Chapter 6 AVOIDANCE AND MINIMIZATION

The following describes actions and measures incorporated into the design of the Applicant's Preferred Alternative – Alternative 5D to avoid and/or minimize direct, indirect, and cumulative effects to the resources and the public uses found within the Permit Area.

1. How will Alternative 5D (Applicant's Preferred Alternative) construction practices avoid and minimize environmental impacts?

Construction Schedule

In order to protect certain threatened and endangered species and other bird and fish species that utilize Rich Inlet complex and the ocean shorelines of Hutaff and Figure Eight Islands, all construction activities are scheduled to occur between November 16 and March 31. The timing of construction activities was specifically scheduled to occur outside of the sea turtle nesting season, the West Indian manatee summer occurrence in North Carolina, the piping plover (and other shorebirds) migratory and breeding seasons, the seabeach amaranth flowering period, and when most biological activities are at their lowest. Working during this time frame is expected to minimize any potential adverse impacts to offshore, nearshore, intertidal, and beach biological resources to the maximum extent possible.

Also, the construction of the rubble mound portion of the terminal groin as well as the sand placement and dredge operations will be conducted outside of primary invertebrate production and recruitment periods (spring and fall) which will limit impacts to amphipods, polychaetes, crabs and clams.

Construction work during the November 16-March 31 time frame will occur at the lowest peak of public use. Both residential and visitor use on Figure Eight Island are at its minimal and boater use within Rich Inlet and the surrounding waters being infrequent. With public presence on both islands and in adjacent waters at its lowest, impacts to navigational and recreational uses are anticipated to be non-appreciable. This would also reduce any public safety concerns.

Terminal Groin Structure

Two terminal groin designs were considered for the Applicant's Preferred Alternative. One option, Alternative 5C, included a 1,300-foot terminal groin with a 305-foot section extending seaward of the 2007 mean high water shoreline and the other design, Alternative 5D, consisted of a 1,500-foot long structure with a 505-foot section extending seaward of the 2007 mean high water shoreline. Both design lengths of the terminal groin were evaluated through the use of the Delft3D model using 2006 baseline conditions; and the 1,500-foot long option was further modeled using the 2012 baseline conditions. After assessing all the modeling results, Figure "8" Beach HOA Board determined that Alternative 5D would be the preferred and best option to serve their purpose and need for long-term protection of the island.

The Applicant's Preferred Alternative includes a combination of both the rubble mound and sheet pile design. The structure's anchor is being constructed in a manner to reduce any impacts to the salt marsh community located in the northern spit of Figure Eight Island. For the 995-foot long sheet piled anchor section, the sheets will be driven in a manner that the tops will be approximately 2 feet below the surface elevation of the salt marsh area. Leaving this 2-foot space is expected to provide continued tidal exchange and not interrupt normal flow patterns. Additionally, the rubble scour protection apron for the anchor was minimized to a width of 10 feet in ordere to reduce impacts to the marsh community while still supporting the integrity of the structure. For the seaward 505-foot section of the groin, a rubble mound design was selected over sheet piles. This will provide some spacing in the structure to allow some sediment to migrate through and not eliminate sediment bypass into the inlet. The rubble design is also expected to provide habitat for sessile benthic organisms as well as crustaceans and fin fish, increasing beneficial use to the marine environment more than that of sheet piles.

During the construction of the groin, a construction corridor varying in width from 50 feet to 200 feet will be established around the footprint of the structure and all construction activity will be required to remain within the corridor. This will ensure that the environmental impacts will be kept to a minimum within the construction area. As stated in Chapter 5, a portion of the shore anchorage component of the terminal groin will be constructed within an area of high marsh habitat. In order to minimize temporary direct impacts to these resources, the orientation of the groin will be designed such that it will span the shortest distance through the wetlands totaling 303 feet (Figure 6.1) and the construction corridor will be reduced to 50 feet. In addition, the construction corridor for this portion of the groin will be located to the south of the creek that meanders from Nixon Channel into the wetland such that tidal exchange will continue. Furthermore, the top of the sheet pile structure will be installed below grade which will also allow for the continuation of proper tidal exchange. Finally, the location for the unloading of the rubble mound material from the barge will be situated along the Nixon Channel shoreline in an area containing minimal vegetation.

Beach Fill along Nixon Channel Shoreline

For Alternative 5D, the initial placement of 57,000 cubic yards of material encompassed a length of 1,800 linear feet along the Nixon Channel shoreline terminating near the end of the Figure Eight Island spit. With this design, material would have covered the mouth of the small tidal creek that feeds the salt marsh community, eventually choking off the tidal influence. The shoreline footprint was modified and shortened the length of placement to 1,400 linear feet in order to avoid impacting the tidal finger and indirectly affecting the marsh community located in this area.

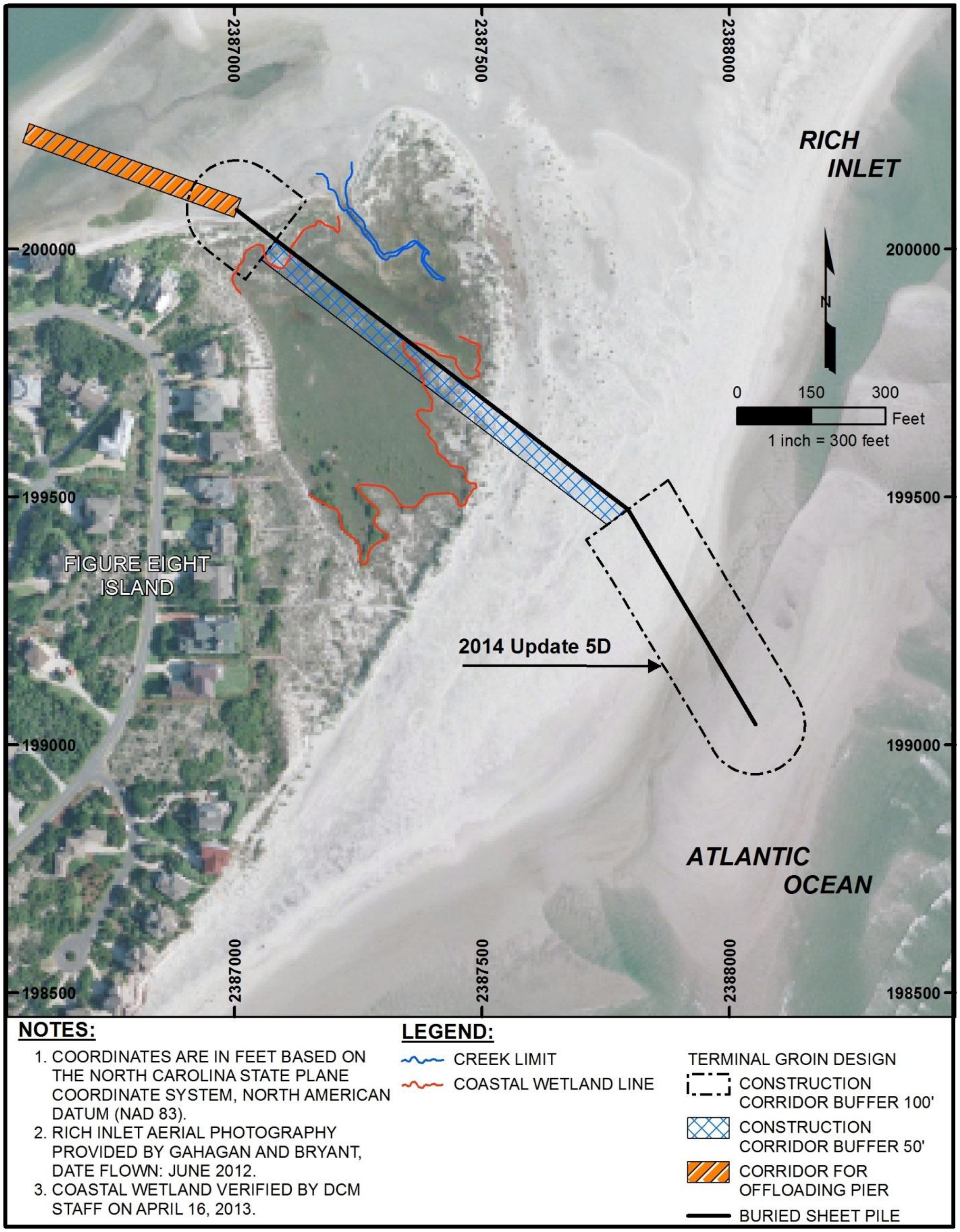

Figure 6.1. Location of the shore anchorage section of the terminal groin spanning areas of high marsh

Dredge Type

A hydraulic cutterhead is proposed for dredging the proposed borrow area within Nixon Channel. A cutterhead dredge uses a rotating cutter assembly at the end of a ladder arm to excavate bottom material, which is then drawn into the suction arm and pumped to the shoreline. On the beach, pipelines will transport the sediment to the designated beach fill area. Bulldozers will be used to construct seaward shore parallel dikes to contain the material on the beach, and to shape the beach to the appropriate construction cross-section template. During construction, the contractor will utilize surveying techniques for compliance with the designed berm width, height, and slope.

Compared to similar types of dredging methodologies, a cutterhead dredge creates minimal disturbance to the seafloor resulting in lower sedimentation and turbidity levels. Anchor (2003) conducted a literature review of suspended sediments from dredging activities. This report concluded that the use of a hydraulic dredge (i.e., cutter suction) limits the possibilities for resuspension of sediment to the point of extraction. Also, since the sediment is suctioned into the dredge head, the sediment cannot directly enter into the middle or upper water column.

No incidences of sea turtle takes from a hydraulic dredge have been identified during the research and development of this document. Therefore, the use and methods involved with this type of machinery reduces or eliminates the likelihood of an incidental take.

Dredge Positioning

DREDGEPAK® or similar navigation and positioning software will be used by the contractor to accurately track the dredge location in relation to the hardbottom buffer protection zones. The software will provide real-time dredge positioning and digging functions to allow color display of dredge shape, physical feature data as found in background Computer Aided Design (CAD) charts and color contour matrix files from hydrographic data collection software described above on a Cathode Ray Tube (CRT) display. The software shall also provide a display of theoretical volume quantities removed during actual dredging operations.

