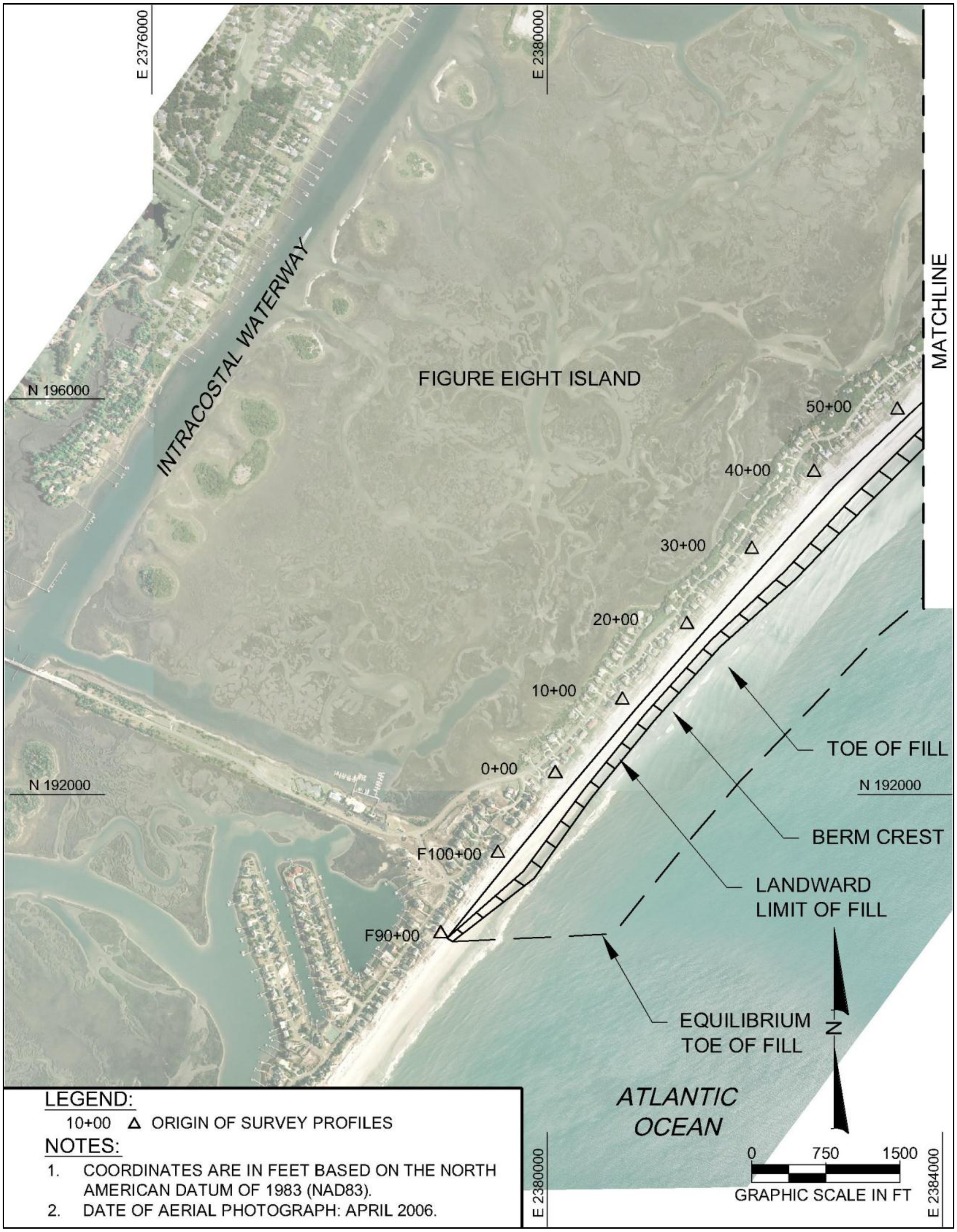

Figure 3.6d Alternative 4: Southern portion of beach fill; 2006 shoreline conditions.

As discussed in Appendix B, the model simulation of Alternative 4 under both the 2006 and 2012 conditions indicated the beach fill would perform very well between baseline stations F90+00 and 60+00 and would not require periodic nourishment for the foreseeable future. However, losses from the fill area between stations 60+00 and 105+00 of the beach under Alternative 4 were relatively high and resulted in complete removal of the fill, including that placed above the -6-foot NAVD contour, by the end of year 4 given the 2006 condition and by the end of year 5 for the 2012 condition. Theoretically, more material could be placed between stations 60+00 and 105+00 in an attempt to prolong the life of the fill, however, there is a point of diminishing returns due to diffusion losses in which volume losses from the fill area increase exponentially with increased fill volume and fill width. Therefore, in order to limit periodic nourishment volumes needed for Alternative 4, a 4-year periodic nourishment interval was selected. Based on the model volume changes, the 4-year periodic nourishment requirement for Alternative 4 between stations 60+00 and 105+00 would be 764,000 cy given the 2006 conditions and 508,000 cy under 2012 conditions. Given the likelihood that the Rich Inlet bar channel will assume an alignment toward Hutaff Island in the near future and initiate another round of high erosion rates on the north end of Figure Eight Island, future maintenance of a beach fill under Alternative 4 was based on providing 764,000 cy every 4 years.

The identified borrow sources for Alternative 4 include the previously permitted area within Nixon Channel as described in Alternative 1, three (3) potential borrow sources located between 3 and 4 miles directly offshore of Figure Eight Island and three (3) upland dredged material disposal areas located next to the AIWW.

Nixon Channel. The six (6) dredging events carried out in Nixon Channel since 1993 removed a total of 1,748,000 cy. The volume of material for each event was generally limited to less than 300,000 by the Figure "8" Beach HOA in order to avoid the establishment of a static vegetation line. If dredging of the existing Nixon Channel permit area was not constrained by the static vegetation line rule, the volume of material that could have been removed could have ranged between 400,000 and 500,000 cy every 4 or 5 years. Since the last maintenance dredging in Nixon Channel occurred in 2011, at least 400,000 cy should be available for use during initial construction of Alternative 4. The balance of the material needed for initial construction and periodic nourishment would be obtained from other borrow sources.

Offshore Borrow Areas. The potential offshore sand sources were investigated by Dr. Cleary (Cleary, 2000 and Cleary, 2003) with the 2000 investigation focusing on potential sources inside the State 3-mile territorial limit and the 2003 investigation extending the search to 5 miles offshore. No appreciable sand resources were located landward of the 3-mile limit, however, the three potential sites beyond the 3-mile limit shown on Figure 3.7 each contain an estimated 4.6 million cy of material. No further geotechnical or geosurvey work has been conducted within the sites, so the extent of compatibility at each borrow area has not been verified at this time.

What is a Static Vegetation Line?

Under current Coastal Resources Commission (CRC) rules, the seaward most line of stable vegetation existing immediately prior to the implementation of a large-scale beach nourishment project is designated as a “static vegetation line” following fill placement. The “static vegetation line” becomes the reference for establishing oceanfront setbacks in perpetuity even if the vegetation line moves seaward.

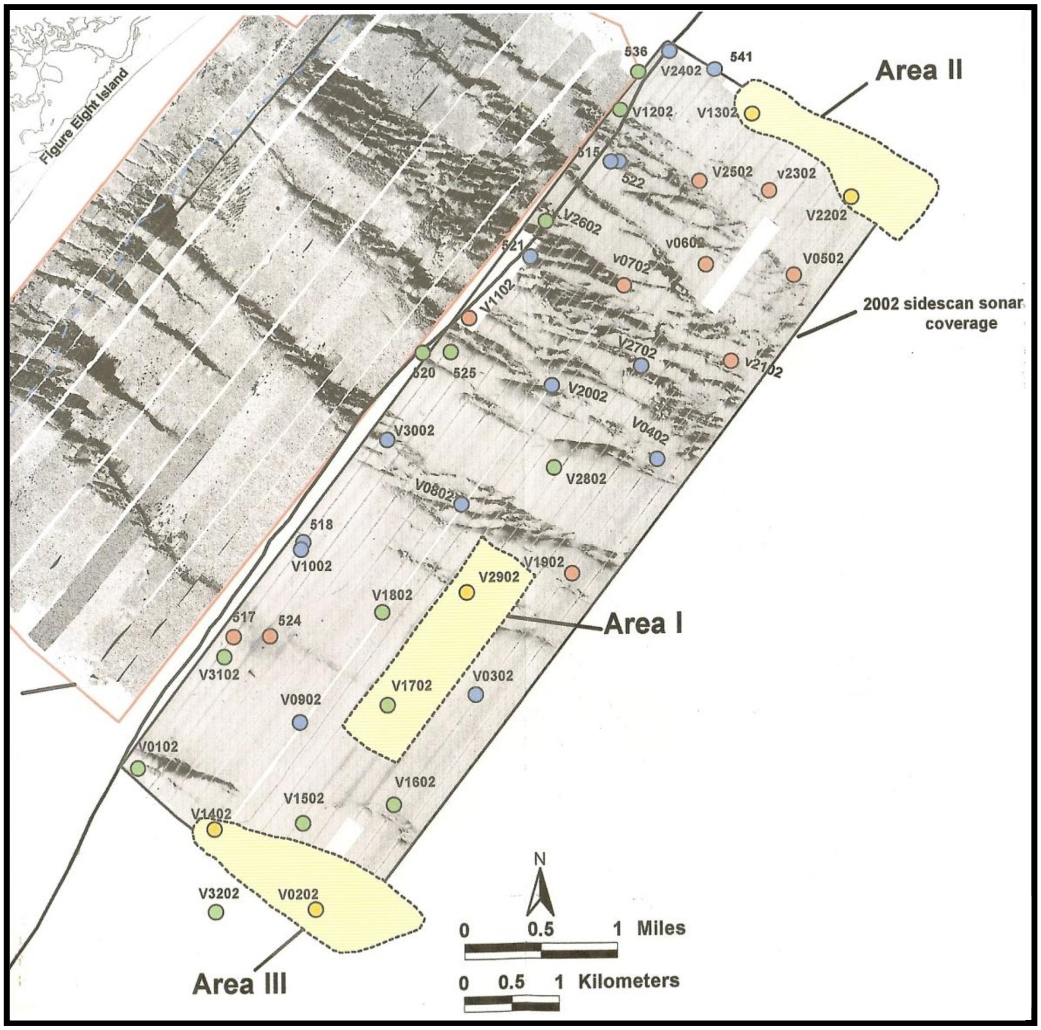

Figure 3.7. Potential offshore borrow areas identified by Dr. William Cleary.

<u>AIWW dredged material disposal sites</u>

Three (3) dredged material disposal sites are located adjacent to the AIWW behind Figure Eight Island near the confluence of Nixon Channel with the AIWW. These three (3) northern disposal sites shown on Figure 3.8 had been used in the past by the USACE for disposal of shoal material removed from the confluence of Nixon Creek with the AIWW. The islands are relatively small and have reached their maximum storage capacity with elevations ranging from 20 to 25 feet NAVD.

Figure 3.8. Location of AIWW dredged material disposal sites 1, 2, and 3.

The Figure "8" Beach HOA contracted with Criser, Troutman, Tanner Consulting Engineers (CTT) to determine the quantity and quality of material stored in each of the disposal areas. The investigation included detailed topographic surveys, 9 to 12 core borings in each disposal site, core logs, soil classification, and grain size analyses. An estimate of the volume of material down to an elevation of -19 feet NAVD (-18 feet NGVD), the median grain size, silt content, and calcium carbonate content for each disposal site is provided in Table 3.6.

Table 3.6. Characteristics of the AIWW dredged material disposal areas near Nixon Creek.

Disposal Area	Estimated Volume (cy)	Median Grain Size (mm)	Silt Content(1) (%)	Calcium Carbonate (%)
1	202,000	0.19	5.7	2.2
2	225,000	0.15	4.8	2.0
3	132,000	0.17	6.9	3.5

(1) Based on #200 sieve.

The total volume of material contained in the three disposal sites is 559,000 cy. Adjusting this total volume for silt content, approximately 527,000 cy of sandy material is stored in the three (3) disposal sites.

Borrow Area Selection for Alternative 4

Additional borrow sources were assessed for beach placement, but were eliminated from further consideration. The elimination of these other source options for Alternative 4 is discussed in Chapter 5. Of all the potential borrow sources outside Rich Inlet discussed above, the maintenance dredging of the previously permitted area within Nixon Channel, the potential offshore borrow areas identified by Dr. Cleary, and the three (3) northern AIWW disposal sites would be suitable for nourishing the Figure Eight Island shoreline north of Bridge Road. Due to the relative small volume available from the three (3) AIWW disposal sites, these sites would be held in reserve and only used for periodic nourishment if the volume of material shoaling the previously permitted area within Nixon Channel is insufficient to meet nourishment requirements or other concerns over the removal of the material from Nixon Channel prevent its use. Also, the relatively high rate of periodic nourishment for Alternative 4 indicated by the model results, which exceeds the estimated shoaling rate of the previously permitted area in Nixon Channel, would require the continued use of the offshore borrow sites in order to satisfy the nourishment requirements.

The removal of material from borrow sources, with the exception of the upland sources and disposal on both the Nixon Channel and ocean shoreline would be accomplished by an 18-inch or smaller cutter-suction pipeline dredge. Material from the offshore borrow area would be transported to the beach via a trailer-suction hopper dredge equipped with direct pumpout capability. The dredge would attach to a mooring buoy positioned at two locations off Figure Eight Island and pump the material to the beach through a submerged pipeline.

Periodic Nourishment – Alternative 4.

Based on the Delft3D model results for Alternative 4 under both the 2006 and 2012 conditions, the beach fill between stations F90+00 and 60+00 would not require periodic nourishment on a regular basis. North of baseline station 60+00, modeled losses from the fill over four years totaled 704,000 cy under the 2006 condition and 520,000 cy for the 2012 condition. Periodic nourishment of the beach fill in Nixon Channel would require approximately 24,000 cy every 4 years. Therefore, the total 4-year nourishment requirement for Alternative 4 would be 728,000 cy given the 2006 conditions and 544,000 for the 2012 conditions.

Material for periodic nourishment under Alternative 4 would be derived from maintenance of the previously permitted area in Nixon Channel and the offshore borrow areas. Based upon documented shoaling rates in the Nixon Channel area, the previously permitted site should supply around 400,000 cy every 4 years. The balance of the periodic nourishment requirements would be obtained from the offshore sites to satisfy the 4-year nourishment needs.

Implementation Cost. Over the thirty year planning period, the total implementation cost for Alternative 4, based on the April 2006 survey conditions, would be about $84.9 million in current dollars. This total cost includes $12.7 million for initial construction of the beach fills along the ocean and Nixon Channel shorelines, $1.0 million for geotechnical investigations and permitting offshore borrow area, and $71.2 million to nourish the beach fills every four (4) years. Over the thirty year planning period, the total implementation cost for Alternative 4, based on the March 2012 survey conditions, would be about $69.0 million in current dollars. This total cost includes $13.3 million for initial construction of the beach fills along the ocean and Nixon Channel shorelines, $1.0 million for geotechnical investigations and permitting offshore borrow area, and $54.7 million to nourish the beach fills every four (4) years. Initial construction is expected to take approximately 4 months. The unit dredging cost per cubic yard for Alternative 4 would be more costly compared to Alternative 3 due to the use of offshore borrow areas for both initial construction and periodic beach nourishment. See Appendix B and Appendix G for more information regarding cost.