Dredge anchors shall not be placed any further than 61 m (200 ft) from the edge of the areas to be dredged. The dredge contractor will be required to verify the location of the anchors with real time positioning each and every time the anchors are relocated.

Sediment Compatibility

The North Carolina Coastal Resources Commission adopted State Sediment Criteria Rule Language (15A NCAC 07H .0312) for borrow material aimed at preventing the disposal of an inordinate amount of coarse material (primarily shell and shell hash) on the beach (NCDCM, 2007) and is summarized in Chapter 4. The native material on Figure Eight Island contains an average gravel content of 0.05% and an average granular content of 0.26%; the upper limit of gravel and granular that could be placed on the beach is 5.05% and 5.26%, respectively (Table 6.1). Based on a native silt average of 1.04% at Figure Eight Island, the allowable silt content of material to be placed on the beach is 6.04% (Table 6.1). Based on a native calcium carbonate percentage of 6.0%, the allowable calcium carbonate % of material to be placed on the beach would be limited to 21.0% (Table 6.1). The rule language has been adhered to during the planning and development of the Figure Eight Island Shoreline Management Project, which reduces the potential for negative effects of beach nourishment (See Appendix D –Geotechnical Report).

Table 6.1
Characteristics of the Native Beach and Borrow Area 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)	1.0	9.9	1.15	0.33	0.21
State Standard Limit	6.0	24.9	6.15	5.33	
Nixon Channel Borrow Area	1.25	8.12	0.77	0.52	0.22

(1) 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.

As noted above, the Sediment Criteria Rule provides beneficial guidelines for both grain size and percent weigh of calcium carbonate (NCDCM, 2007) which is intended to minimize compaction which could otherwise impact nesting sea turtles and bentic macroinfauna populations. Aside from these beneficial guidelines, other important characteristics such as organic content, heavy mineral content, and color are not addressed. These aspects of the beach fill will be considered during nourishment construction to reduce the effects of compaction and unsuitable material. A monitoring program will be developed that will ensure the material is compatible in composition and nature to the native material. See the section entitled "Construction Observations" below for more detail regarding this monitoring program which will be designed to ensure that only compatible material will be placed on the oceanfront and Nixon Channel shorelines. This quality management protocol is likely to reduce any potential direct, indirect, and/or cumulative impacts to fish and bird resources by shortening the recovery time of the benthic community food source. It is also expected to benefit sea turtle nest construction and incubation of the eggs and to not interrupt any of their nesting habits.

Pipeline Observations

In order to minimize impacts on wintering piping plover, the pipeline alignment will be designed to avoid potential piping plover wintering habitat. The alignment will be coordinated with, and approved by, the USACE and NC DCM. As-built positions of the pipeline will be recorded using GPS technology and included in the final construction observation report.

In order to avoid impacts associated with the transport of fill material to the disposal sites, the Figure "8" Beach HOA will negotiate with the dredging contractor to monitor and assess the pipeline during construction. This will serve to avoid leaking of sediment material from the pipeline couplings, other equipment, or other pipeline leaks that may result in sediment plumes, siltation and/or elevated turbidity levels. The Figure "8" Beach HOA, along with their Engineer, will coordinate with the dredgers and have in place a mechanism to cease dredge and fill activities in the event that a substantial leak is detected (leaks resulting in turbidity that exceed state water quality standards or sedimentation). Operations may resume upon appropriate repair of affected couplings or other equipment.

2. What are the monitoring initiatives being developed?

Several monitoring initiatives have been implemented along Figure Eight Island as part of permit conditions for previously implemented beach nourishment projects. A description of existing and proposed monitoring initiatives in support of the Figure Eight Island Shoreline Management Project is included below.

Construction Observations

Several initiatives will be undertaken by Figure "8" Beach HOA, the Engineer, or his duly authorized representative to monitor construction practices. Construction observation and contract administration will be periodically performed during periods of active construction. Most observations will be during daylight hours; however, random nighttime observations may be conducted. The Figure "8" Beach HOA, the Engineer, or his duly authorized representative will provide onsite observation by an individual with training or experience in beach nourishment and construction observation and testing, and that is knowledgeable of the project design and permit conditions. The project manager, a coastal engineer, will coordinate with the field observer. Multiple daily observations of the pumpout location will be made by the Figure "8" Beach HOA, the Engineer, or his duly authorized representative for QA/QC of the material being placed on the beach. Information pertaining to the quality of the material will periodically be submitted to the USACE and NC DCM for verification. If incompatible material is placed on the beach, the USACE and NC DCM will be contacted immediately to determine appropriate actions.

Material Color
The Figure "8" Beach HOA, the Engineer, or their duly authorized representative, will collect a representative sub-surface (6 in below grade) grab sediment sample from each 100-ft long (along the shoreline) section of the constructed beach to visually assess grain size, wet Munsell color, granular, gravel, and silt content. Each sample will be archived with the date, time, and location

of the sample. Samples will be collected during beach observations. The sample will be visually compared to the acceptable sand criteria (Table 6.1). If determined necessary by the Engineer, or his duly authorized representative, quantitative assessments of the sand will be conducted for grain size, wet Munsell color, and content of gravel, granular and silt. A record of these sand evaluations will be provided within the Engineer's daily inspection reports and submitted to USACE and NC DCM for verification.

Escarpments
Visual surveys of escarpments will be made along the beach fill area immediately after completion of construction. Escarpments in the newly placed beach fill that exceed 18 inches or greater than 100 ft shall be graded to match adjacent grades on the beach. The decision for escarpment removal will be determined upon consultation with USACE and NC DCM. Removal of any escarpments during the sea turtle hatching season (May 1 through November 15) shall be coordinated with the North Carolina Wildlife Resources Commission (NCWRC), USFWS, and the USACE – Wilmington District.

Water Quality
The inlet, nearshore and offshore water columns are classified as SA and High Quality Water (HQW) under the North Carolina State water quality standards. This classification requires that work within the water column shall not cause turbidity levels to exceed 25 NTU or background (ambient) conditions that are above 25 NTU.

Dredge and fill operations are expected to temporarily elevate turbidity levels in the water column at the borrow area and fill sites. Higher turbidity levels are likely to be found in the discharge zone (nearshore swash zone) during periods of active construction. The use of a cutter suction dredge will minimize the area of disturbance since this type of dredge involves suction for the extraction of sediment.

Turbidity monitoring during construction will be managed by the contractor. The contractor will be responsible for notifying the construction engineer in the event that turbidity levels exceed the State water quality standards.

Bird Monitoring

The University of North Carolina at Wilmington (UNCW), under the direction of Dr. David Webster, conducts shorebird and colonial waterbird monitoring throughout the year along the beachfront of Figure Eight Island and the areas surrounding Mason and Rich Inlet. In addition, Audubon North Carolina has monitored the Rich Inlet complex which includes Figure Eight Island's northern spit since 2008. These monitoring efforts are expected to continue for the foreseeable future (Webster, pers. comm.). The annual monitoring report will be submitted to the USACE and NC DCM for determining project impacts to endangered and threatened bird species.

Seabeach Amaranth (*Amaranthus pumilus*)

Since 2002, UNCW has conducted regular monitoring, paid by Figure "8" Beach HOA, along the entire beachfront of Figure Eight Island for the presence of seabeach amaranth. This monitoring is anticipated to continue for the foreseeable future (Webster, pers. comm.). Audubon North Carolina also reports upon the occurrence of seabeach amaranth along the beachfront on Hutaff Island (Mangiameli, pers. comm., 2008). The annual monitoring report will be submitted to the USACE and NC DCM for determining project impacts to seabeach amaranth.

Sea Turtles

Since 2001, sea turtle nesting activity has been monitored on a daily basis throughout the nesting season along the Figure Eight Island beachfront by UNCW under the direction of Dr. David Webster (Godfrey, pers. comm.). This monitoring, paid by the Figure "8" Beach HOA, begins on approximately May 1 and continues through the last hatch date each year. Audubon North Carolina performs a similar monitoring effort throughout nesting season on Hutaff Island, however, this monitoring is not conducted on a daily basis. The annual monitoring report will be submitted to the USACE and NC DCM for determining project impacts to sea turtles. Dr. Matthew Godfrey of the NCWRC expressed the difficulties in reporting sea turtle population and nesting trends since the availability of observers and consistency in data collection can contribute to the unreliability of the data (Godfrey, pers. comm.). With the continuation of UNCW's monitoring along Figure Eight Island, the data collection will be more reliable and provide accurate information that aids with the assessment of turtle nesting conditions along the northern end of Figure Eight.

West Indian Manatee (*Trichechus manatus*)

Inwater activity associated with Alternative 5D will occur outside the period when *T. manatus* are likely to be present, which is June to October. Although the manatee should be absent during dredge and fill operations, precautions will be taken by the contractor to further reduce the risk of impacting the West Indian manatee. The dredging contractor will adhere to the precautionary guidelines established by the USFWS – Raleigh Office for construction activities in North Carolina waters and will have these guidelines on the dredging plant at all times. Refer to the *Guidelines for Avoiding Impacts to the West Indian Manatee*.

Aerial Habitat Mapping

Purpose and Goals

It is anticipated that the implementation of the proposed project has the potential to impact certain biological resources and habitats found within the proposed Permit Area, particularly within the complex of Rich Inlet. These include resources such as the salt marsh within the Figure Eight Island spit, inlet dry beach, intertidal flats and shoal communities, SAV, and shellfish habitats found within the area to be investigated. Determining the baseline conditions of the resources prior to construction is a fundamental step in quantifying changes in response to the implementation of Alternative 5D. Existing data and newly acquired data were utilized to delineate and characterize habitats and select species within the proposed Permit Area (Figure 4.1). Data gathered from these efforts provided the baseline conditions of a number of biological resources as reported in Chapter 4 of this document.