Alternative 5: Beach Fill with Terminal Groin

Introduction. This option has (4) variations: Alternatives 5A, 5B, 5C, and 5D. Each one is being considered as a separate alternative and was evaluated as such. For each alternative, a terminal groin would be constructed on the north end of Figure Eight Island near the south shoulder of Rich Inlet and the area immediately south of the terminal groin would be artificially filled to create an accretion fillet. Periodic nourishment would be used to maintain the shoreline south of the terminal groin to Bridge Road. As stated previously, all (4) options were modeled using the revised model set-up for the 2006/2007 inlet and shoreline conditions and only Alternative 5D was simulated using the 2012 inlet and shoreline conditions. Although not modeled using the 2012 conditions, quantities and cost estimates to construct Alternatives 5A, 5B, and 5C, given the 2012 conditions, were computed using actual 2012 survey data. A summary of the four (4) alternatives are provided below with details given in Appendix B, Sub-Appendix B, Sub-Appendix B-1, and Sub-Appendix B-2.

Terminal Groin Legislation. Prior to 2011, terminal groins and other so-called hard erosion response structures were prohibited along the ocean shoreline of North Carolina by NC Division of Coastal Management. During the 2011 legislation session, the North Carolina Legislature passed Session Law 2011-387, Senate Bill 110, which allows consideration of terminal groins adjacent to tidal inlets. The legislation limited the number of terminal groins to four (4) statewide and included a number of provisions and conditions that must be met in order for the groins to be approved and permitted.

A terminal groin, as defined by the above referenced legislation, is:

> "*a structure that is constructed on the side of an inlet at the terminus of an island generally perpendicular to the shoreline to limit or control sediment passage into the inlet channel*"

In 2013, the State Legislature passed the Coastal Policy Reform Act of 2013 (SL2013-384) that modified some of the requirements included in the 2011 legislation. The major changes include:

(a) *Elimination of the requirement to show an imminent erosion threat to structures and infrastructure. Now the applicant only needs to demonstrate structures and infrastructure are threatened.*
(b) *Eliminated the need to demonstrate that nonstructural measures, including relocation of threatened structures, are impractical.*
(c) *The required inlet management plan "must be reasonable and not impose requirements whose costs outweigh the benefits."*
(d) *Eliminated the requirement of the applicant to fund restoration of public, private, or public trust property if the groin has an adverse impact on the environment or property.*
(e) *Provided more flexibility in providing financial assurances for maintenance and/or removal of the terminal groin.*

Terminal groins differ from jetties both in size and in intended function. Jetties are used to stabilize navigation channels through tidal inlets by concentrating tidal flow in the navigation channel and controlling the influx of sediment to the channel. Jetties are relatively long structures that normally extend from the shoreline seaward to a depth comparable to the depth of the navigation channel or at least to the outer lobe of the ebb tide delta of the inlet. Terminal groins, by virtue of their relatively short length compared to a jetty, will only retain sediment within a limited area immediately adjacent to the structure. This area is generally referred to as an accretion fillet. Once the accretion fillet is fully formed, wave driven sediment transport will move either through, over, or around the seaward end of the structure. The terminal groin legislation allowing consideration of terminal groins in North Carolina requires the structure to be accompanied by beach fill which would artificially create the accretion fillet.

In the May 2013 Draft EIS for the Figure Eight Island Shoreline and Inlet Management Project, only Alternatives 5A and 5B were presented and both alternatives included the same terminal groin design with a position and alignment shown schematically in Figure 3.9. These two options remain unchanged from the Draft EIS. The difference in the two terminal groin alternatives was primarily associated with the source of material that would be used to construct beach fills along the ocean shoreline and the Nixon Channel shoreline and the size of the fill along the ocean shoreline.

Alternative 5A included the construction of a channel that would extend from the previously permitted area in Nixon Channel across the flood tide delta of Rich Inlet and connect to the gorge of Rich Inlet. The purpose of the new channel was to divert flow in Nixon Channel away from the back side of Figure Eight Island to reduce current induced erosion pressures in that area. The material removed to construct the channel would be used to construct a beach fill from the terminal groin south to station F90+00, which is just south of Bridge Road. Some of the material would also be used to construct a beach fill along the Nixon Channel shoreline on the back side of Figure Eight Island.

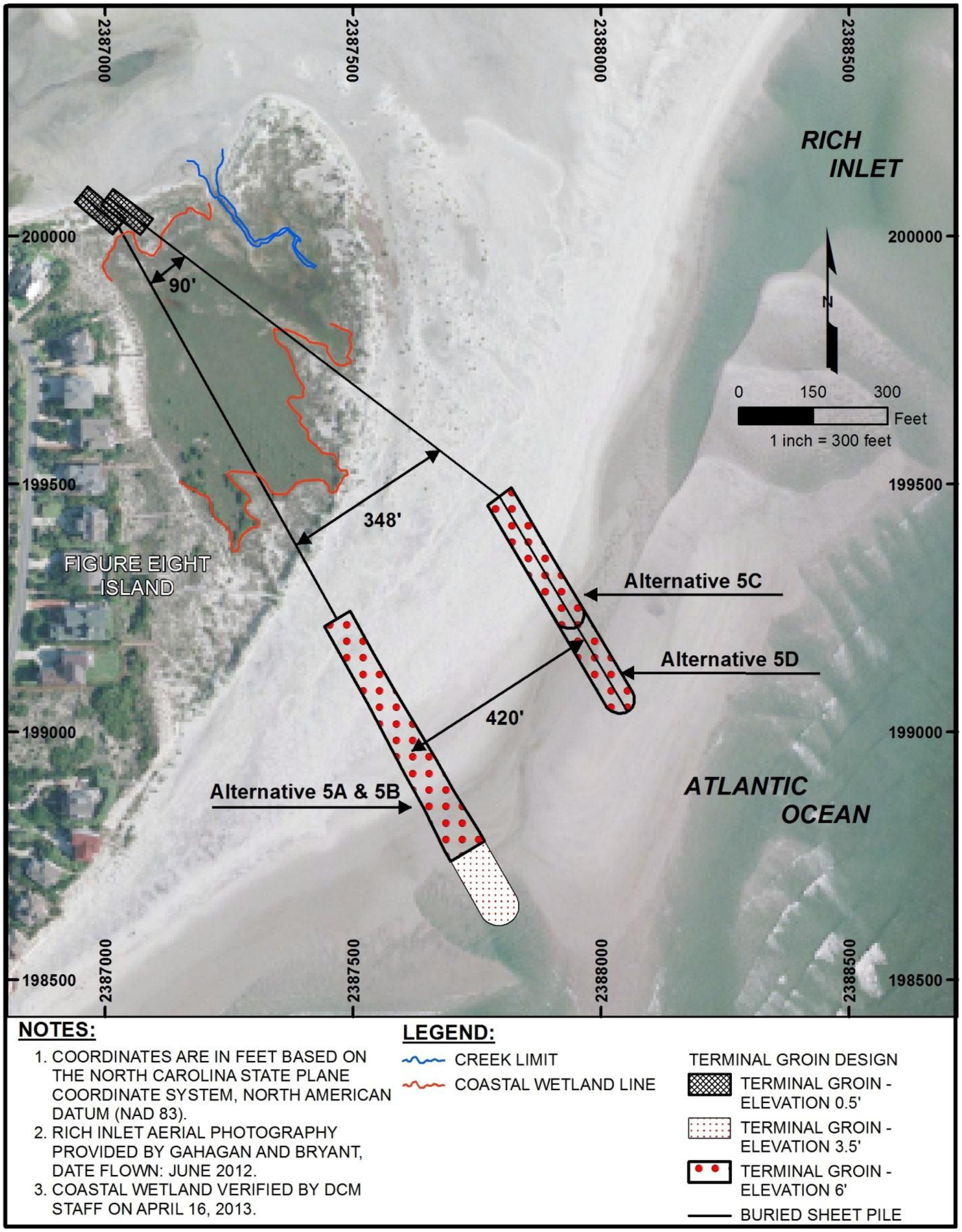

Figure 3.9. Terminal groin layout for all four (4) terminal groin alternatives on the north end of the island.

Alternative 5B has a much smaller beach fill on the ocean side that would extend from the terminal groin south to station 60+00 (located near 322 Beach Road North). A beach fill of the same design as Alternative 5A would also be provided along the Nixon Channel shoreline. Material to construct both beach fills would be obtained from maintenance of the previously permitted area in Nixon Channel (Figure 3.1).

In addition to Alternatives 5A and 5B presented in the DEIS, the initial screening process evaluated two (2) terminal groin lengths (1,600 feet and 2,100 feet), multiple channel sizes associated with Alternative 5A, and the effectiveness of orienting the terminal groin along an alignment rotated 10, 20, and 30 degrees toward Figure Eight Island. A discussion of these preliminary terminal groin screening options is provided in Appendix B with model results shown in Sub-Appendix B.

After the release of the Draft EIS, the Figure "8" Beach HOA determined the need to consider a more northerly terminal groin location (approximately 420 feet north of 5A and 5B) and opted to evaluate two (2) additional terminal groin options designated as Alternatives 5C and 5D as shown in Figure 3.9. Their decision was based upon the potential complications in obtaining all the necessary easements for constructing 5A and 5B, as some of the property owners on the extreme north end of the island were concerned about the position and alignment of Alternatives 5A and 5B. This prompted the Figure "8" Beach HOA to agree to reconsider a new northerly location for the structure, which initiated new Delft3D simulations for the terminal groin structures.

For Alternatives 5C and 5D, the total length of the terminal groin is 1,300 feet and 1,500 feet, respectively. Alternative 5C had a similar beach fill design as Alternative 5A (described below) with the beach fill being constructed using material derived from excavation of the previously permitted area in Nixon Channel and a new channel connecting Nixon Channel to the gorge of Rich Inlet. The excavation in Nixon Channel and the new channel connector would be the same as Alternative 5A. The beach fill along the ocean shoreline for Alternative 5D was similar to Alternative 5B with material for the fill to be obtained from maintenance of the previously permitted area in Nixon Channel.

A description of features of each of the terminal groin options (5A, 5B, 5C, and 5D) and a discussion of the model results for each follows.

Structural Design of Terminal Groins.

The following description of the structural design of the terminal groins is applicable to all terminal groin alternatives and is based on preliminary design considerations and the latest survey information. These considerations are subject to change during the preparation of detailed plans and specifications. The primary differences in the terminal groin designs between the various alternatives are the lengths of the shore anchorage and rubblemound sections as well as the position and alignment of the structures not with the type of material that would be used for their construction or the construction methodology.

The shore anchorage portion of the terminal groins would be constructed with sheet pile, either steel or concrete, and would have a top elevation of just below the elevation of the existing ground. The shore anchorage section would begin near the Nixon Channel shoreline and extend seaward to approximately the location of the 2007 mean high water shoreline (Figure 3.10). In general, the top elevation of the sheet pile will vary from +0.5 feet NAVD for the first 200 feet on the landward end to +1.5 ft NAVD over the remaining portion of the shore anchorage section. The top of the sheet pile over most of the shore anchorage section will be more than 0.5 ft below the existing ground level. This will facilitate continuing hydrologic exchange during all phases of the tidal cycle. Based on the April 2014 survey shown in Figure 3.10, the only portion of the shore anchorage section that would have a top elevation near the existing ground would be an 80-foot section located between 220 and 300 feet from the baseline measured along the centerline of the terminal groin.

The sheet pile section will begin near the Nixon Channel shoreline and end near the position of the 2007 mean high water line. To account for possible scour around the landward end of the shore anchorage section, a 10-foot wide rubble scour protection apron would be installed along both sides of the landward most 100 feet of the anchorage section. The toe apron would be installed at a depth of approximately -2 ft NAVD and would require the excavation of approximately 300 cy. Material excavated for the toe apron would be used to bury the toe protection stone following placement.

The total square feet of sheet pile will vary depending on the length of the shore anchorage section. The present preliminary design for the sheet pile would penetrate to a depth of -21 feet NAVD. Detailed design considerations would include soil borings along the alignment of the proposed structure to obtain soil characteristics as well as assumptions with regard to possible future positions of the south shoulder of Rich Inlet relative to the sheet piles. The assumed position of the south shoulder of the inlet would dictate soil and water loadings on the piles and hence dictate how deep the piles would need to be driven for stability.

The portion of the terminal groins extending seaward of the 2007 mean high water shoreline would be constructed with loose armor stone placed on top of a foundation mat or mattress. The top elevation of the rubblemound structure would not exceed +6.0 feet NAVD which is an elevation roughly equivalent to the elevation of the natural beach berm near Rich Inlet. Again, the final design of the rubblemound portion of the structure is subject to change given conditions near the time of actual construction.

The loose nature of the armor stone would be designed to facilitate the movement of littoral material through the structure. A typical profile of the terminal groin is shown on Figure 3.10. Figure 3.10 also shows the ground elevation along the centerline of the structure surveyed in April 2014 and the April 2007 profile taken at station 105+00 which was used as the basis of the terminal groin design. A typical cross-section of the rubblemound portion is shown in Figure 3.11.

As shown on Figure 3.11, the rubblemound section of the structure would include a 25-foot wide scour protection apron along the inlet side to protect the structure against undermining should the channel through Rich Inlet migrate next to the structure. Construction of the seaward portion of the terminal groin would require excavation of a trench approximately 75 to 80 feet wide at a depth of -5.5 ft NAVD. The excavated material would be returned to the trench, partially burying the structure, once construction is complete.

The concept design for the terminal groin presented here is intended to allow littoral sand transport to move over, around, and through the structure once the accretion fillet south of the terminal groin is artificially filled. This would be accomplished by setting the maximum crest elevation of the terminal groin to +6 feet NAVD, which is an elevation equal to approximately the natural berm elevation, and constructing the structure with large voids between adjacent stones. The relatively short length of the terminal groins seaward of the 2007 mean high water shoreline would also facilitate movement of sediment around the seaward end of the structures. The seaward 200 feet to 250 feet of the structure should be visible at all stages of the tide from both sides of the structure, however, the remaining portions of the structure would be buried below ground and would not be visible from the south side. While the north side of the rubblemound section may project a foot or two above ground, during normal weather conditions, wind-blown sand is expected to accumulate along the north side of the structure partially burying the exposed section.

Navigation aids to mark the location of the terminal groin, particularly its seaward end, will conform with the requirements of the US Coast Guard.

The shore anchorage section would be completely below ground and would not be visible. The only time the shore anchorage section could be visible would be in the unlikely event the entire north end of the island is eroded back to the position of the sheet piles.

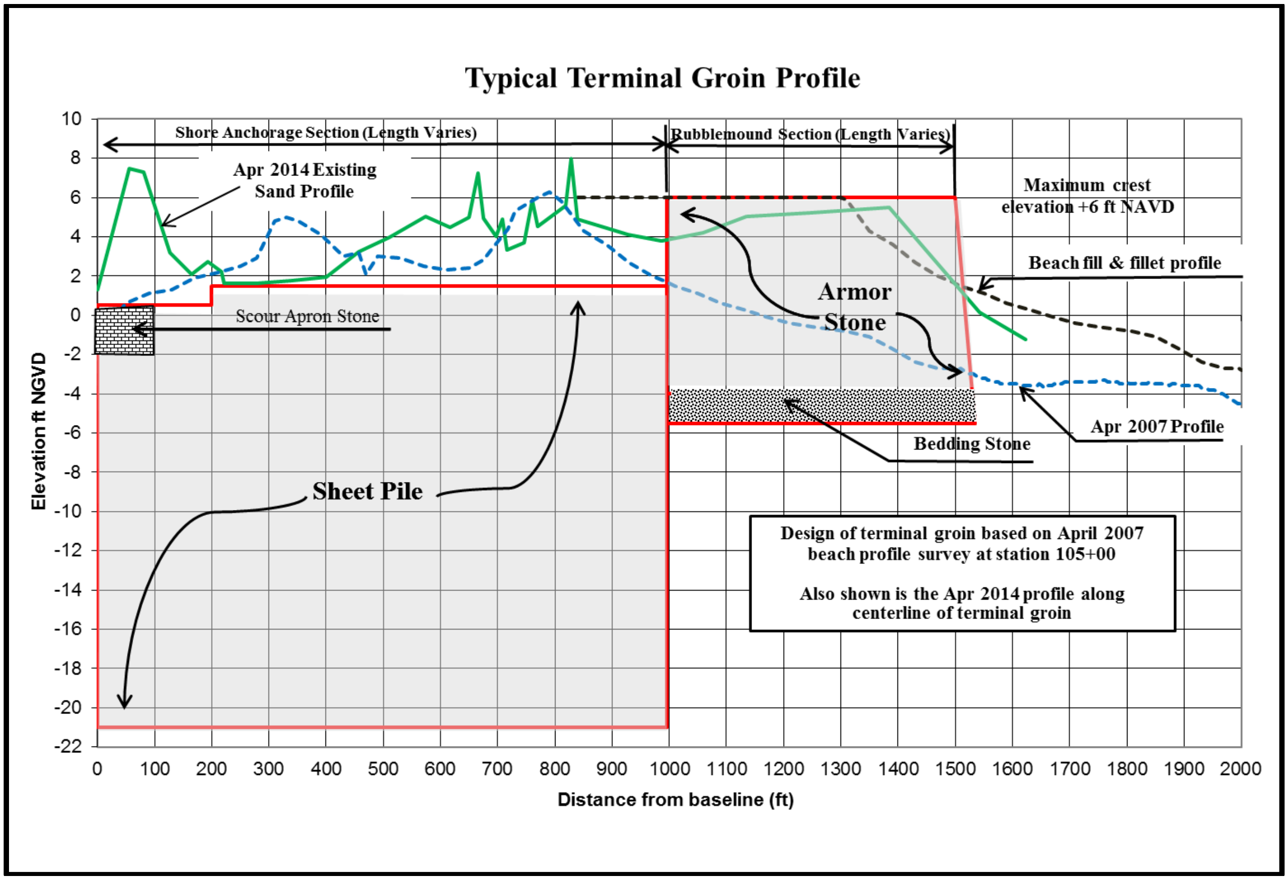

Figure 3.10. Typical Profile of terminal groins.

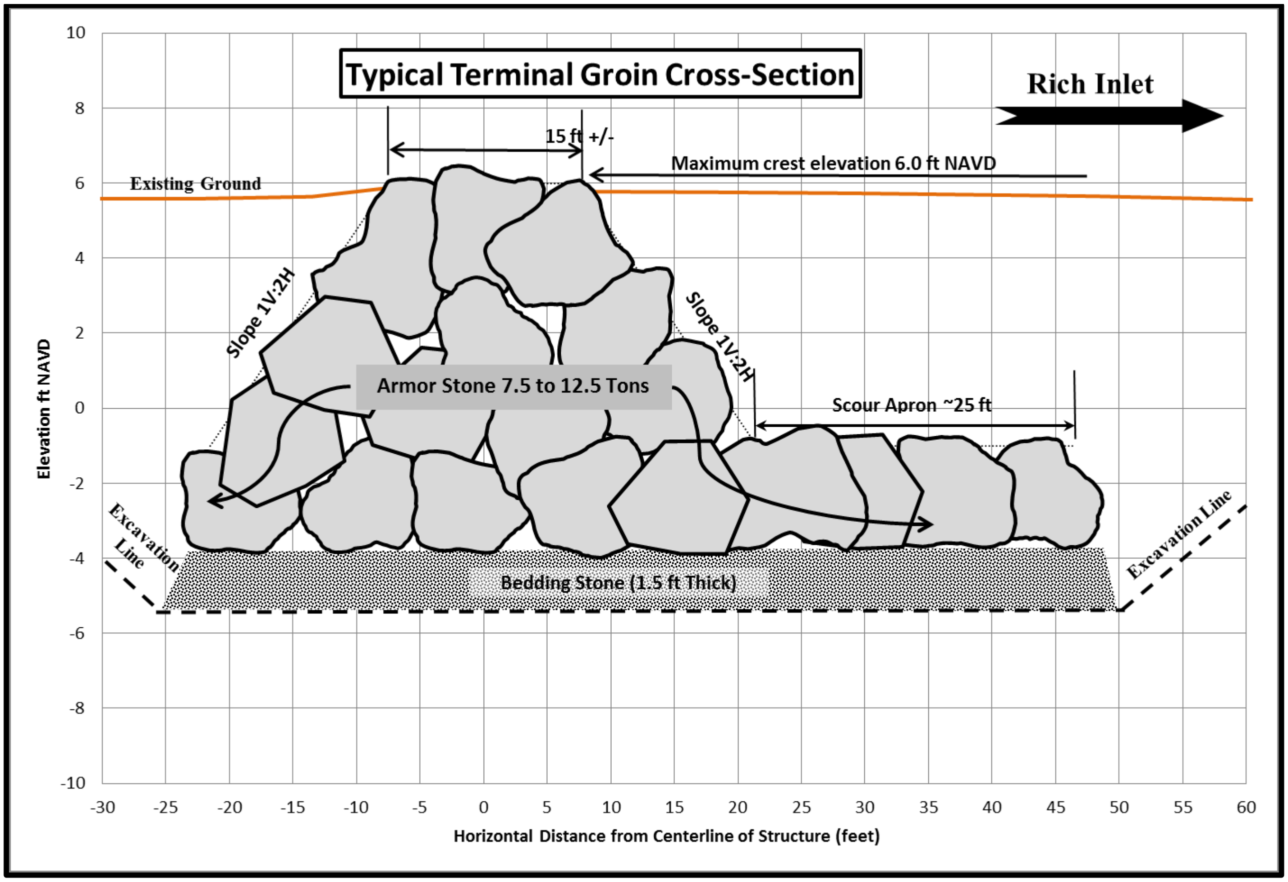

Figure 3.11. Typical terminal groin cross-section.

Terminal Groin Construction Methodology. The exact method used to construct the terminal groin would be left to the discretion of the construction contractor; however, the contractor would have to abide by defined construction corridors, shown in Figure 3.12, approved access locations, staging areas, permitted construction timeframes, and other restrictions that would limit adverse environmental impacts directly associated with the construction activity as defined below.

The stone required to construct the terminal groin would be transported via rail from commercial quarries to Wilmington Harbor where it would be offloaded onto barges and transported to the north end of Figure Eight Island via the Cape Fear River, Snows Cut, the AIWW, and Nixon Channel. A temporary offloading pier, a possible location of which is shown in Figure 3.12, could be constructed from the shoreline near the landward end of the terminal groin and extend northwestward into deep water in Nixon Channel. Note that during the time of actual construction, the contractor may be able to maneuver the stone barges close enough to shore to offload the stone directly to the shore without having to construct the temporary pier. The stone would be offloaded directly from the barges onto trucks which would transport the stone to the terminal groin site. Should the use of Beach Road North be permissible to transport stone to the terminal groin site, this option may be utilized by the contractor as well.

The sheet pile for the landward portion of the terminal groin would be transported directly to the site by truck from where it would be offloaded and driven into place with typical pile driving equipment.

A construction corridor of 100 ft on both sides of the terminal groin centerline would be established in all areas except portions of the shore anchorage section where the width of the corridor would be reduced to 50 ft and would only encompass the southeastern side of the centerline of the structure (Figure 3.12). This narrower construction corridor would apply to about 300 feet of the shore anchorage section that passes through the salt marsh on the north end of Figure Eight Island. A 75 to 80-ft wide trench would be excavated down to a depth of -5.5 ft NAVD along the seaward portion of the construction corridor to accommodate the rubblemound section of the terminal groin. Backhoes or large cranes would be used to excavate the trench. Excavation of the trench would involve the temporary removal of 8,000 cy. The excavated material would be temporarily stockpiled next to the trench within the construction corridor. The excavated material will be replaced around and on top of the terminal groin during the final construction stages.

A 1.5-foot thick foundation blanket consisting of stones ranging in size from 4 inches to 12 inches would be spread over the bottom of the trench. The foundation blanket could be replaced by a stoned-filled articulated mattress once the construction moves into open waters. This would be followed by the placement of armor stone directly on top of the foundation blanket in the form of a trapezoidal mound with side slopes of 1V:2H. The size of the armor stone used for the rubblemound portion of the structure would range from 7.5 tons to 12.5 tons.

For the section of the groin that would be constructed on dry land, trucks would carry the stone to the crane over land while staying within the construction corridor. Once the groin projects into the water, the stones would be delivered to the crane by the trucks traveling down the top of the groin or, if conditions allowed, delivery of the stones via barge may be possible. As another option, the construction contractor could elect to construct a temporary pier adjacent to the terminal groin and place the stone directly from the trucks.

The construction corridor would be restored to pre-construction conditions as much as possible by grading any disturbed land and replanting with native vegetation.

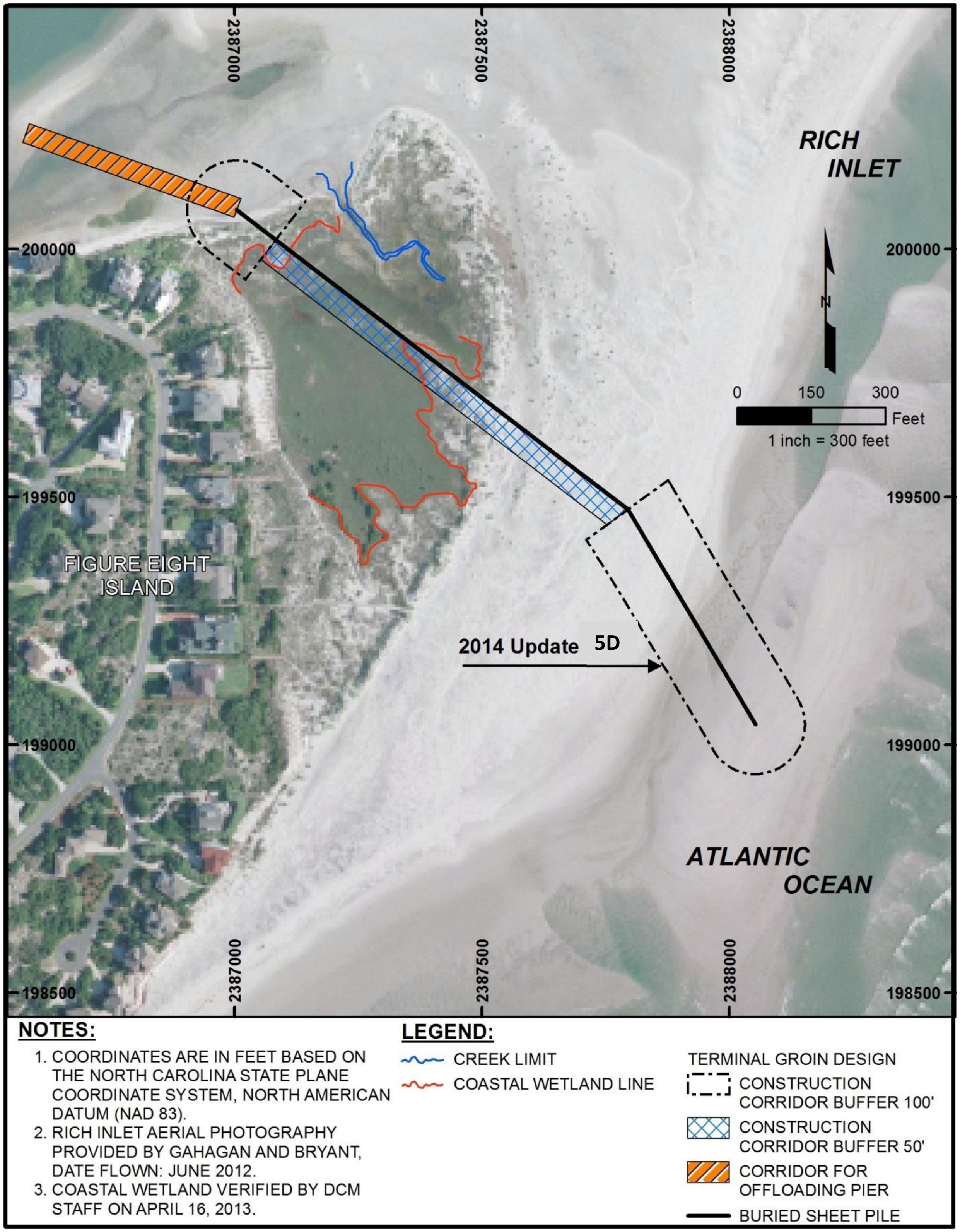

Figure 3.12. Footprint of the terminal groin, construction corridor, and offloading pier for Alternative 5D.

Alternative 5A: Terminal Groin with Beach Fill from Nixon Channel and a New Connector Channel

A 1,600-foot long terminal groin would be constructed at the extreme north end of Figure Eight Island to control both wave and tidal current induced shoreline changes immediately south of Rich Inlet (Figure 3.13a). The terminal groin would include a 900-foot shore anchorage section constructed with either steel or concrete sheet pile. The landward 100 feet of the shore anchorage section would include a 10-foot wide stone scour protection mat on both sides of the sheet pile. The purpose of the shore anchorage section is to protect against possible flanking of the landward end of the structure. In this regard, flanking is defined as erosion around the landward end of a structure which ultimately exposes the normally “dry” side of the structure to the water. The seaward portion of the structure would extend 700 feet seaward of the 2007 mean high water shoreline and would be constructed with loosely placed stone to facilitate the movement of sand through the structure.

Alternative 5A includes the construction of a new channel that would connect the previously permitted area within Nixon Channel with the inlet gorge (Figure 3.13a). The purpose of the new channel connector is to concentrate ebb flows away from the eroding portion of the Nixon Channel shoreline. Preliminary Delft3D model runs and engineering analysis were conducted to determine the optimal dredge options within Nixon Channel and the connector channel. All of the preliminary model runs were based on 2006 conditions; however, initial dredge quantities were computed using both the 2006 and 2012 survey data. These dredging options included:

- Option 1 – 660-740 foot wide connecting cut.
- Option 2 – 600 foot wide connecting cut.
- Option 3 – 395-416 foot wide connecting cut.