In an effort to understand any potential habitat changes resulting from Alternative 5D, plans are to continue the aerial photo delineation or mapping of the habitats with the Permit Area. The effort will not focus on the entire Permit Area, but will target the Rich Inlet complex as depicted in Figure 6.2. The mapping is confined to this area since habitat changes resulting from Alternative 5D are expected at this location. It is acknowledged that the data in Figure 4.1 within the Rich Inlet complex has somewhat changed from its initial collection due to the ongoing natural shifting that occurs in inlet systems. With the expectation of a continual shift of resources, an updated mapping of the habitat baseline conditions will be performed within a time period closer to the construction of Alternative 5D. Following the completion of Alternative 5D, subsequent habitat mapping efforts will be conducted on an annual basis for 3 years. Each post-construction habitat map will be compared to the updated baseline conditions. An assessment will be conducted to determine what changes have occurred and to what extent. This evaluation will also help to determine if the project attributed to any of those changes.

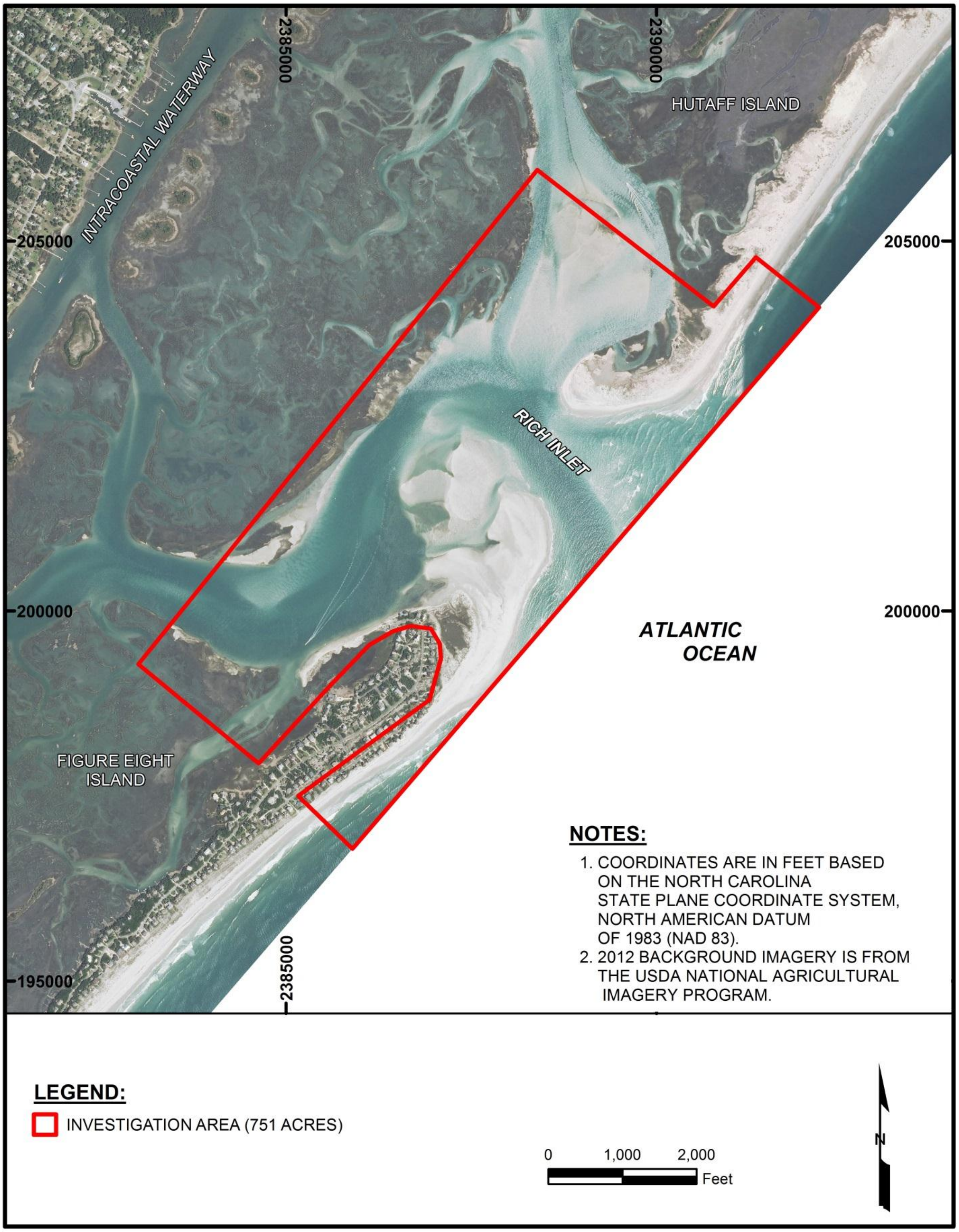

Figure 6.2. Rich Inlet Habitat Mapping Boundary

Monitoring Schedule
Photographic interpretation of biotic communities and groundtruthing investigations within the proposed habitat mapping area was completed in April 2009 utilizing high resolution aerial photography acquired in 2008. Pre-construction investigations will further update the 2009 effort and will be conducted within a time period closer to any implementation of Alternative 5D.

The acquisition of high resolution aerial photographs, ground-truth investigations, and identification of biotic communities will be conducted within the Proposed Habitat Mapping Area between 1 September and 30 November in the 3 years following construction of the proposed project. All surveys will be compared to the most recent pre-construction conditions.

Monitoring Parameters

Aerial Photography:
Cartographic aerial photography will include the acquisition of ortho-rectified color digital imagery of the 751 acre Rich Inlet Habitat Mapping area. Resolution of the acquired imagery will be sufficient to accurately delineate and map habitats and features of environmental significance within the survey area. The aerial platform from which the imagery is acquired will have an onboard GPS that will provide an accurate basis for product correction. NMFS will be consulted regarding the performance specifications on the imagery prior to finalizing the plan by the Figure "8" Beach HOA and authorizing a contract.

In compliance with State and Federal agency requests, digital image acquisition will be scheduled, to the greatest extent possible, to coincide with good weather conditions and an ebb tide that may provide for increased accuracy of habitat interpretation. Considering the weather-dependent nature of this activity, every effort will be made to accomplish this task under optimum conditions.

Aerial imagery analysis conducted pre- and post-construction will be used to monitor any changes in SAV distribution. Aerial imagery will be collected in accordance with NOAA's Coastal Services Center 2001 *Guidance for Benthic Habitat Mapping – An Aerial Photographic Approach* (Finkbeiner et al., 2001). Aerial photographs include the acquisition of ortho-rectified color digital imagery of the Rich Inlet Habitat Mapping area. Resolution of the acquired imagery will be sufficient (<0.6 m [2 ft]) to accurately delineate and map habitats and features of environmental significance within the survey area. An emphasis will be placed on those marine and estuarine habitats located immediately within and adjacent to the Rich Inlet Habitat Mapping area. The aerial platform from which the imagery is acquired will include an onboard Global Positioning System (GPS) that will provide an accurate basis for product correction.

Submerged Aquatic Vegetation:
Resource maps depicting SAV communities along coastal North Carolina do not show SAV communities occurring within the Rich Inlet Habitat Mapping area. However, the pre-construction field investigations performed by CPE-NC confirmed the presence of SAV resources.

Post-construction assessment of SAV resources will be conducted using the same methodology as the pre-construction survey. Areas identified from aerial photography as potential SAV resources within the Rich Inlet Habitat Mapping area and areas confirmed to contain SAV from the pre-construction assessment will be visually groundtruthed. Coordinates of these sites will be obtained and a Global Positioning System (GPS) will be utilized to navigate to each location. Snorkeling will be conducted to locate and map SAV resources. Should the visibility in the water be poor, snorkelers will utilize both visual cues and tactile cues to assess the presence or absence of SAV resources. The extent of identified SAV beds will be determined by following the boundary of the bed while periodically recording GPS coordinates. These coordinates will be converted to a Geographic Information System (GIS) shapefile using ArcView 9.3 software and overlaid on high resolution aerial photography. The boundaries of the mapped SAV beds will then refined through visual interpretation of the aerial photos. Additional SAV resources within the Rich Inlet Habitat Mapping area may be extrapolated from areas with similar color signature in the updated high resolution (<2 feet) geo-referenced aerial photography. Once the SAV beds are digitized, acreages will be determined by utilizing the Xtools area calculation function in ArcView.

Shellfish Resources:
The NCDMF shellfish habitat maps contain 23 individual polygons representing the W stratum within the limited area in the Rich Inlet Habitat Mapping area. Pre-construction field investigations were conducted on 15, 17, and 22 September 2008 by CPE-NC staff biologists to visually groundtruth these potential shellfish areas within the Rich Inlet Habitat Mapping area that may receive impacts due to project-related activities. Coordinates of the center point of these polygons were obtained and GPS was utilized to navigate to each location. Water clarity was generally poor with visibility less than 2 ft; therefore snorkelers utilized both visual cues and tactile cues to assess the presence or absence of shellfish resources. A description of the benthic conditions was recorded at each location. The spatial extents of discrete shellfish beds were determined by following the boundary while periodically recording GPS coordinates. These coordinates were then converted to a Geographic Information System (GIS) shapefile using ArcView 9.3 software and overlaid upon high resolution aerial photography. The boundaries of the mapped shellfish beds were then refined through visual interpretation of the aerial photos. Additional shellfish resources within the entire Permit Area were then identified via extrapolation of areas with similar color signature in the 2008 high resolution (<2 feet) geo-referenced aerial photography. Once the shellfish beds were digitized, acreages were determined by utilizing the Xtools area calculation function in ArcView.

Salt Marsh, Intertidal Shoals, Supratidal Shoals, and Subtidal Communities:
Visual interpretations of biotic community types were digitally mapped using ArcView 9.3 software over high-resolution georeferenced digital multispectral aerial photographs as part of the initial pre-construction assessment of biotic communities. The methods employed for interpretation of aerial photography included visual analysis of color variations in the photographs to delineate habitats (dark areas = submerged land; white areas = sediment exposed above high tide line). Resolution of this imagery (< 2 feet) allowed for adequate delineation of the habitats and features within the Rich Inlet Habitat Mapping area. Following the development of the preliminary biotic community mapping within the Rich Inlet Habitat Mapping area via

visual interpretation, field investigations were conducted to groundtruth the initial delineations. Sites selected for groundtruthing were determined by identifying areas that were difficult to classify from the aerial photography. These locations were visited via boat and the biotic community type (as identified through aerial photographic interpretation) was then verified. Based on the results of the field investigations, the preliminary habitat map was revised as necessary and acreages were determined.

Reporting
The final product from each post-construction assessment will include a report describing the biotic community map derived from the methods explained above. This report will summarize the acreage of each habitat identified and will compare the acreages to previous investigations (pre-construction and any post-construction efforts that may have occurred). Results of these mapping efforts will be incorporated into the Global Information System (GIS) database developed for this project. Acreages of each habitat type present within the permit area will be provided in a report to the USACE – Wilmington District, NMFS, USFWS, NCWRC, and NCDCM by January 1st of each year.

Shoreline Management Plan

<u>Introduction</u>
Legislation passed by the NC General Assembly in June 2011(SB 110) and in 2013 (SB 151) authorized the permitting of terminal groins at four (4) inlets in North Carolina with the requirement to provide a plan for managing inlet and the estuarine and ocean shorelines likely to be under the influence of the inlet. This legislation requires the management plan to include the following:

(1) A monitoring plan.
(2) A baseline for assessing adverse impacts and thresholds for when adverse impact must be mitigated.
(3) A description of mitigation measures to address adverse impacts.
(4) A plan to modify or remove the terminal groin if adverse impacts cannot be mitigated.

The following sections describe the historic shoreline change information used to develop past shoreline trends along both Figure Eight Island and Hutaff Island. The historic data will also be used to determine the variability of past shoreline behavior. The past shoreline changes establishes the basis on which to develop expected future trends in shoreline behavior in the absence of any changes in shoreline erosion response measures along Figure Eight Island. The expected future trends in shoreline behavior will form the basis of establishing shoreline change thresholds that would be used to determine if mitigation is required to offset adverse shoreline impacts of the proposed terminal groin.

The development of the shoreline change thresholds is followed by a description of the monitoring plan that would be used to identify adverse impacts and proposed mitigation measures, including possible removal of the terminal groin.

Shoreline Change Information.
The basis for establishing the shoreline change thresholds is the history of shoreline changes that have occurred under existing conditions that were determined by Dr. William Cleary as reported in Sub Appendix A of Appendix C. Dr. Cleary used ten (10) sets of georectified aerial photographs taken between March 1938 and April 2007 and measured changes in the position of the wet/dry line at each transect shown on Figure 6.3. The transects covered the ocean shoreline of Figure Eight Island 9,500 feet south of Rich Inlet and 10,000 feet north of Rich Inlet on Hutaff Island. Transect spacing was 500 feet along both shorelines. The time interval between various sets of aerial photographs ranged from 1.5 years to 18.7 years. As shown by the transect location on Figure 6.2, the analysis did not include the extreme northern tip of Figure Eight Island or the extreme southern tip of Hutaff Island as the sand spits that characterize these two areas are ephemeral and shorelines simply did not exist in these areas on all sets of aerial photographs.

As a matter of reference, on Figure Eight Island, Transect 1 corresponds approximately to baseline station 5+00 while Transect 20 is located at approximately baseline station 100+00, as shown in Figures 3.14a and 3.14b in Chapter 3. On Hutaff Island, Transect 21 is located at approximately baseline station 150+00 and Transect 41 is approximately equal to baseline station 160+00.

The area covered by the shoreline change analysis on Figure Eight Island extends about 4,500 feet southwest of the proposed new Inlet Hazard Area for Rich Inlet being considered by the Coastal Resources Commission. On Hutaff Island, all of which is included in the proposed new Inlet Hazard Area, the shoreline change analysis extended to a point just south of the location of the former Old Topsail Inlet which closed sometime between 1996 and 1998.

The measured shoreline changes along Figure Eight Island reported by Dr. Cleary were adjusted for the impacts of numerous beach fills that occurred during his period of analysis (March 1938 to April 2007). This adjustment was made by determining the average density of each beach fill, expressed as cubic yards/lineal foot of beach, and translating this placement density into an effective fill width. For example, if the measured shoreline change during a time increment at a particular transect was -35 feet and the effective width of beach fills placed on this transect during the time increment was 40 feet, the adjusted shoreline change during the period would be -75 feet.

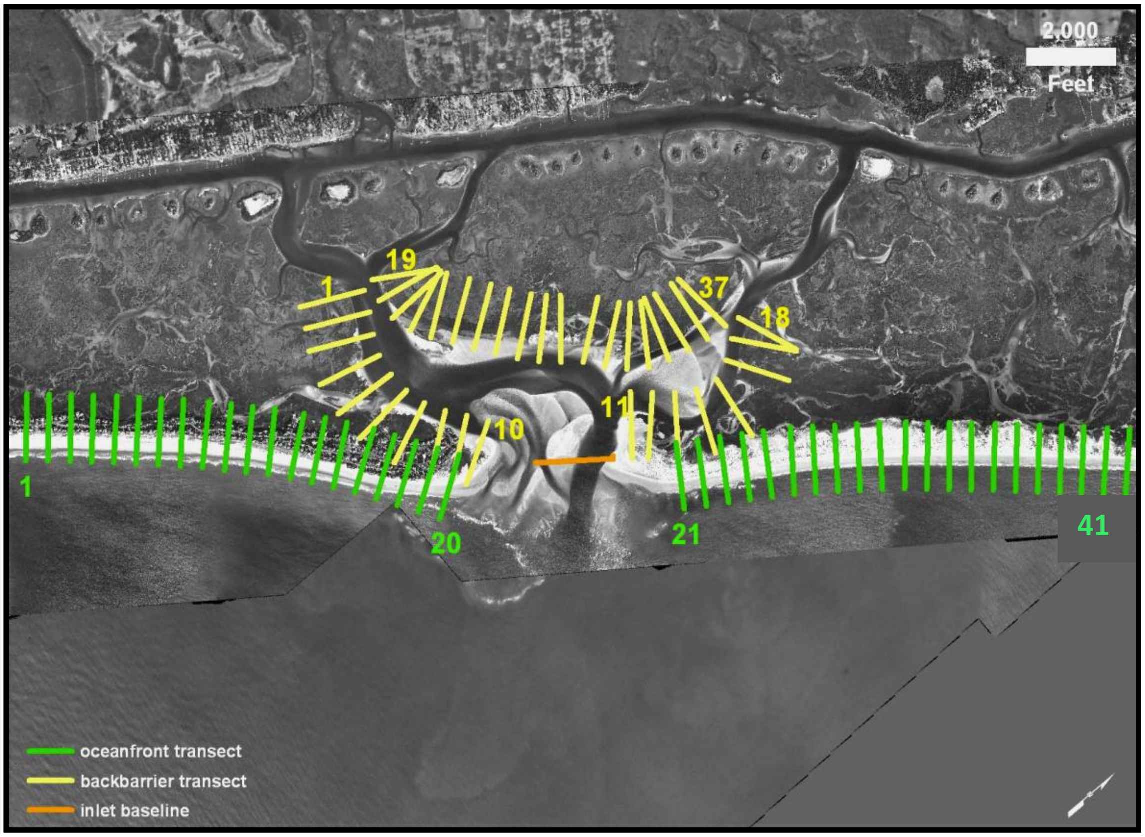

Figure 6.3. Shoreline transects.

Cumulative shoreline changes were developed for each transect along the ocean shorelines of Figure Eight Island and Hutaff Island (green transects on Figure 6.2). These cumulative plots are provided in Attachment 1. Transects were grouped based on similar shoreline change characteristics and average cumulative changes computed for each group. Transect 20, which is located immediately south of Rich Inlet, did not display shoreline change characteristics similar to transects immediately to its south and was therefore treated as a one-transect group. The table in Attachment 1 provides the average cumulative changes for the transect groups and the shoreline change rates determined for each time increment between the 10 sets of aerial photographs. Average cumulative changes for each transect group on Figure Eight Island and Hutaff Island are provided on Figures 6.4 and 6.5 for Figure Eight Island and Hutaff Island, respectively.

Methods to monitor shoreline changes on the estuarine side of Figure Eight Island and Hutaff Island (yellow transects 1-37 in Figure 6.3) would be similar to the ones conducted for Bogue Inlet and Mason Inlet. However, DCM did not seek guidance on how to monitor the estuarine areas.

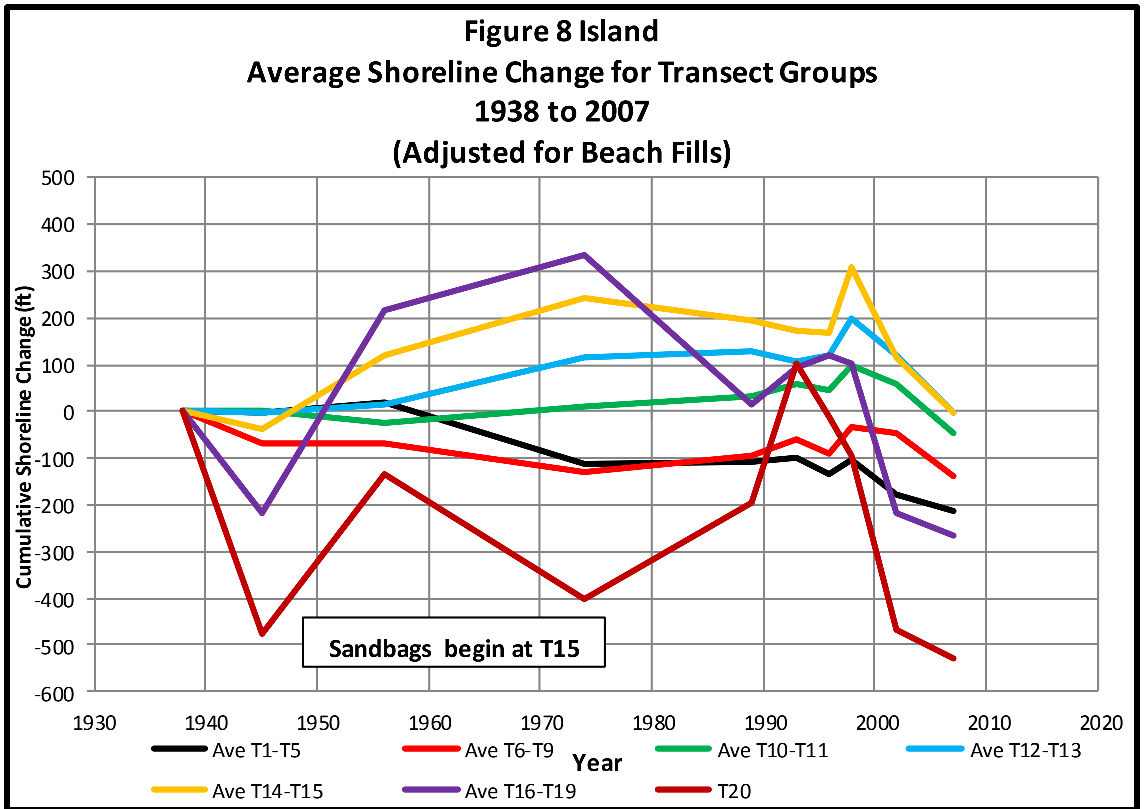

Figure 6.4. Cumulative shoreline changes between 1938 and 2007 for transect groups on Figure Eight Island.