Engineering analysis determined that dredging Option 2 would provide the desired level of flow control by keeping concentrated flows away from the Nixon Channel shoreline. In addition, the model results found Option 2 would be conducive to navigation by maintaining a depth of at least -10 feet NAVD at the seaward end of Nixon Channel over the 5-year simulation period. Construction of the new channel connector and reestablishing the permitted dimensions in Nixon Channel would involve the total excavation of 994,400 cy based on the April 2006 survey condition and 1,077,100 cy based on the 2012 survey. Based on the 2006 survey, 319,600 cy would come from the existing Nixon Channel permit area and the remaining 675,300 cy excavated to construct the new channel connector. For the 2012 survey condition, 375,200 cy would come from the existing Nixon Channel permit area and the remaining 701,900 cy excavated to construct the new channel connector.

An estimated 29,700 cy of the channel material is clay and would be deposited in an upland disposal site. This would leave 964,700 cy of sandy or beach quality material based on the 2006 survey conditions and 1,047,400 cy or beach quality material based on the 2012 survey. For both the 2006 and 2012 conditions, the beach fill along the Nixon Channel shoreline would require 57,000 cy leaving 907,700 cy for the ocean shoreline based on the 2006 conditions and 990,400 cy based on the 2012 conditions.

The material removed to construct the new channel connector into Nixon Channel and reestablish the dimensions of the previously permitted area within Nixon Channel would be used to construct a beach fill in the same two areas as Alternatives 3 and 4, i.e., one fronting Nixon Channel and a second covering the ocean shoreline from Beachbay Lane (F90+00) to the terminal groin located at station 100+00. Dune fill would also be included in the area from stations 77+50 to 95+00. Excavation of the material from the Nixon Channel and construction of the new connector into Nixon Channel could be accomplished by a 20-inch or smaller cutter-suction pipeline dredge.

The beach fill design along the ocean shoreline for Alternative 5A was based on the optimal distribution of the 964,700 cy and 1,047,400 cy of beach quality material that would be removed based on the 2006 and 2012 surveys, respectively, to construct the new channel connector and maintain the previously permitted area within Nixon Channel. The volume of fill material placed along the 1,400-foot shoreline along Nixon Channel would be 57,000 cy which is the same as Alternatives 3 and 4 and will be tapered to terminate prior to the tidal creek which drains the marsh area on the north end of the island. The volume of fill needed for Nixon Channel was the same for both the 2006 and 2012 conditions. The distribution of balance of the material along the ocean shoreline would concentrate more of the fill in the area immediately south of the terminal groin in the area generally referred to as an accretion fillet. Also, no fill would be placed north of the terminal groin. The design berm widths and beach fill placement densities along the ocean shoreline for the 2006 and 2012 conditions are provided in Tables 3.7a and 3.7b, respectively.

An artificial dune similar to Alternatives 3 and 4 would be provided in the existing sandbag area between stations 77+50 and 95+00. If required by permit conditions, the sandbags could be removed upon completion of the beach fill by manually tearing the fabric and utilizing heavy machinery to extract the bag leaving the sand in place.

The plan layout for Alternative 5A, which is applicable for both the 2006 and 2012 conditions, is shown in Figures 3.13a-d.

Table 3.7a Alternative 5A beach fill design (based on 2006 condition).

Shoreline Segment (Baseline Stations)	Design Berm Width (ft)	Fill Volumes (cy/lf)		
		Berm	Dune	Total
Terminal groin (100+00) to 95+00	91	106	0	106
95+00 to 75+00	91	106	21 to 23	127 to 129
75+00 to 50+00	74	106	0	106
50+00 to 40+00 (transition)	74 to 28	106 to 40	0	106 to 40
40+00 to F100+00	28	40	0	40
F100+00 to F90+00 (transition)	28 to 0	40 to 0	0	40 to 0

Table 3.7b Alternative 5A beach fill design (based on 2012 condition).

Shoreline Segment (Baseline Stations)	Design Berm Width (ft)	Fill Volumes (cy/lf)		
		Berm	Dune	Total
Terminal groin (100+00) to 95+00	99	115	0	115
95+00 to 75+00	99	115	21 to 23	136 to 138
75+00 to 50+00	99	115	0	115
50+00 to 40+00 (transition)	99 to 37	115 to 43	0	115 to 43
40+00 to F100+00	37	43	0	43
F100+00 to F90+00 (transition)	37 to 0	43 to 0	0	43 to 0

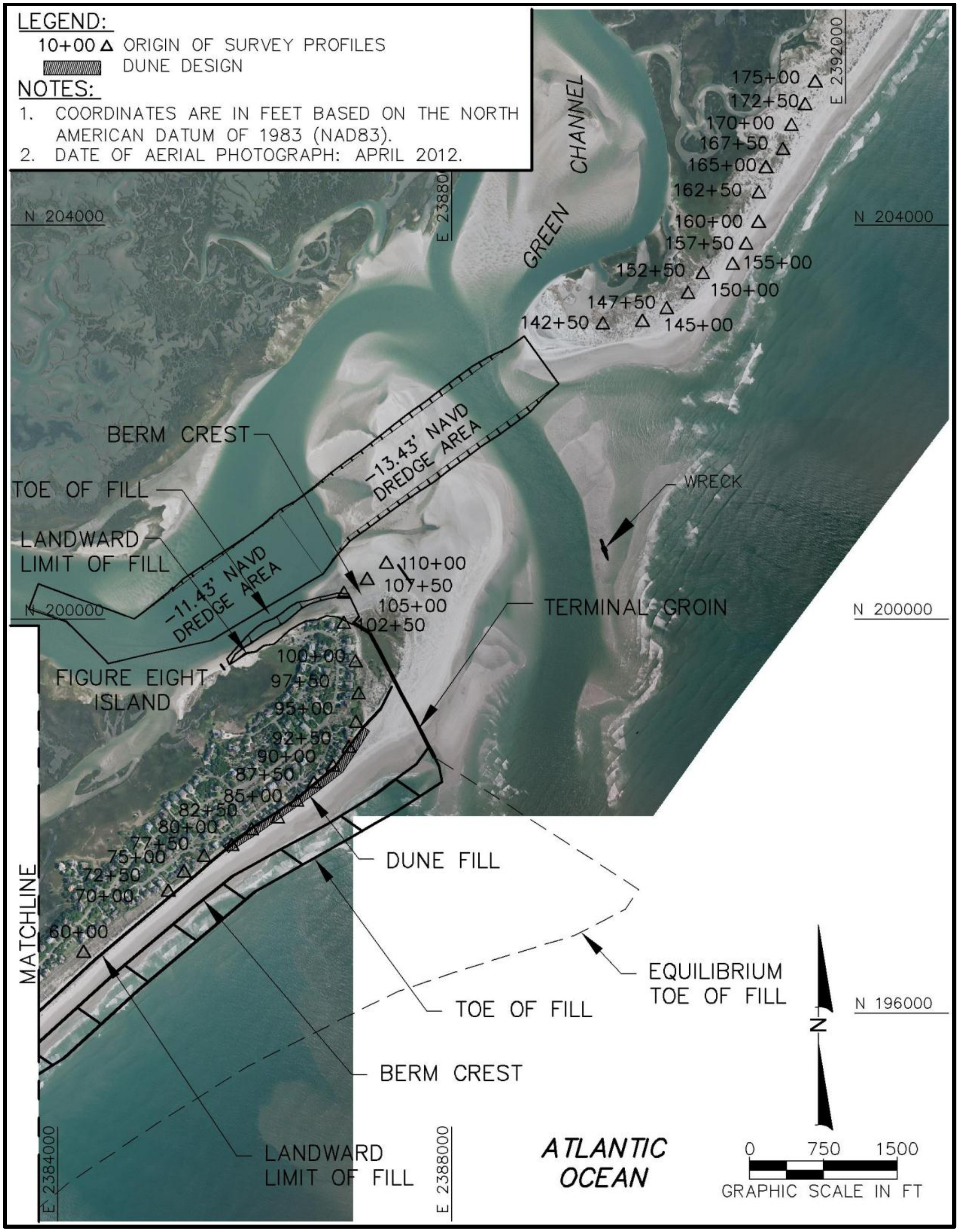

Figure 3.13a. Plan view of northern portion of Alternative 5A; 2012 shoreline conditions.

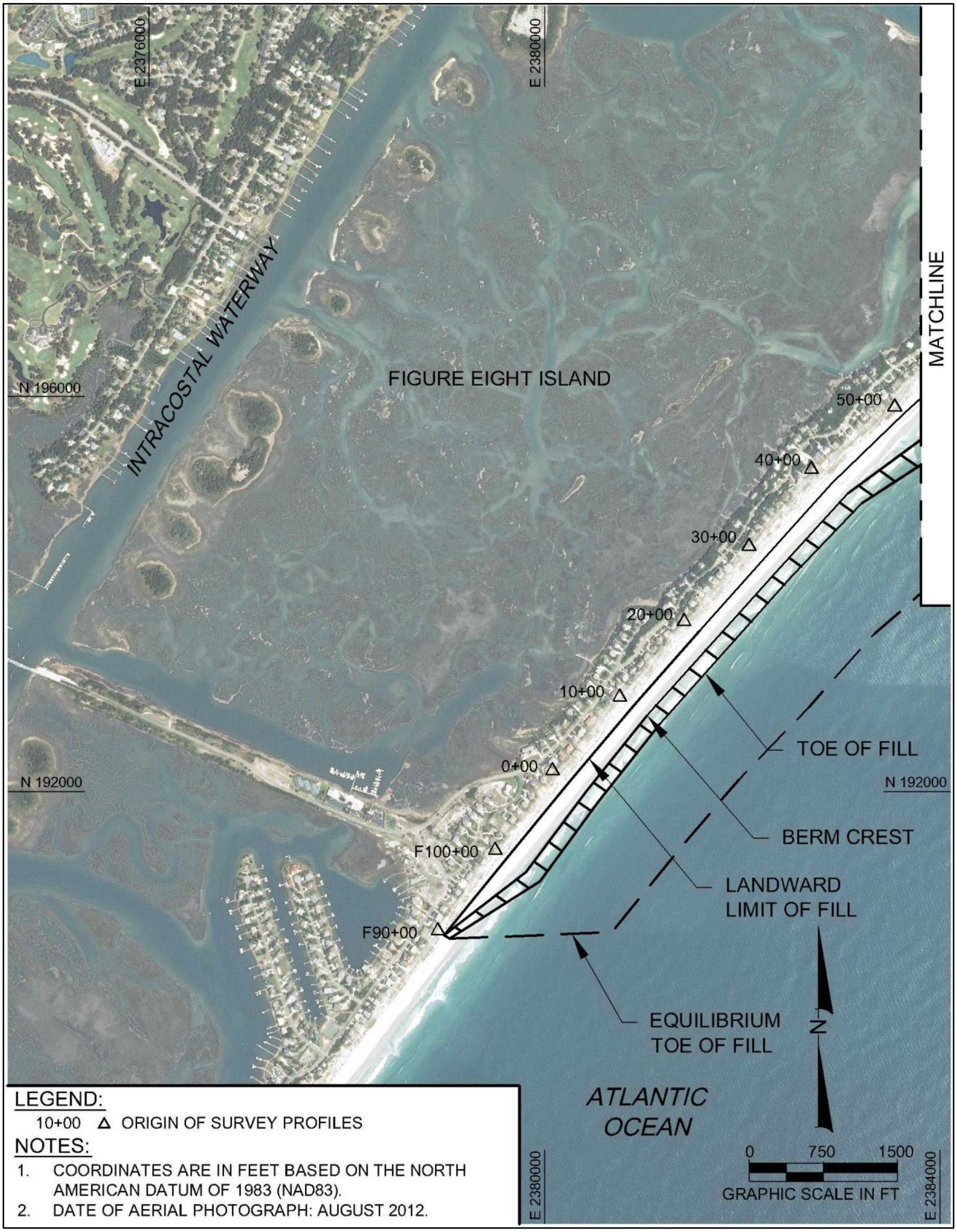

Figure 3.13b. Plan view of southern portion of Alternative 5A; 2012 shoreline conditions.

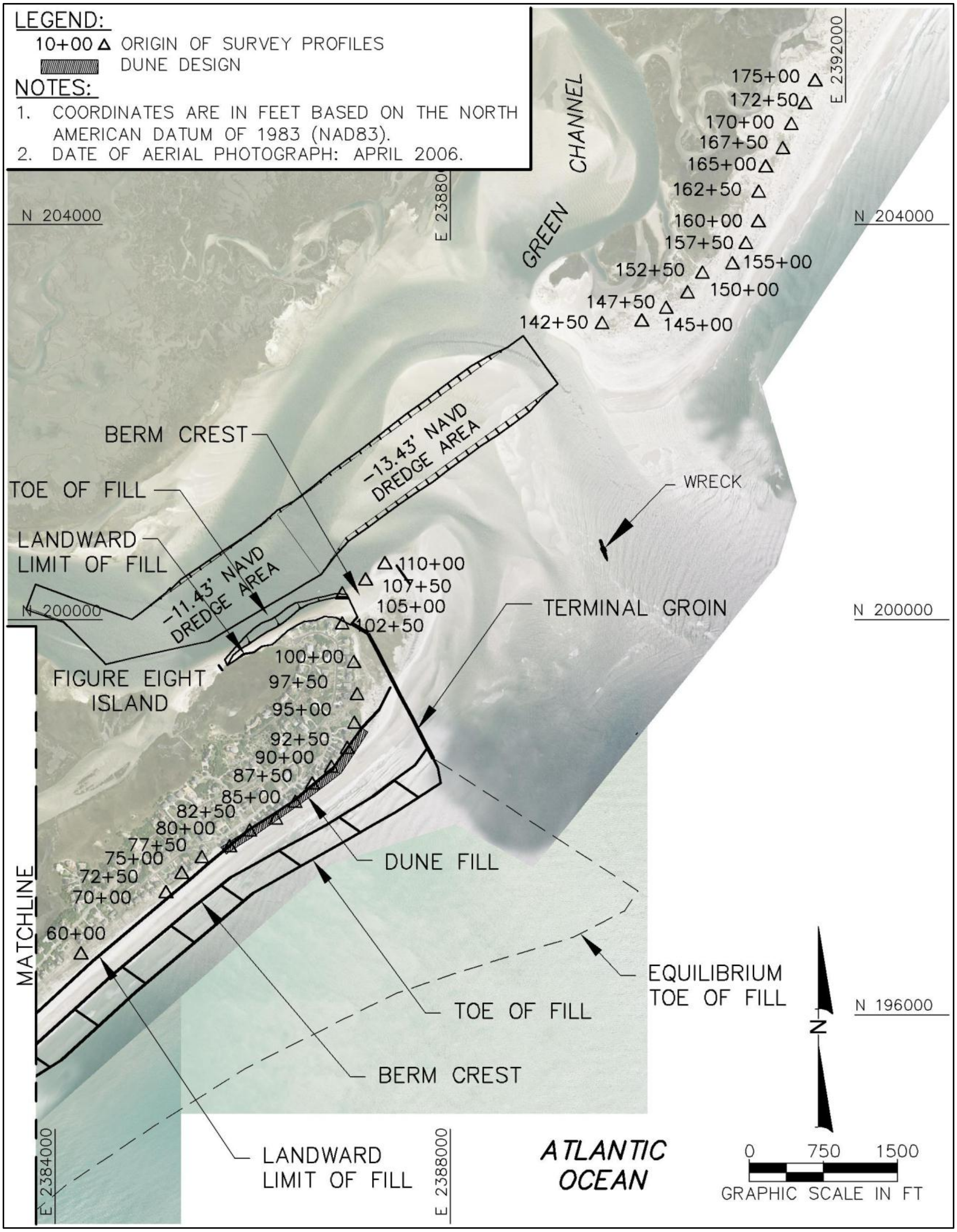

Figure 3.13c. Plan view of northern portion of Alternative 5A; 2006 shoreline conditions.