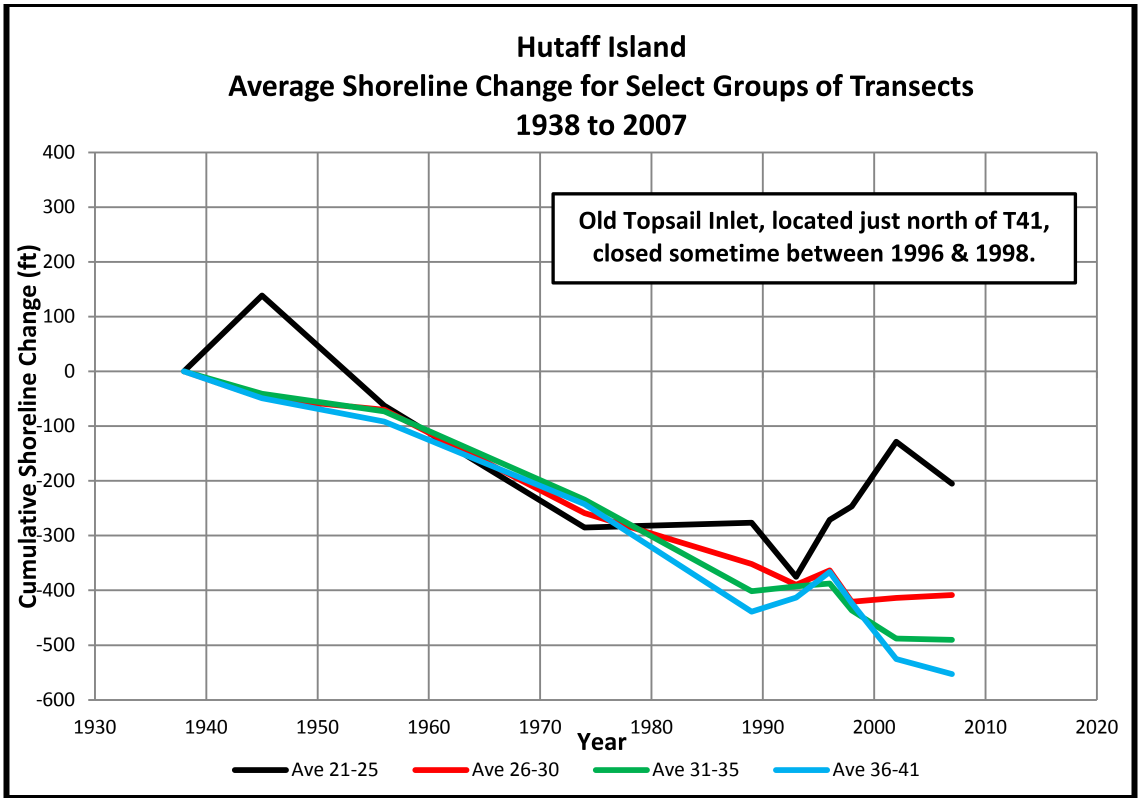

Figure 6.5. Cumulative shoreline changes between 1938 and 2007 for transect groups on Hutaff Island.

Evaluation of Shoreline Changes.
Linear regression shoreline change rates were determined for each transect group for the 1938 to 2007 time period as well as the time period between 1974 and 2007. In 1974, the bar channel of Rich Inlet began to migrate northeast or toward Hutaff Island with this migration continuing until 1999 (Sub Appendix A of Appendix C). During subsequent time periods between 1999 and 2007, the bar channel shifted back and forth between Figure Eight Island and Hutaff Island but generally maintained a position closer to Hutaff Island. This persistent position of the bar channel closer to Hutaff Island resulted in distinct differences in shoreline behavior during the 1974-2007 time period for the transects on Figure Eight Island closest to Rich Inlet and to a lesser extent on Hutaff Island. Also, the frequent movement of the bar channel during the 1974-2007 time period produced a rather wide range of shoreline responses, particularly on the extreme north end of Figure Eight Island.

The following figures (Figures 6.6 to 6.15) provide plots of the average cumulative changes in the shoreline position for each group of transects on Figure Eight and Hutaff Islands. The figures include linear regression trends through the data for the complete record from 1938 to 2007 and the more recent time period 1974 to 2007 that included significant impacts of shifts in the position and alignment of the Rich Inlet ocean bar channel.

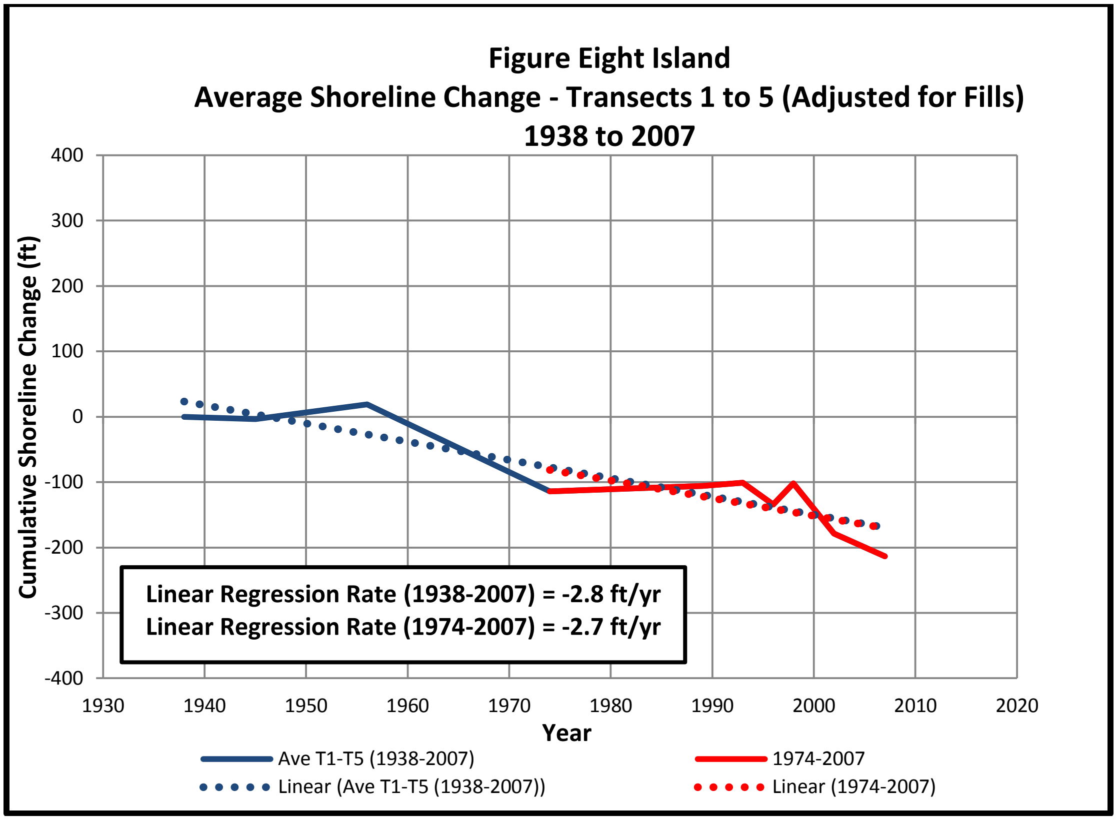

Figure 6.6. Figure Eight Island 1938-2007 average shoreline change for transects 1-5.

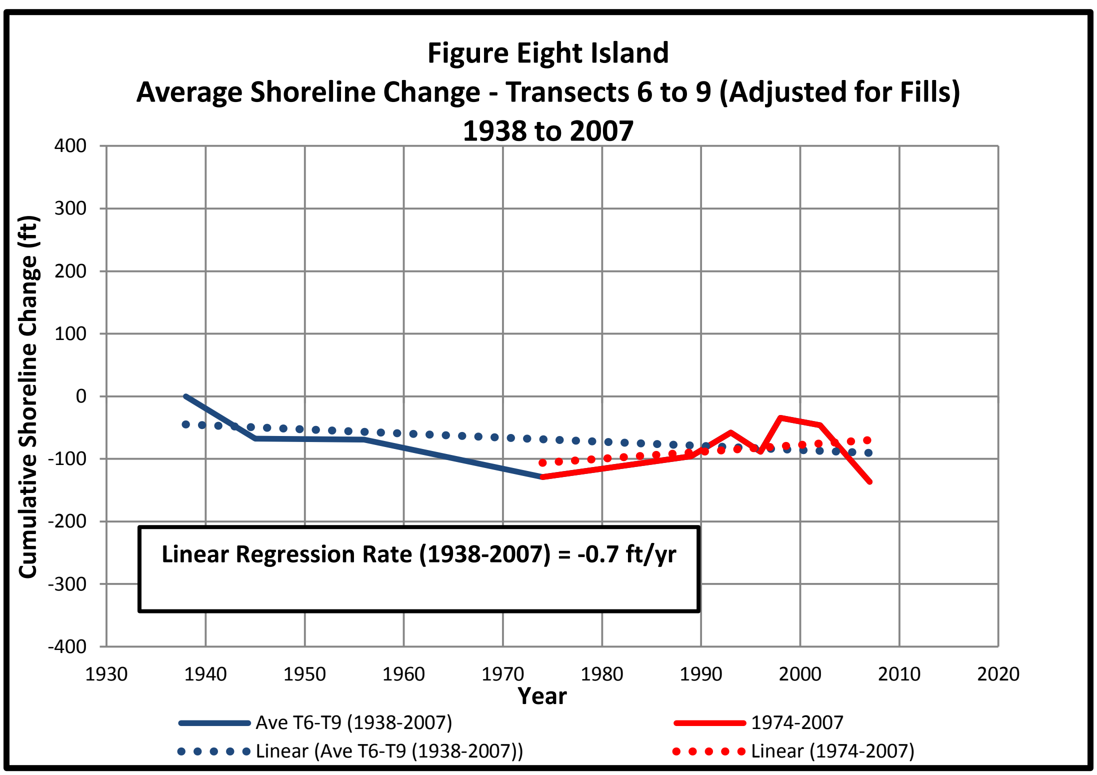

Figure 6.7. Figure Eight Island average shoreline change for transects 6-9.

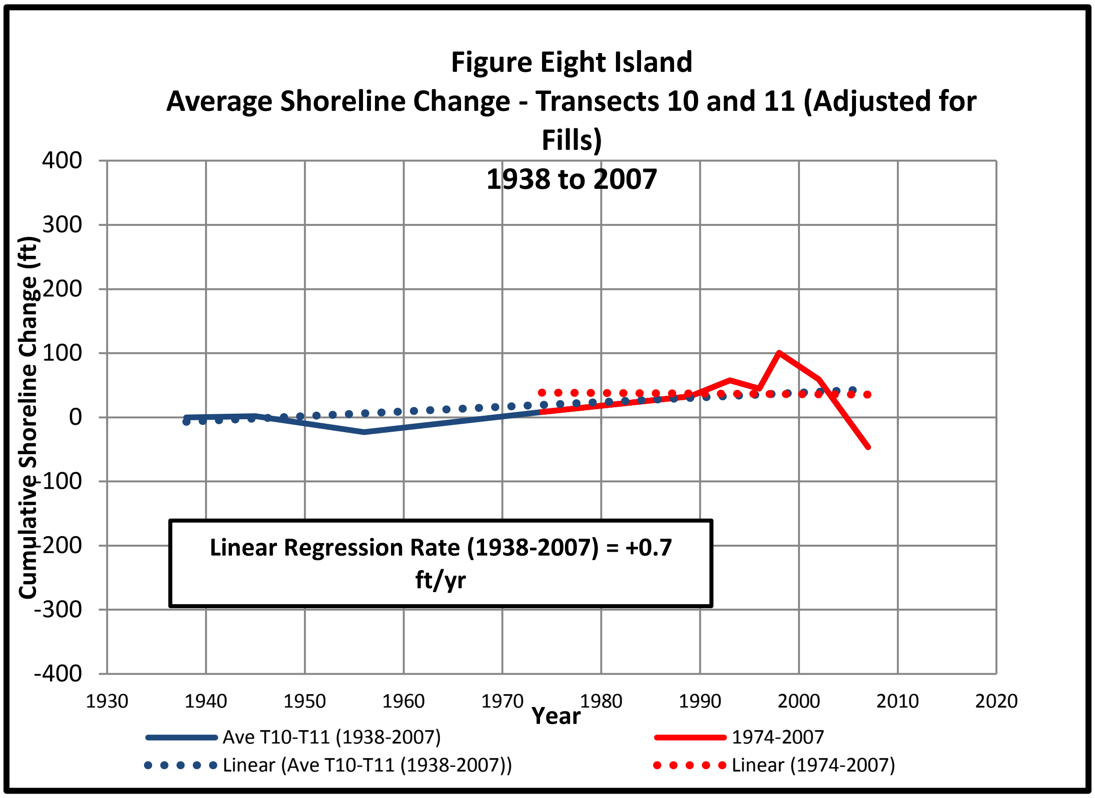

Figure 6.8. Figure Eight Island average shoreline change for transects 10-11.

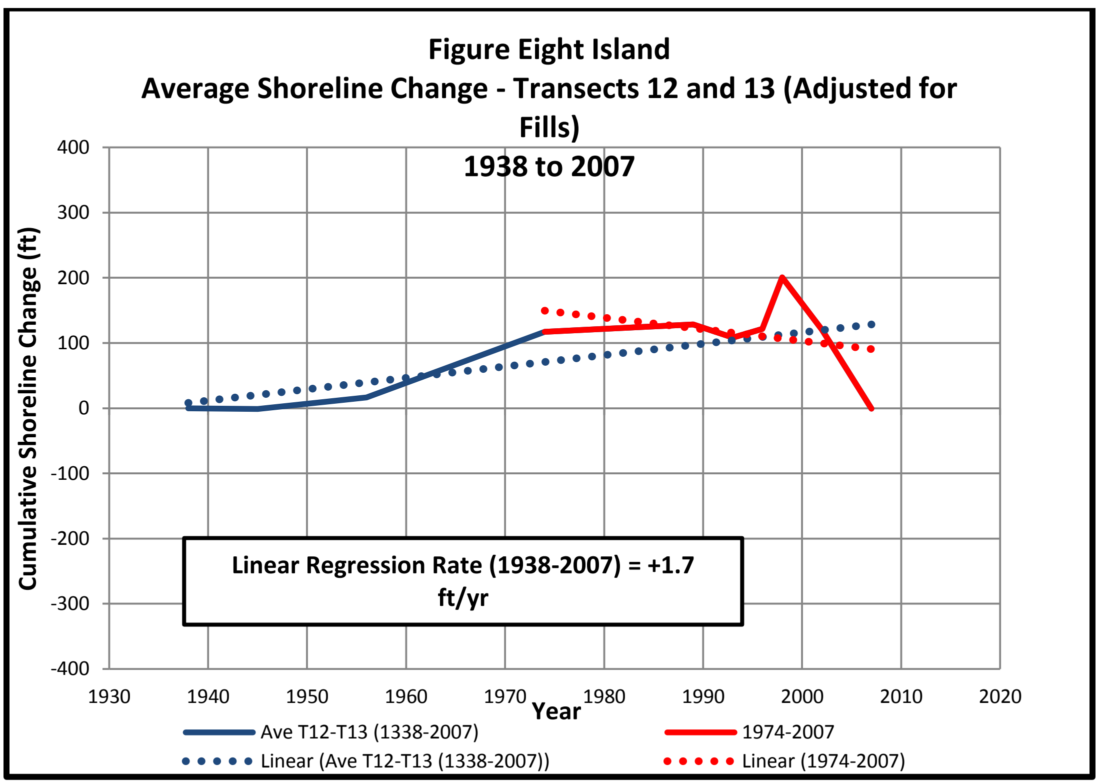

Figure 6.9. Figure Eight Island average shoreline change for transects 12-13.

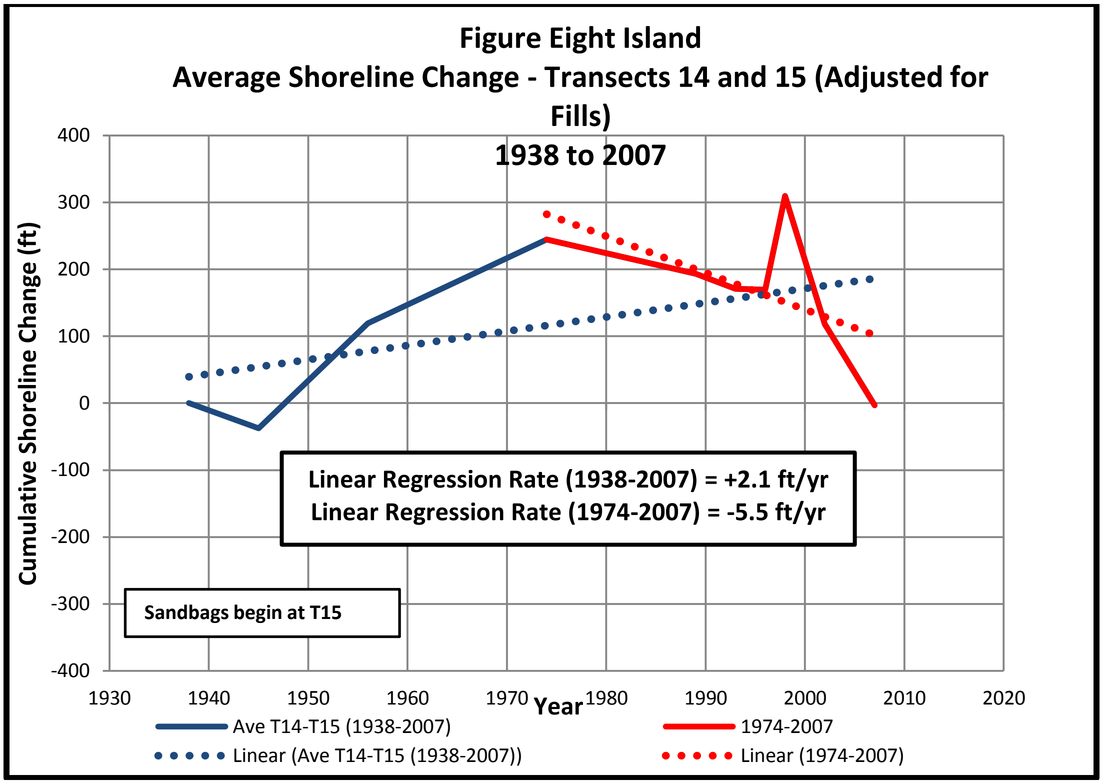

Figure 6.10. Figure Eight Island average shoreline change for transects 14-15.