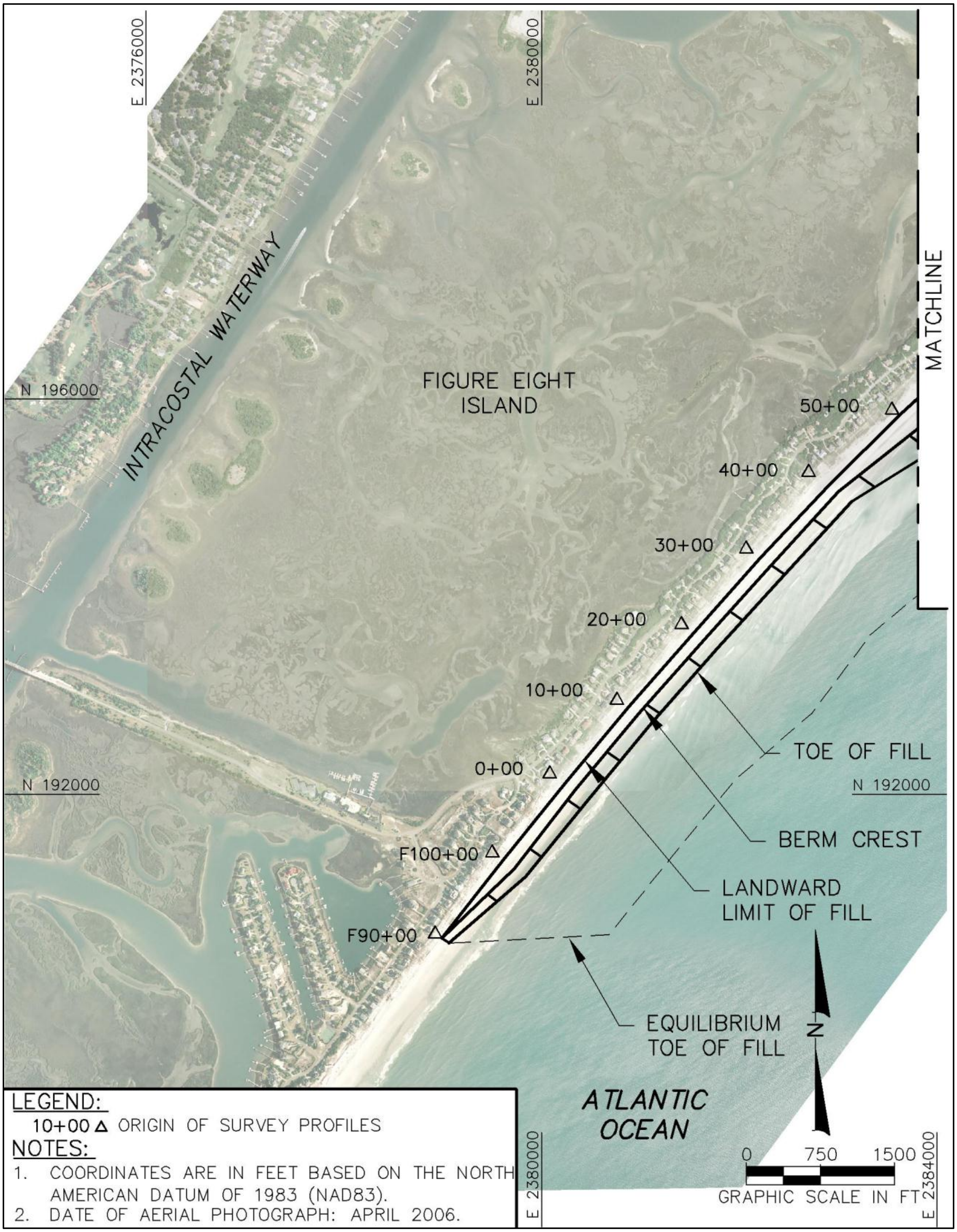

Figure 3.13d. Plan view of southern portion of Alternative 5A; 2006 shoreline conditions.

Channel Maintenance Requirements.

Based on the results of the Delft3D model simulation for Alternative 5A, the rate of shoaling of the previously permitted area was fairly steady during the five-year simulation while the proposed channel connector experienced rapid shoaling over the first two years. Shoaling of the proposed connector moderated between years 3 and 4 of the simulation with the model predicting some possible scour during the last year of the simulation. Based on the model results using the 2006 conditions, the 5-year channel maintenance requirement would be 487,000 cy. While Alternative 5A was not simulated using the 2012 conditions, maintenance of the channel in Nixon Channel would be comparable to that indicated by the model for the 2006 conditions.

Periodic Nourishment – Alternative 5A.

The beach area between stations F90+00 and 30+00 accreted during the 5-year simulation and would not require periodic nourishment. Using the 2006 conditions only, the computed volume losses from the fill between stations 30+00 and 100+00 averaged 85,000 cy/year over the 5-year simulation period. Assuming periodic maintenance of the previously permitted area in Nixon Channel and the proposed connecting channel is accomplished every five years, the nourishment requirement for the ocean shoreline would be 425,000 cy. Nourishment of the Nixon Channel fill area would also require 30,000 cy as with the other alternatives bringing the total five year nourishment requirement to 455,000 cy.

Material for periodic nourishment of Alternative 5A would be derived from maintenance of the previously permitted area in Nixon Channel and the new channel connecting Nixon Channel to the inlet gorge. The maintenance dredging would be performed by an 18-inch or smaller cutter-suction pipeline dredge.

The channel maintenance requirement of 487,000 cy every 5 years or 97,400 cy/year is approximately equal to the average annual amount of material removed to maintain the previously permitted area since 1993. As mentioned above, maintenance of the previously permitted area removed about 1.75 million cy between 1993 and 2011 which is equivalent to an annual rate of about 97,000 cy/year. Therefore, based on both actual experience and model predictions, maintenance of the previously permitted area in Nixon Channel and the new connector channel should be sufficient to satisfy periodic beach nourishment requirements for Alternative 5A.

Implementation Cost. The costs for implementing Alternative 5A are summarized below. Detailed cost estimates for Alternative 5A, as well as cost estimates for the other alternatives discussed in this Chapter, are provided in Appendix B and Appendix G.

Construction costs for Alternative 5A would include the cost of constructing the new channel from the inlet gorge into Nixon Channel with the disposal of that material along 1,400 feet of the Nixon Channel shoreline and along the ocean shoreline north of Bridge Road plus the cost of constructing the terminal groin. Construction of the new channel would involve the removal of 1,077,100 cy given the 2012 conditions and 994,400 for the 2006 conditions. As presented above, the terminal groin would be constructed with both sheet pile and rubblemound.

The initial construction cost of the terminal groin is estimated to be $4,836,000 which includes engineering and design and construction oversight. Maintenance of the terminal groin would depend on the number of times the design conditions for the structure would be exceeded over the 30-year planning period. Since this cannot be predicted with any degree of certainty, maintenance of the structure was based on an assumption that an average of 1% of the armor stone would have to be replaced every year. Given this assumption, maintenance of the Alternative 5A terminal groin would average $25,000 per year. Note this does not mean maintenance of the structure would be needed every year. Over the course of the 30-year evaluation period, maintenance of the structure may only be needed two or three times with the average annual equivalent cost of these future repairs equal to $25,000 per year.

Construction of the beach fills along Nixon Channel and the ocean shoreline and the dredging of Nixon Channel and the new channel to the inlet gorge would cost $8,984,000 based on the 2006 conditions and $9,617,000 based on the 2012 conditions. The total initial construction cost of Alternative 5A would be $13,820,000 for the 2006 conditions and $14,453,000 for the 2012 conditions.

Excavation of the material from Nixon Channel and the new channel connector would take about 4 months. Ideally, construction of the terminal groin would take place following completion of the beach fill; however, this is not a requirement as the rubblemound section could be installed either before or after initial beach fill placement. However, construction of the terminal groin following beach fill placement could be advantageous in terms of construction cost as most of the terminal groin could be constructed using land-based equipment. Overall, the total construction time for Alternative 5A is expected to take between 6 and 6.5 months.

Periodic nourishment of the beach fills in Nixon Channel and the ocean shoreline using material obtained from maintenance of the existing Nixon Channel permit area would cost $4,856,000 every five years.

The average annual equivalent cost for constructing and maintaining Alternative 5A, which was computed using a 6% discount rate over the 30-year planning period, would be $1,890,000 for the 2006 conditions and 1,936,000 for the 2012 conditions. Over the 30-year planning period, the total implementation cost for Alternative 5A in current dollars would range from $43.68 million for the 2006 condition to $44.31 million for the 2012 condition. See Appendix B and Appendix G for more information regarding cost.

Alternative 5B: Terminal Groin with Beach Fill from Nixon Channel and Other Sources

For Alternative 5B, the terminal groin would have the same design as that described for Alternative 5A as would the beach fill along Nixon Channel. With regard to the beach fill along the ocean shoreline, analysis of the Delft3D model results for Alternative 5A indicated the initial beach fill was excessive, particularly along the segment of the beach south of station 80+00. Also, the segment of the shoreline between stations F90+00 and 30+00 accreted while the area between stations 30+00 and 60+00 experienced very minor losses. Again, the beach fill design associated with Alternative 5A was based on the optimal utilization of the material removed to construct the new channel connector from the inlet gorge into Nixon Channel not on the beach fill volume needed to offset shoreline erosion tendencies. Therefore, the beach fill for Alternative 5B was designed to address erosion protection needs along the northern portion of Figure Eight Island.

The beach fill for Alternative 5B was limited to the area between station 60+00 (approximately 322 Beach Road North) and the terminal groin (station 100+00) since the Delft3D simulation for Alternative 5A indicated the shoreline south of station 60+00 would either be stable or only experience minor volume losses that would not require periodic nourishment on a regular basis. Details of the Delft3D model results for Alternative 5B are provided in Appendix B. The placement rates and design berm widths for the Alternative 5B beach fill are given in Table 3.8 with the plan layout provided in Figures 3.14a and 3.14b. The beach fill design for Alternative 5B would be the same for both the 2006 and 2012 survey conditions. The beach fill for Alternative 5B would not include an artificial dune in the areas presently fronted by sandbags. The total volume of beach fill along the ocean shoreline would be 197,500 cy. The Nixon Channel beach fill would require 57,000 cy bringing the total beach fill volume to 254,500 cy.

The material to construct the beach fill for Alternative 5B would be derived from maintenance of the previously permitted area in Nixon Channel. Based on past maintenance operations in the previously permitted area of Nixon Channel and anticipated shoaling rates indicated by the Delft3D simulations, the volume of material available from the previously permitted area would satisfy the volumetric requirements for Alternative 5B. The beach compatible material contained in the three (3) northern upland disposal areas (discussed under Alternative 4) would serve as contingency sediment sources. These sources would be used in the event shoaling of the previously permitted area in Nixon Channel is not sufficient to satisfy periodic beach nourishment needs and/or if Figure Eight Island needs additional material to respond to storm damage.

Construction of the beach fill could be accomplished with a 16-inch to 18-inch cutter-suction pipeline dredge which are similar to the ones that perform routine maintenance in the AIWW.

Table 3.8. Alternative 5B beach fill placement volumes and design berm widths under both 2006 and 2012 conditions.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
Terminal groin (100+00) to 80+00	80	69
80+00 to 72+50 (transition)	80 to 20	69 to 17
72+50 to 70+00	20	17
70+00 to 60+00 (transition)	20 to 0	17 to 0

<u>Periodic Nourishment – Alternative 5B</u>.

Simulation of Alternative 5B in the Delft3D model indicated the beach fill area (station 60+00 to the terminal groin) would lose an average of 51,000 cy/year over the 5-year simulation period using both 2006 and 2012 survey conditions. As was the case for Alternative 5A, the segment south of stations 60+00 to F90+00 was stable to accretionary with the area actually gaining material at a rate of 50,000 cy/year.

Beginning in year 4 of the simulation and continuing into year 5, erosion began to affect the pre-nourishment profile primarily north of station 80+00. Given these model results under both 2006 and 2012 conditions, periodic nourishment of the beach fill under Alternative 5B would be needed about every 5 years. Based on the model indicated loss rate of 51,000 cy/year, the 5-year periodic nourishment requirement would be 255,000 cy. The beach fill along the Nixon Channel shoreline would again require 30,000 cy every five years resulting in a total 5-year periodic nourishment requirement for both fills of 285,000 cy.

The maintenance dredging would be performed by a 16-inch to 20-inch cutter-suction pipeline dredge, which is the same size dredge that would be used for initial construction of the Alternative 5B beach fill.

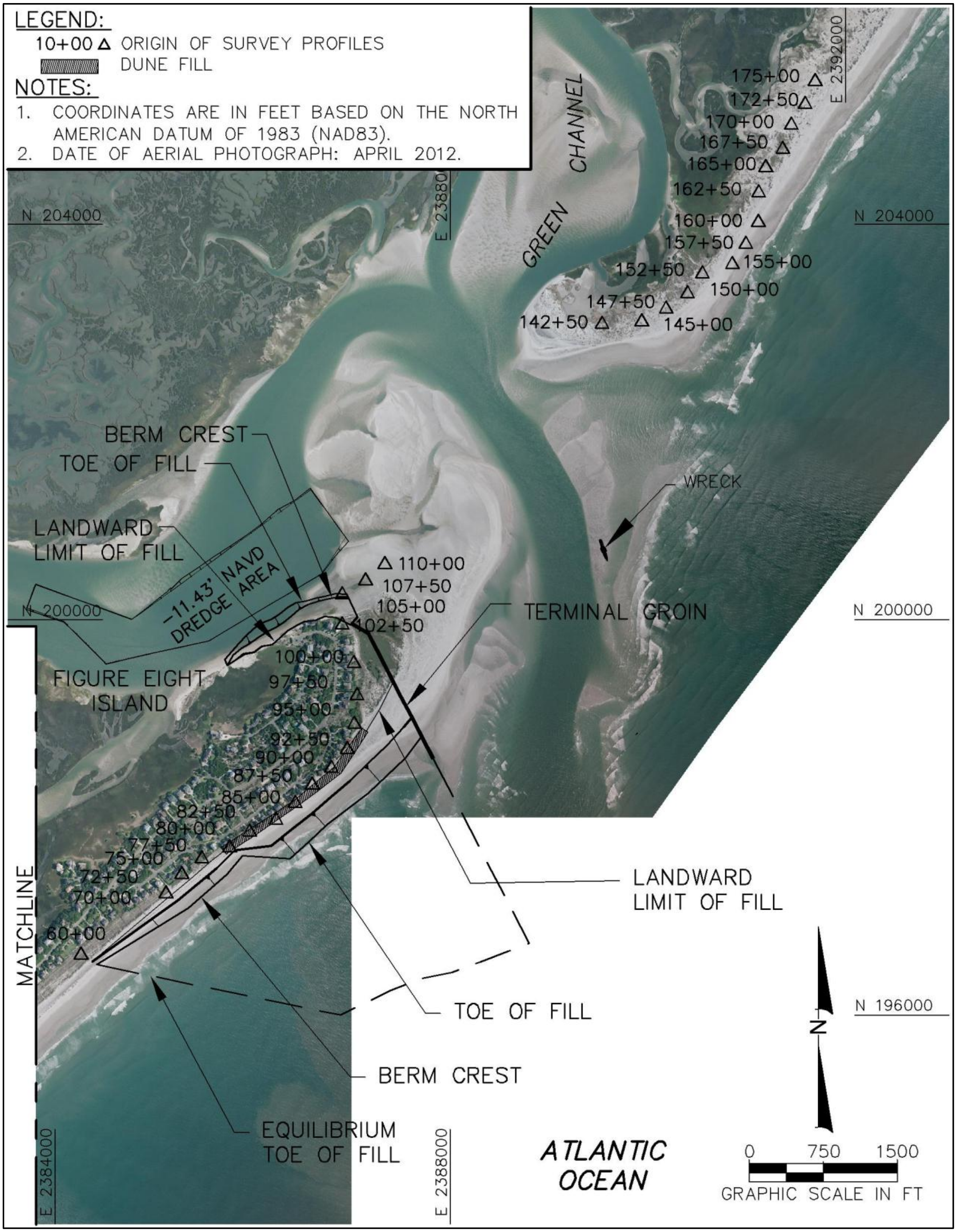

Figure 3.14a. Plan View of Alternative 5B; 2012 shoreline conditions.

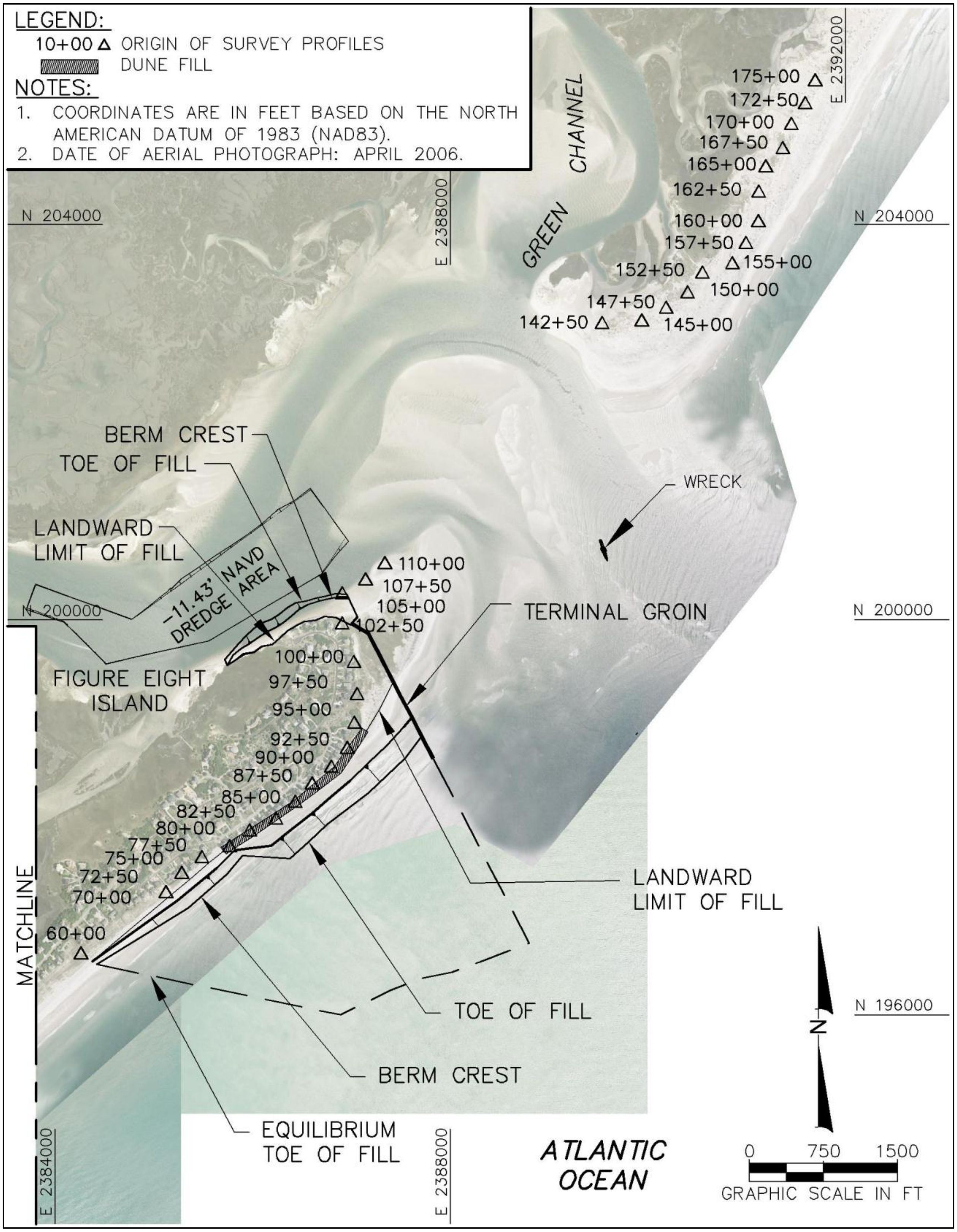

Figure 3.14b. Plan View of Alternative 5B; 2006 shoreline conditions.

<u>Implementation Cost</u>. Initial construction costs for the terminal groin would be $4,836,000 which is the same as Alternative 5A. The initial costs of the beach fills along the Nixon Channel and ocean shoreline using material from the Nixon Channel permit area would be $2,607,000 resulting in a total cost for initial construction (beach fills and terminal groin) of $7,443,000. The costs for Alternative 5B would be the same for both the 2006 and 2012 survey conditions. The construction time of the terminal groin would be the same as Alternative 5A, however, construction of the beach fill would only require about 1.5 months. The total construction time for Alternative 5B could range from 4 to 5 months.

Maintenance of the terminal groin would average $25,000 per year which is the same as Alternative 5A. Maintenance of the previously permitted area in Nixon Channel with disposal of the material along Nixon Channel shoreline and the ocean shoreline would cost $2,764,000 every 5 years. Over the 30-year planning period, the total cost for Alternative 5B in current dollars would be about $24.76 million.

The equivalent average annual cost for Alternative 5B, computed with a discount rate of 6% over an amortization period of 30 years is $1,056,000. See Appendix B and Appendix G for more information regarding cost.

Alternative 5C: Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and a New Connector Channel

Alternative 5C includes a 1,300-foot terminal groin located near baseline station 105+00 or in the more northerly position relative to Alternatives 5A and 5B as shown in Figure 3.9. The terminal groin would include a 995-foot shore anchorage section extending landward of the 2007 mean high water shoreline and a 305-foot section extending seaward of the 2007 mean high water shoreline. The shore anchorage section would be constructed with sheet pile (steel or concrete) while the seaward section would be of rubblemound construction. The landward 100 feet of the shore anchorage section would include a 10-foot wide scour protection mat on both sides of the sheet pile. The beach fill for Alternative 5C would have a similar design as the fill described for Alternative 5A with material to construct the beach fill also being derived from the same source as described under Alternative 5A, i.e., the previously permitted area in Nixon Channel and a new channel connecting Nixon Channel with the gorge of Rich Inlet.

Excavation of the previously permitted area in Nixon Channel and the new channel connecting Nixon Channel with the gorge of Rich Inlet would involve the removal of 994,400 cy based on the 2006 conditions and 1,077,100 cy based on the 2012 condition. An estimated 29,700 cy of the channel material is clay and would be deposited in an upland disposal site. This would leave 964,700 cy of sandy or beach quality material based on the 2006 survey conditions and 1,047,400 cy or beach quality material based on the 2012 survey. For both the 2006 and 2012 conditions, the beach fill along the Nixon Channel shoreline would require 57,000 cy leaving 907,700 cy for the ocean shoreline based on the 2006 conditions and 990,400 cy based on the 2012 conditions.

Given the two possible dredge volumes from Nixon Channel and the new channel connector based on the 2006 and 2012 conditions, two possible beach fill plans were developed with the berms widths and fill distributions for each provided in Table 3.9a for the 2006 condition and

Table 3.9b for the 2012 condition. The plan layout for Alternative 5C is shown in Figures 3.15a-d.

Table 3.9a. Alternative 5C beach fill placement volumes and design berm widths based on 2006 conditions.

Shoreline Segment (Baseline Stations)	Design Berm Width (ft)	Fill Volumes (cy/lf)		
		Berm	Dune	Total
Terminal groin (105 +00) to 95+00	91	106	0	106
95+00 to 75+00	91	106	21 to 23	127 to 129
75+00 to 50+00	91	106	0	106
50+00 to 40+00 (transition)	91 to 34	106 to 40	0	106 to 40
40+00 to F100+00	34	40	0	40
F100+00 to F90+00 (transition)	34 to 0	40 to 0	0	40 to 0

Table 3.9b. Alternative 5C beach fill placement volumes and design berm widths based on 2012 conditions.

Shoreline Segment (Baseline Stations)	Design Berm Width (ft)	Fill Volumes (cy/lf)		
		Berm	Dune	Total
Terminal groin (105 +00) to 95+00	99	115	0	114.9
95+00 to 75+00	99	115	21 to 23	136 to 138
75+00 to 50+00	99	115	0	115
50+00 to 40+00 (transition)	99 to 37	115 to 43	0	115 to 43
40+00 to F100+00	37	43	0	43
F100+00 to F90+00 (transition)	37 to 0	43	0	43 to 0

Periodic Nourishment – Alternative 5C.

The 5-year simulation of Alternative 5C in the Delft3D model, under both 2006 and 2012 conditions, indicated the beach area between stations F90+00 and 30+00 would accrete while the segment between stations 30+00 and 60+00 would only experience minor losses and would not require periodic nourishment. As a result, periodic nourishment for Alternative 5C would be required primarily between stations 60+00 and 105+00. Even though model results indicate the area south of station 60+00 may not need periodic nourishment that area would continue to be monitored and nourishment provided if future conditions warrant. The Delft3D model simulated losses from the section of the shoreline between station 60+00 and the terminal groin (station 105+00) averaged 93,000 cy/year over the 5-year simulation period. Assuming periodic maintenance of the previously permitted area in Nixon Channel and the proposed connecting channel is accomplished every five years, the nourishment requirement for the ocean shoreline would be 465,000 cy. Nourishment of the Nixon Channel fill area would also require 30,000 cy as with the other alternatives bringing the total five year nourishment requirement to 495,000 cy. Details of the Delft3D model results for Alternative 5C are provided in Appendix B.

Material for periodic nourishment of Alternative 5C would be derived from maintenance of the previously permitted area in Nixon Channel and the new channel connecting Nixon Channel to the inlet gorge. The maintenance dredging would be performed by an 18-inch or smaller cutter-suction pipeline dredge.

Based on the Delft3D simulations, shoaling of Nixon Channel and the new channel connector over the 5-year simulation period totaled 487,000 cy, or 97,400 cy/year, whereas the total periodic nourishment requirement for Alternative 5C is estimated to be 495,000 cy every 5 years, or 99,000 cy/year. As mentioned above, maintenance of the previously permitted area in Nixon Channel removed about 1.75 million cy between 1993 and 2011 which is equivalent to an annual rate of about 97,200 cy/year. Even though the shoaling in the Nixon Channel borrow area over 5 years indicated by the Delft3D model is 8,000 cubic yards less than the periodic nourishment needed for both the ocean shoreline and the Nixon Channel, past operations did not include the new connector channel. Therefore, a reasonable assumption is that maintenance dredging in Nixon Channel and the new channel connector would be sufficient to satisfy periodic beach nourishment requirements for Alternative 5C.

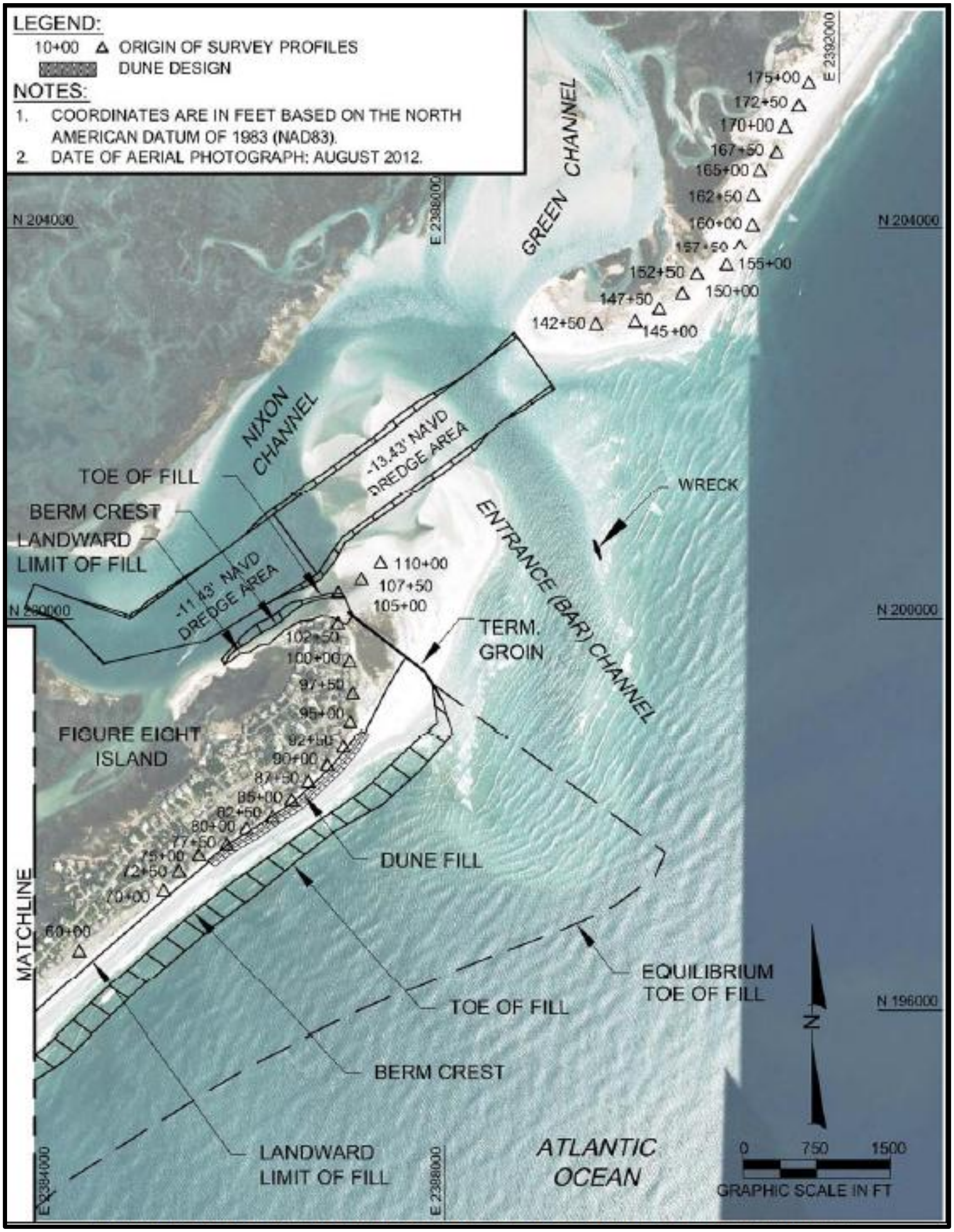

Figure 3.15a. Plan View of the northern portion of Alternative 5C; 2012 shoreline conditions.