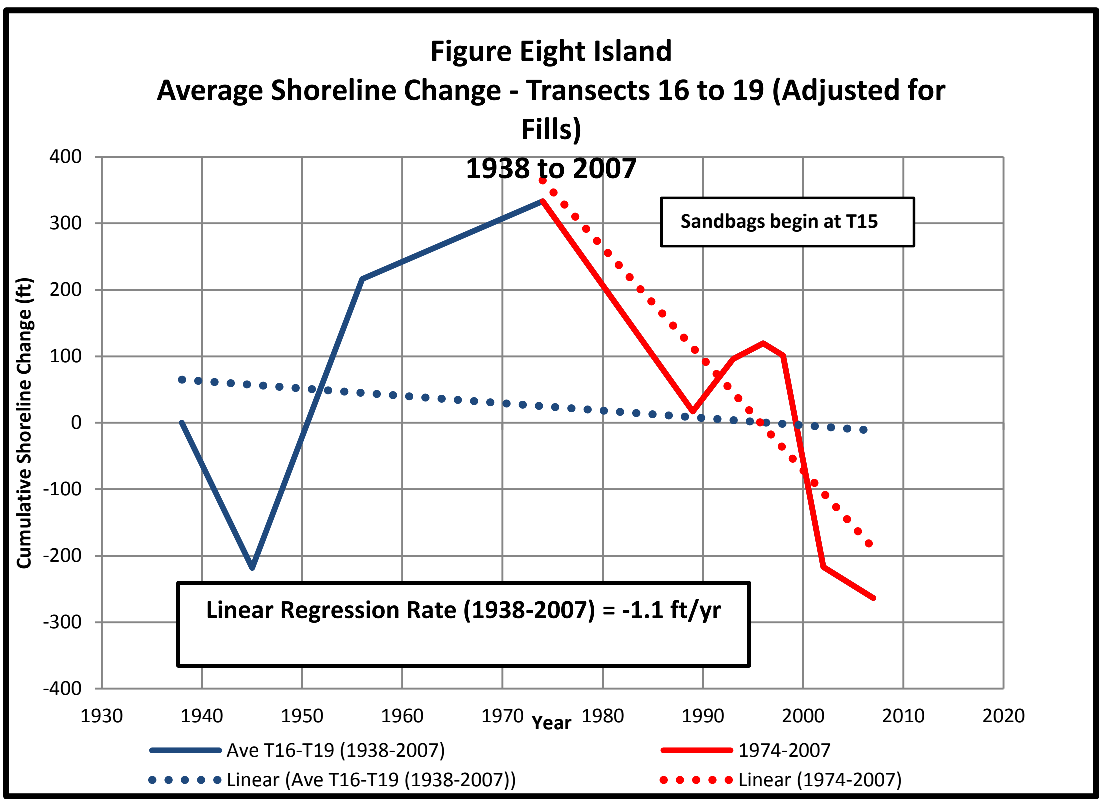

Figure 6.11. Figure Eight Island shoreline change for transects 16-19.

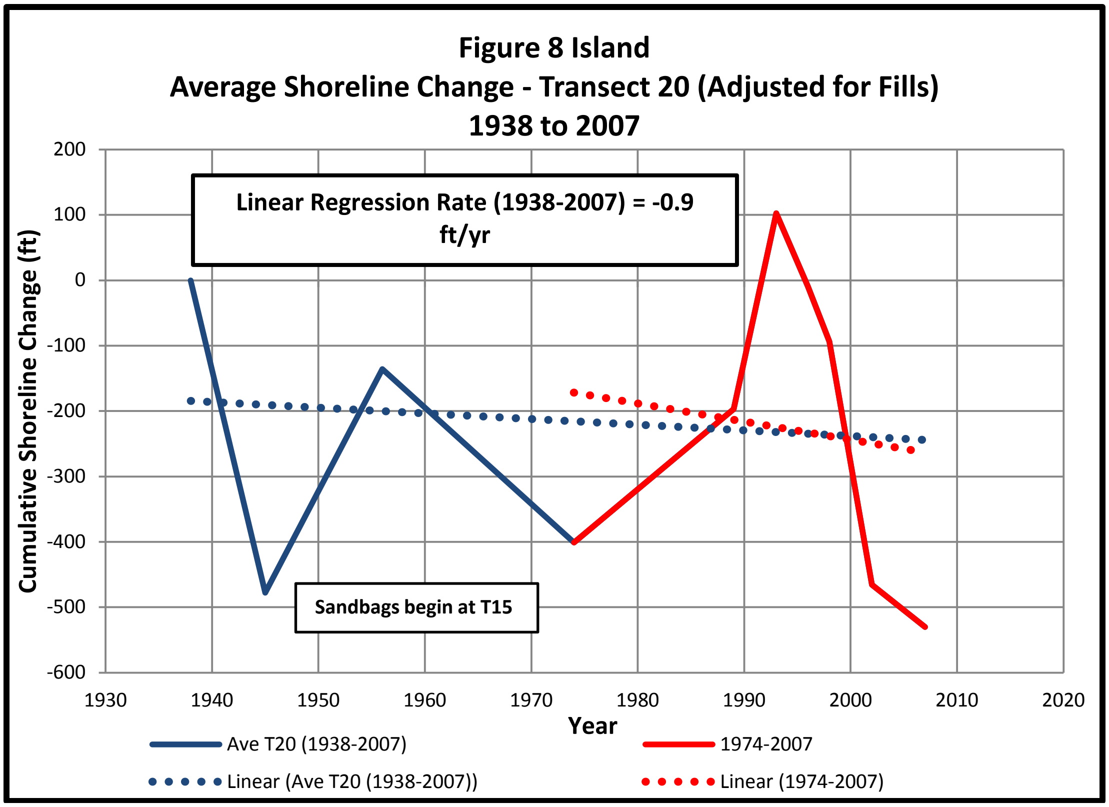

Figure 6.12. Figure Eight Island shoreline change for transect 20.

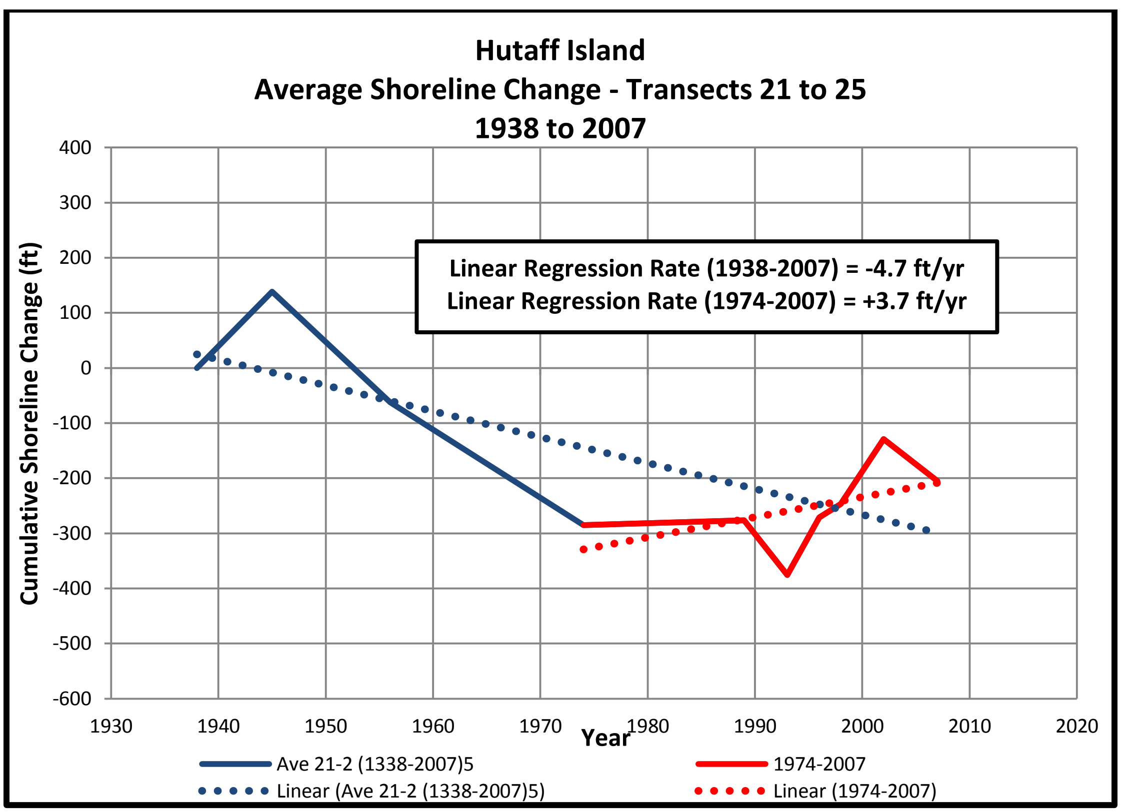

Figure 6.13. Hutaff Island average shoreline change for transects 21 to 25.

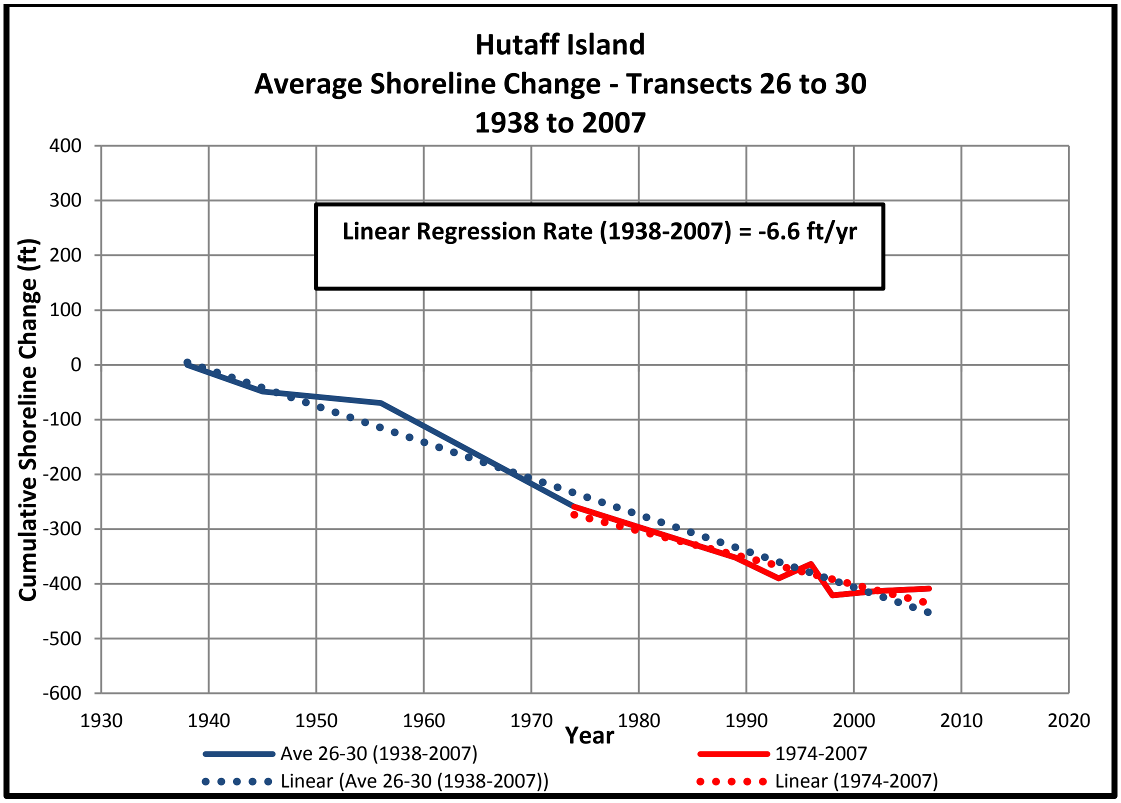

Figure 6.14. Hutaff Island average shoreline change for transects 26 to 30.