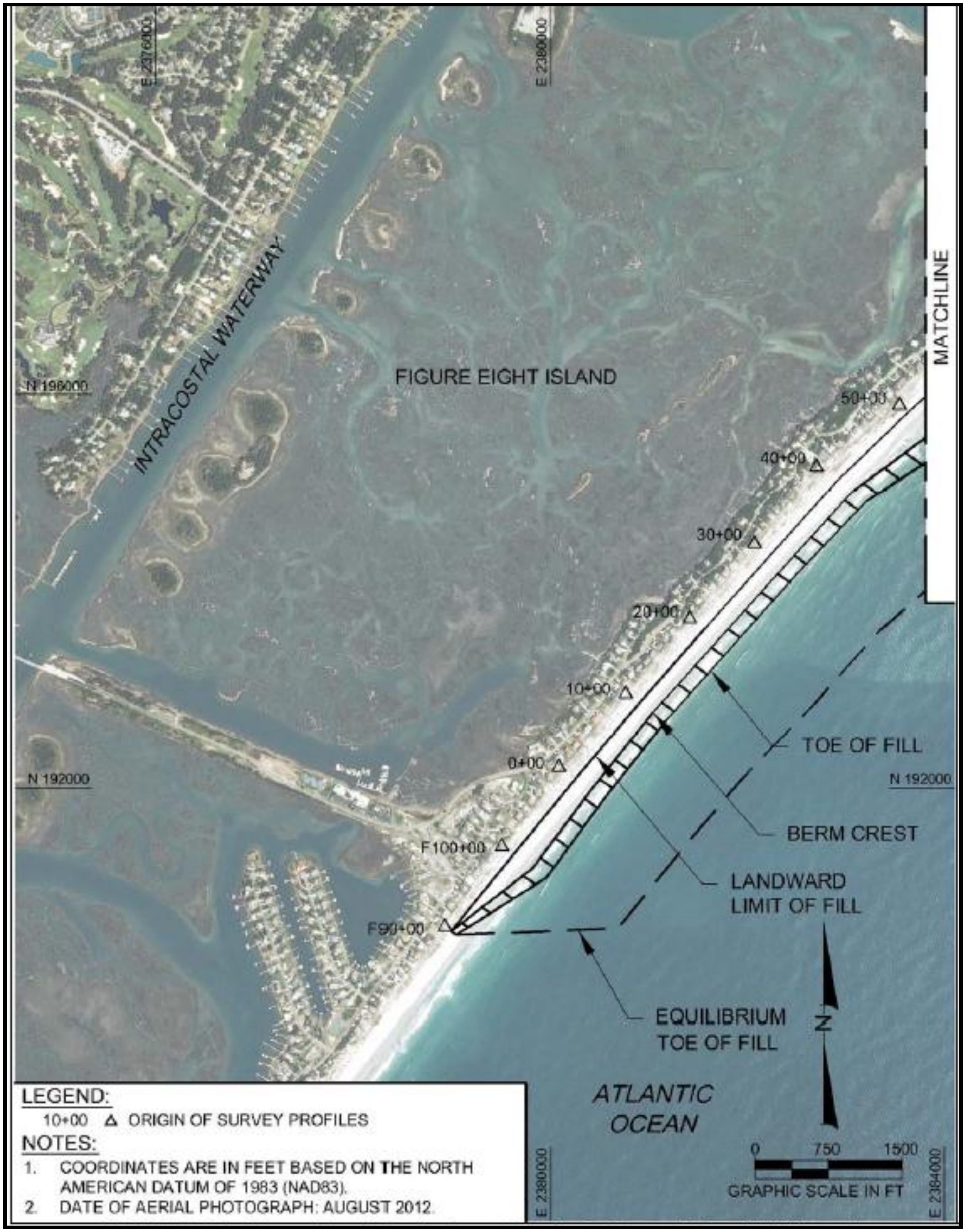

Figure 3.15b. Plan View of the southern portion of Alternative 5C; 2012 shoreline conditions.

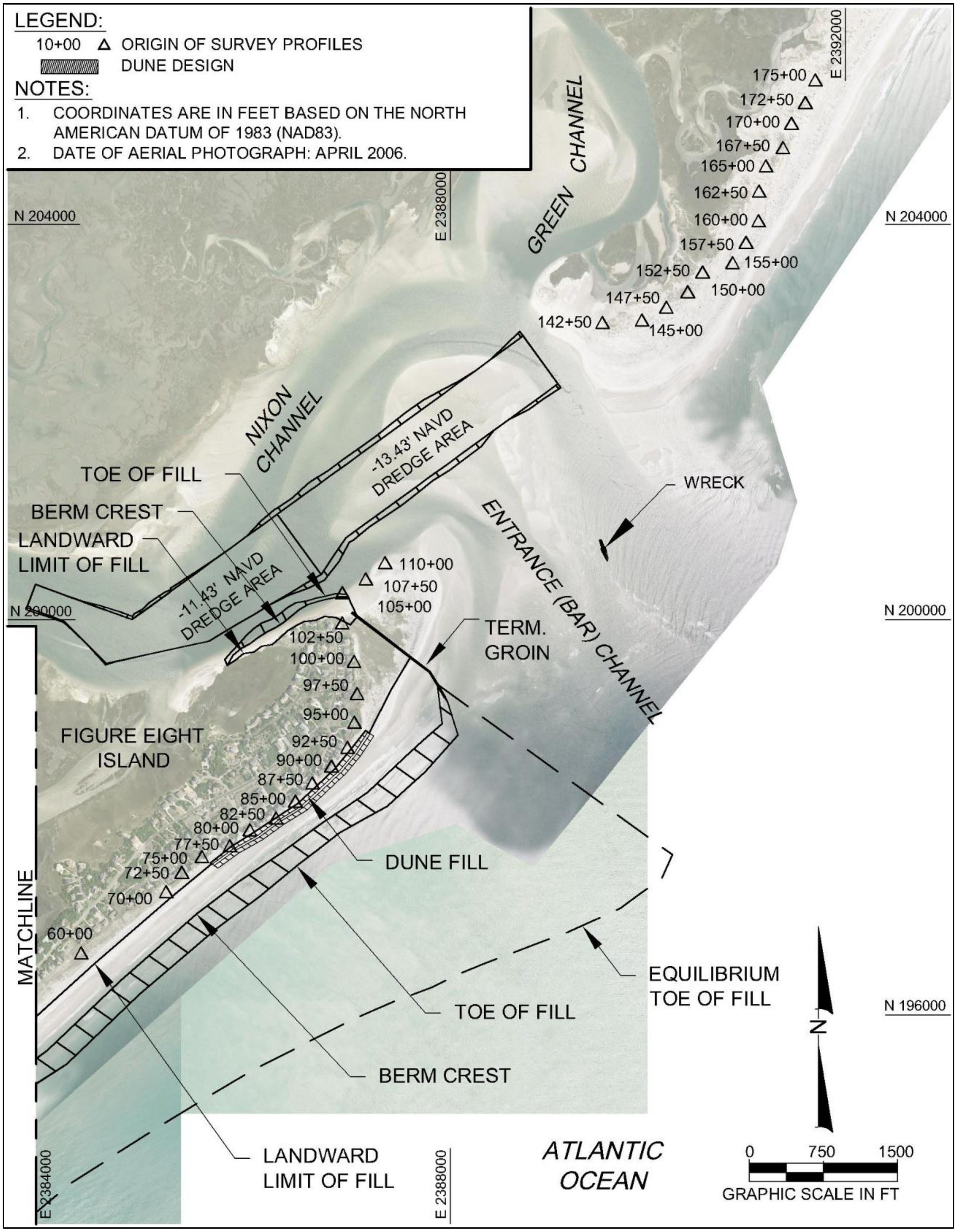

Figure 3.15c. Plan View of the northern portion of Alternative 5C; 2006 shoreline conditions.

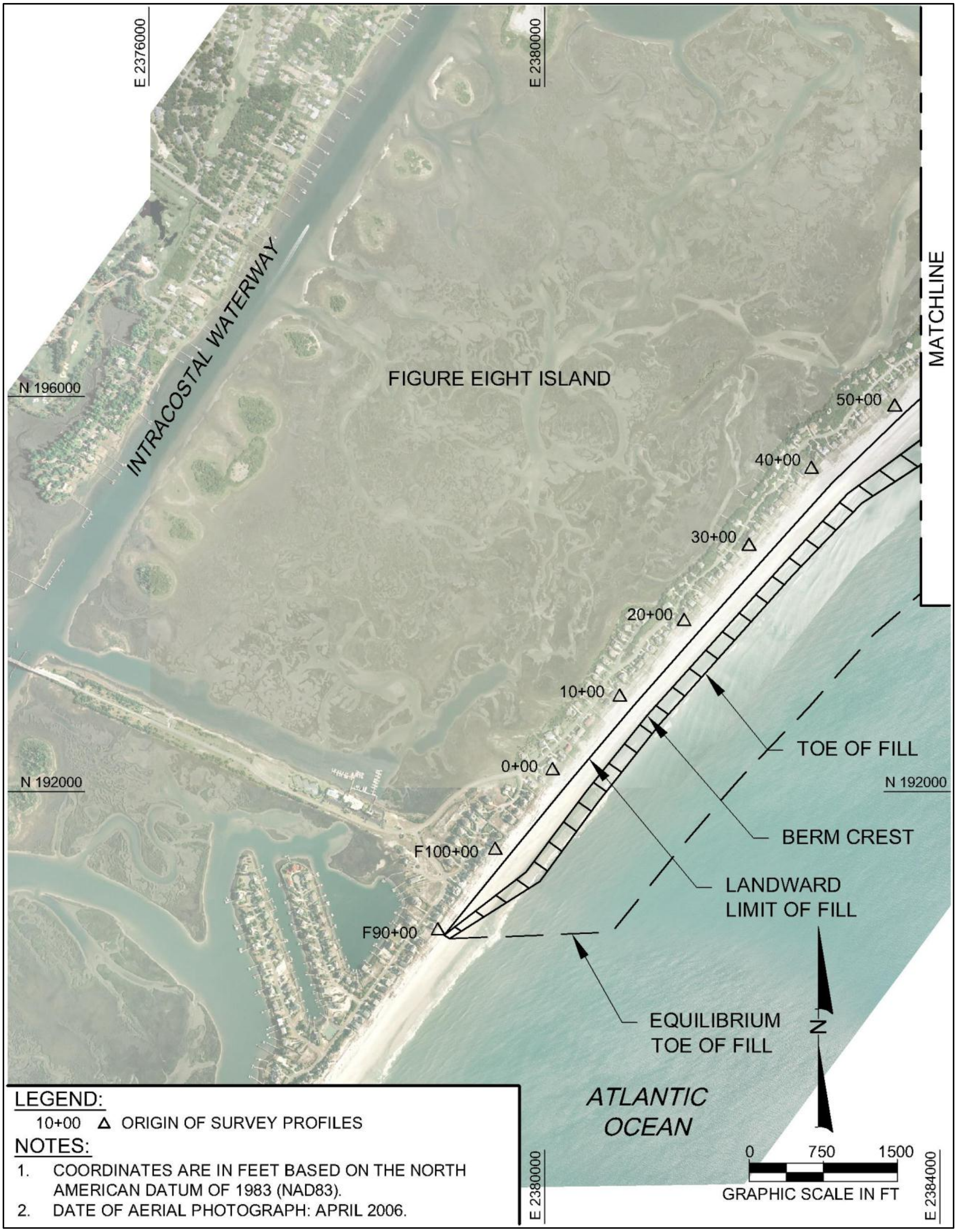

Figure 3.15d. Plan View of the southern portion of Alternative 5C; 2006 shoreline conditions.

Implementation Cost. Construction costs for Alternative 5C would include the cost of constructing the new channel from the inlet gorge into Nixon Channel with the disposal of that material along 1,400 feet of the Nixon Channel shoreline and along the ocean shoreline north of Bridge Road plus the cost of constructing the terminal groin. Removal of material from the previously permitted area in Nixon Channel and construction of the new channel connector would involve the removal of 994,400 cy based on the 2006 survey and 1,077,100 cy given the 2012 survey. Excavation of the material from Nixon Channel and the new channel connector and construction of the two beach fills would be $8,984,000 based on the 2006 conditions and $9,617,000 based on the 2012 conditions.

The initial construction cost of the 1,300-foot terminal groin for Alternative 5C is estimated to be $3,410,000 which includes engineering and design and construction oversight. The total initial construction cost of Alternative 5C given the 2006 survey condition would be $12,394,000. For the 2012 condition, the total initial construction cost would be $13,026,000. The initial construction of Alternative 5C is expected to take approximately 4.5 months.

Periodic nourishment of the beach fills in Nixon Channel and the ocean shoreline using material obtained from maintenance of the existing Nixon Channel permit area as well as the new channel connector would cost $5,162,000 every five years. Maintenance of the rubblemound portion of the terminal groin could average $15,000/year.

The average annual equivalent cost for constructing and maintaining Alternative 5C would be $1,831,000 based on the 2006 conditions and $1,877,000 for the 2012 conditions. Over the 30-year planning period, the total implementation cost for Alternative 5C in current dollars would be about $43.80 million for the 2006 condition and $44.43 million for the 2012 condition. See Appendix B and Appendix G for information regarding cost.

Alternative 5D (Applicant's Preferred Alternative): Terminal Groin at a More Northerly Location with Beach Fill from Nixon Channel and Other Sources

Alternative 5D, as shown in Figure 3.9, includes a terminal groin at the exact northerly location as Alternative 5C and the same beach fill along Nixon Channel as Alternatives 5A, 5B, and 5C. The beach fill along the ocean shoreline would be similar to Alternative 5B, however, with the terminal groin positioned farther north compared to Alternative 5B, the length of the fill would be about 500 feet longer, extending from baseline station 60+00 to the terminal groin which would be positioned near baseline station 105+00. The volume of material needed to construct the beach fill along the ocean shoreline would be 237,500 cy with 57,000 cy needed along the Nixon Channel shoreline resulting in a total beach fill volume of 294,500 cy for Alternative 5D. The volume of fill needed for both the ocean shoreline and the Nixon Channel shoreline would be the same for both the 2006 and 2012 conditions.

The cost for implementing Alternative 5D is not affected by the conditions in Nixon Channel or along the ocean and Nixon Channel shoreline as both the 2006 and 2012 conditions in Nixon Channel could supply the volume of material needed to construct the two fills. In this regard, the beach fill designs are based on providing a given volume of material per linear foot of shoreline regardless of the condition of the beach.

Two terminal groin lengths were evaluated for Alternative 5D, one having the same length as Alternative 5C (1,300 feet) and the other 200-feet longer (1,500 feet). Based on the Delft3D model results, which are presented in Appendix B, volume losses from the beach fill with the 1,300-foot terminal groin occurred rather rapidly with only 6% of the fill placed above the -6-foot NAVD depth contour remaining at the end of the 5-year simulation. Over the whole active profile, that is from the berm crest seaward to the depth of closure (-24 ft NAVD), the entire fill was removed by the end of year 3. For the 1,500-foot structure and the same beach fill design as used in the evaluation of the 1,300-foot structure, the Delft3D model indicated the longer terminal groin was able to retain 27.5% of the fill placed above the -6-foot NAVD depth contour through year 5 of the simulation given the 2006 conditions and 52.3% for the 2012 conditions. The improved performance of the fill with the 1,500-foot terminal groin, particularly above the -6 foot NAVD depth contour, resulted in the selection of the 1,500-foot terminal groin for Alternative 5D.

The primary difference between the performance of the 1,300-foot structure used for Alternative 5C and the 1,500-foot structure selected for Alternative 5D was associated with beach fill amounts included with Alternative 5C. That is, due to the overfilling of the beach profile, the beach fill was able to absorb high rates of losses and still prevent encroachment into the pre-nourished profile over the 5-year simulation period. Based on the model results, by adding 200 feet to the length of the terminal groin, the volume of material for the beach fill was reduced from 932,100 cy for Alternative 5C to 264,500 cy for Alternative 5D while still providing erosion protection to the upland area along the north end of Figure Eight Island.

The 1,500-foot terminal groin would include a 995-foot shore anchorage section and a seaward section that would project 505 feet seaward of the 2007 mean high water shoreline. The shore anchorage section would be constructed with either steel or concrete sheet pile while the seaward section would be of rubblemound construction. The landward 100 feet of the shore anchorage section would have a 10-foot wide stone scour protection apron on both sides.

As is the case with Alternative 5B, the material to construct the beach fills would be obtained from maintenance of the previously permitted area in Nixon Channel.

The plan layout for Alternative 5D is shown in Figures 3.16a and 3.16b with the distribution of the fill and design berm widths given in Table 3.10. The terminal groin for Alternative 5D includes the 200-foot extension labeled as optional extension in Figures 3.16a and 3.16b.

Table 3.10 Alternative 5D beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
60+00 to 70+00 (transition	0 to 20	0 to 17
70+00 to 77+50	20	17
77+50 to 80+00 (transition)	20 to 80	17 to 69
80+00 to 105+00	80	69

Periodic Nourishment – Alternative 5D.

Simulation of Alternative 5D in the Delft3D model indicated an average rate of volume loss from the beach fill placed between station 60+00 and the terminal groin (105+00) of 58,000 cy/years for the 2006 conditions and 45,000 cy/year for the 2012 conditions. South of station 60+00 the beach remained stable to slightly accretionary under both conditions. Assuming periodic nourishment would be accomplished every 5 years, the five year nourishment requirement for Alternative 5D would be 290,000 cy given the 2006 conditions and 225,000 cy for the 2012 condition. Periodic nourishment of the Nixon Channel beach fill would also require 30,000 cy every five years resulting in a total 5 year nourishment requirement of 320,000 cy for the 2006 condition and 255,000 cy for the 2012 condition. Like Alternative 5B, material for periodic nourishment of the beach fills would come from maintenance of the previously permitted area in Nixon Channel.

Implementation Cost. Initial construction costs for the 1,500-foot terminal groin would be $4,560,000. The initial cost of the beach fills along the Nixon Channel and ocean shoreline using material from the Nixon Channel permit area would be $2,879,000 for both the 2006 and 2012 conditions resulting in a total cost for initial construction (beach fills and terminal groin) of $7,439,000. As previously stated, the implementation costs for Alternative 5D are independent of the survey conditions. The initial construction of Alternative 5D is expected to take approximately 4 months.

Maintenance of the terminal groin would average $25,000 per year. Periodic nourishment of the beach fills along the ocean shoreline and Nixon Channel using maintenance material removed from the previously permitted area in Nixon Channel would cost $3,002,000 every 5 years under the 2006 conditions and $2,561,000 for the 2012 conditions. Over the 30-year planning period, the total cost for Alternative 5D in current dollars would be about $26.12 million given the 2006 conditions and $23.47 million for the 2012 conditions.

The equivalent average annual cost for Alternative 5D, computed with a discount rate of 6% over an amortization period of 30 years is $1,098,000 for the 2006 conditions and $1,020,000 for the 2012 conditions. See Appendix B and Appendix G for more information regarding cost.

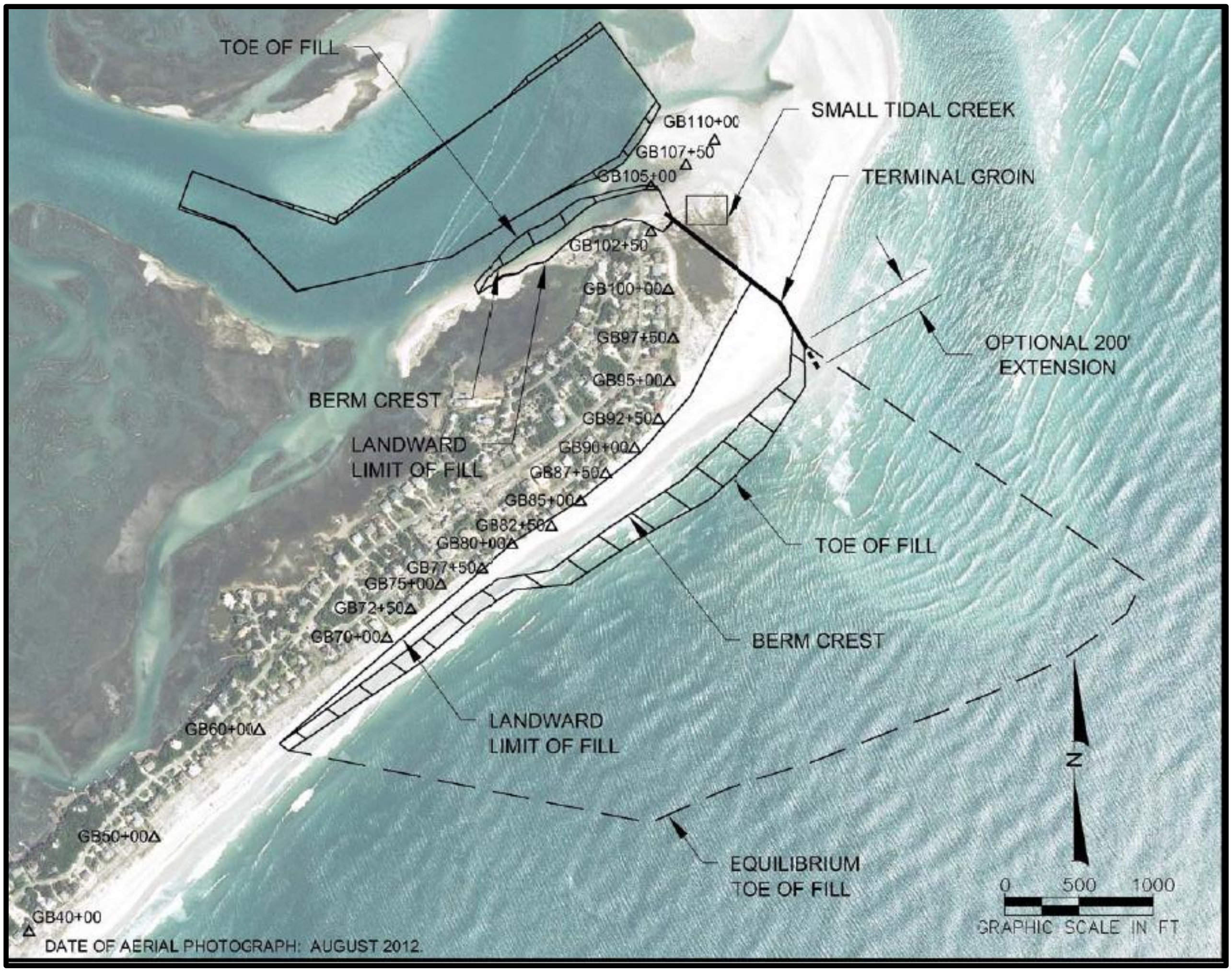

Figure 3.16a. Plan view of Alternative 5D; 2012 shoreline conditions.

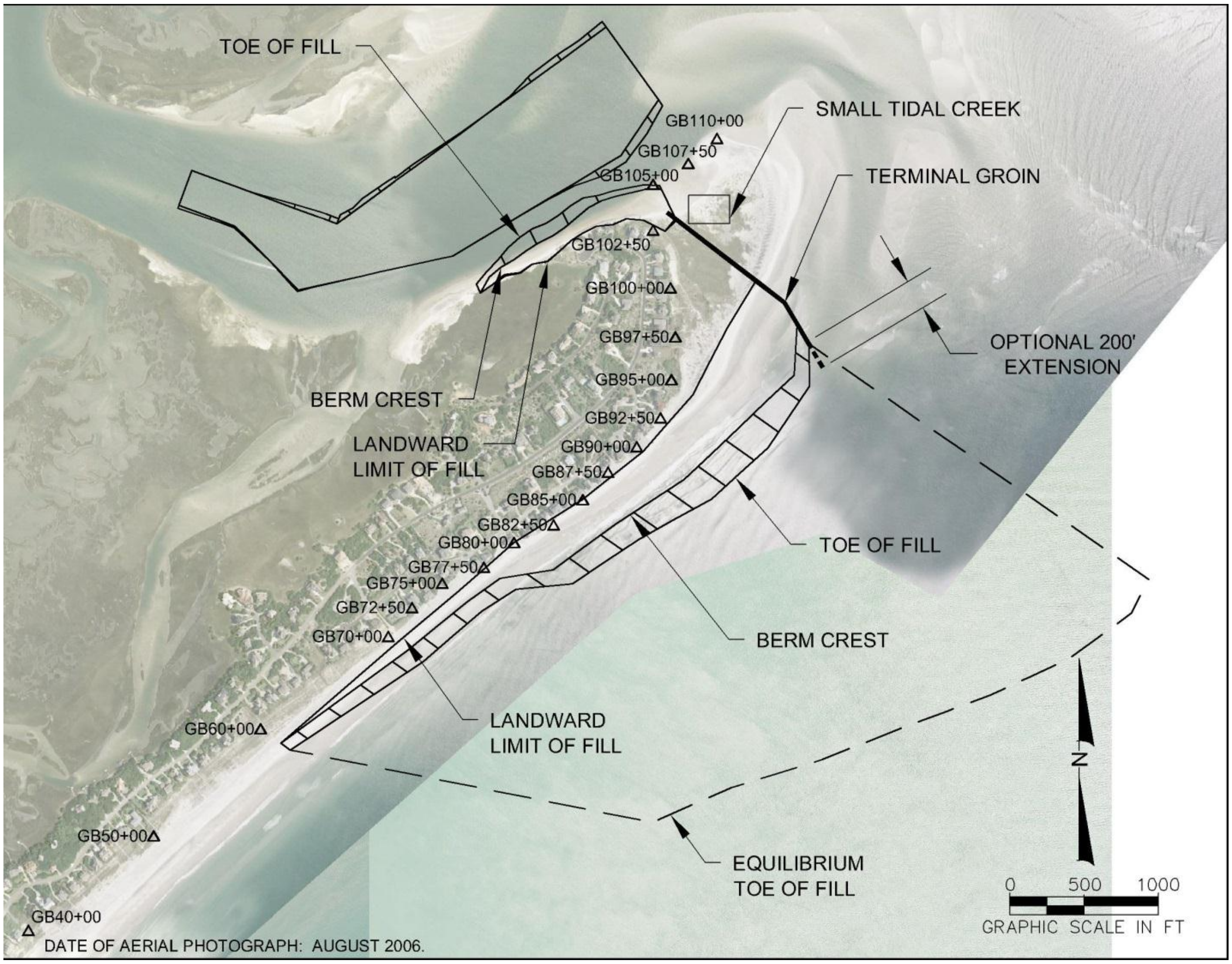

Figure 3.16b. Plan view of Alternative 5D; 2006 shoreline conditions.

Terminal Groin Removal Cost – Alternative 5D.

Removal of the terminal groin would include the cost of labor and equipment minus the salvage value of the sheet piles and stone. The cost for removing the terminal groin under Alternatives 5A and 5B would be $3.4 million whereas removal costs for Alternatives 5C and 5D would be $2.8 million and $3.2 million, respectively.

Cost Summary.

The equivalent average annual economic impact of each alternative is provided in Table 3.11a and Table 3.11b for the 2006 and 2012 conditions, respectively. The annual costs in this table were computed over a 30-year amortization period using a discount rate of 6%. Table 3.12a and Table 3.12b present summaries of the 30-year implementation costs for each alternative given the 2006 and 2012 conditions, respectively.

Table 3.11a. Summary of Average Annual Economic Impact of Alternatives (2006 Conditions).

Alternative	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
1	$1,803,000	$184,000	$1,204,000	$3,191,000
2	$2,166,000	$275,000	$169,000	$2,610,000
3	0	0	$2,564,000	$2,564,000
4	0	0	$3,259,000	$3,259,000
5A	0	0	$1,890,000	$1,890,000
5B	0	0	$1,056,000	$1,056,000
5C	0	0	$1,831000	$1,831,000
5D	0	0	$1,098,000	$1,098,000

Table 3.11b. Summary of Average Annual Economic Impact of Alternatives (2012 Conditions).

Alternative	Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
1	$1,742,000	$179,000	$1,201,000	$3,122,000
2	$2,081,000	$257,000	$165,000	$2,503,000
3	0	0	$2,620,000	$2,620,000
4	0	0	$2,780,000	$2,780,000
5A	0	0	$1,936,000	$1,936,000
5B	0	0	$1,056,000	$1,056,000
5C	0	0	$1,877,000	$1,877,000
5D	0	0	$1,020,000	$1,020,000

Table 3.12a Summary of 30-year Implementation Costs of Alternatives (2006 Conditions)

Alternative	30-Year Implementation Cost
1	$92.5 Million
2	$63.7 Million
3	$61,80 Million
4	$84.90 Million
5A	$43.68 Million
5B	$24.76 Million
5C	$43.80 Million
5D	$26.18 Million

Table 3.12b Summary of 30-year Implementation Costs of Alternatives (2012 Conditions)

Alternative	30-Year Implementation Cost
1	$84.7 Million
2	$63.7 Million
3	$63.5 Million
4	$69.00 Million
5A[(1)]	$44.31 Million
5B[(1)]	$24.76 Million
5C[(1)]	$44.43 Million
5D	$23.53 Million

[(1)])**Periodic nourishment costs based on 2006 conditions.**