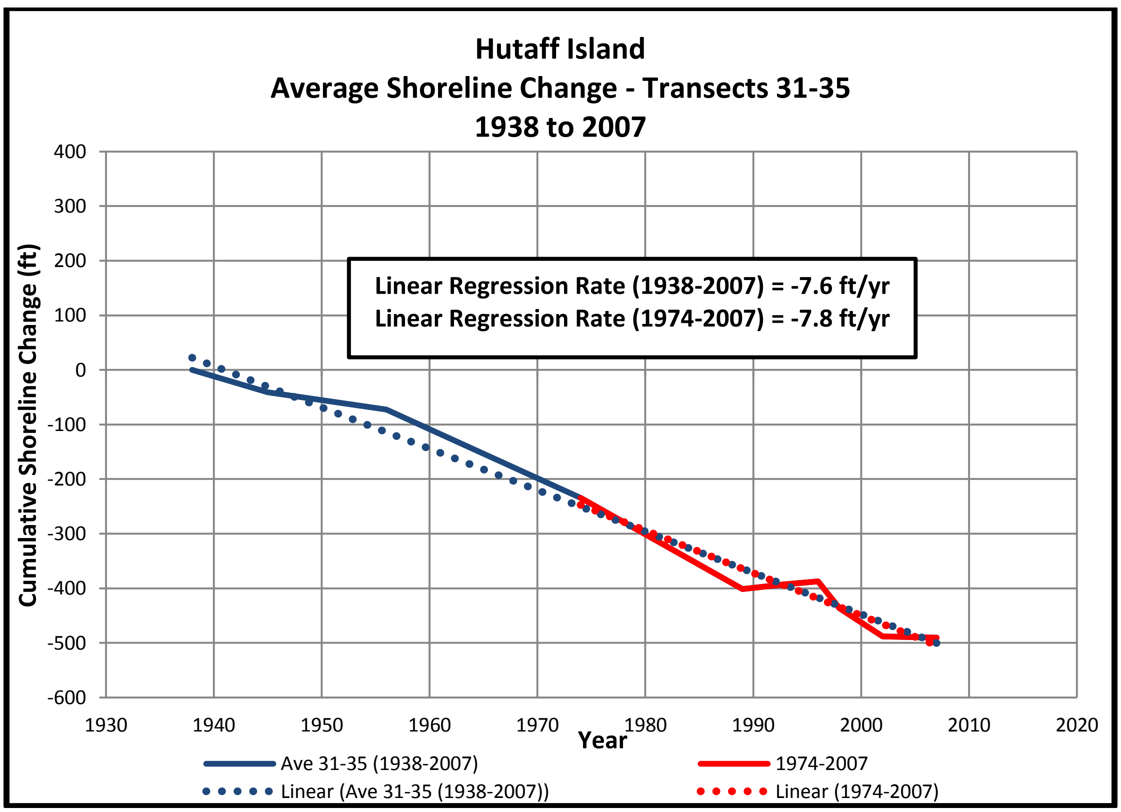

Figure 6.15. Hutaff Island average shoreline change for transects 31 to 35.

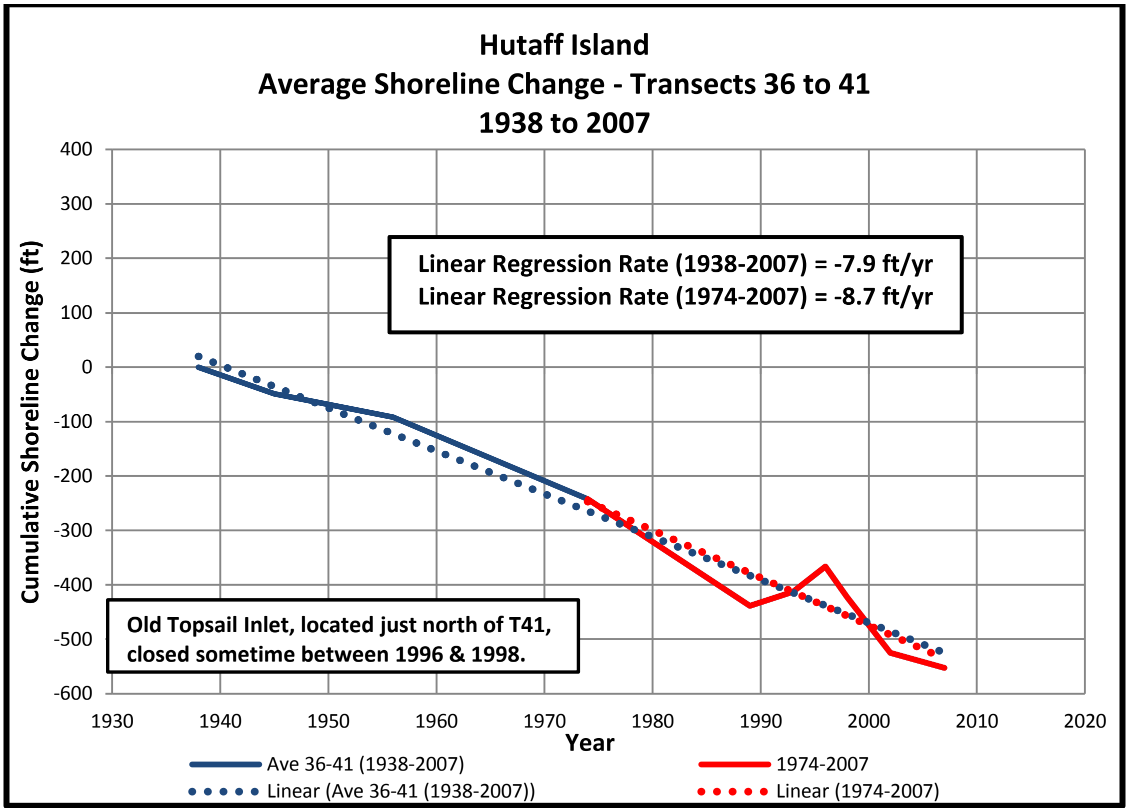

Figure 6.16. Hutaff Island shoreline change for transects 36 to 41.

A summary of the linear regression change rates for the two time periods, 1938-2007 and 1974-2007, for each transect group on Figure Eight Island and Hutaff Island is provided in Table 6.2. Also included in Table 6.2 is the maximum shoreline recession rate computed for each transect group, the time period the maximum rate occurred, the duration of the maximum rate, and the percent of time the two linear regression rates were exceeded.

Table 6.2. Summary of shoreline changes on Figure Eight Island and Hutaff Island.

Transect Group	Shoreline Length in Transect Group (ft)	Linear Regression Rate (ft/yr)		Maximum Shoreline Change			Percent of Time Linear Regression Rate Exceeded	
		1938-2007	1974-2007	Rate (ft/yr)	Time Period	Duration (yrs)	1938-2007	1974-2007
Figure Eight Island								
1-5	2,000	-2.8	-2.7	-19.2	1998-2002	4.01	45.3%	38.8%
6-9	2,000	-0.7	+1.1	-17.1	2002-2007	5.11	55.2%	38.8%
10-11	1,000	+0.7	-0.1	-20.7	2002-2007	5.11	34.4%	38.8%
12-13	1,000	+1.7	-1.8	-23.7	2002-2007	5.11	49.6%	38.7%
14-15	1,000	+2.1	-5.5	-47.7	1998-2002	4.01	54.5%	38.7%
16-19	2,000	-1.1	-16.8	-79.3	1998-2002	4.01	46.8%	58.3%
20	500	-0.9	-2.8	-92.8	1998-2002	4.01	57.4%	43.5%
Hutaff Island								
21-25	1,500	-4.7	+3.7	-29.1	1989-1993	3.41	55.6%	26.3%
26-30	2,000	-6.6	-4.9	-37.7	1996-1998	1.52	44.1%	61.2%
31-35	2,000	-7.6	-7.8	-32.3	1996-1998	1.52	56.6%	63.0%
36-41	2,500	-7.9	-8.7	-37.0	1996-1998	1.52	56.6%	63.0%

The linear regression rates developed for each transect group do not adequately represent the highly variable nature of the behavior of the shorelines over short time intervals. As shown in Table 6.2, the long-term linear regression rates for the 1938-2007 time period were exceeded around 45% to almost 60% of the time while the 1974-2007 rates were exceeded approximately 40% to 60% of the time. Therefore, the shoreline change thresholds developed for Figure Eight Island and Hutaff Island take into account the highly variable nature of shoreline behavior.

Shoreline Change Threshold Development.
In the absence of any new shoreline management initiatives on Figure Eight Island or significant changes in the rate of relative sea level rise, the behavior of the shorelines on both Figure Eight Island and Hutaff Island would be expected to exhibit characteristics similar that which has occurred in the past. This would include continuation of long-term trends, short-term fluctuations in the rates due to storms, and the impacts of changes in the morphology of Rich Inlet. The purpose of the shoreline change thresholds is to provide a basis for determining if the installation of a terminal groin on the north end of Figure Eight Island has an adverse impact on the behavior of the adjacent shorelines. If the shoreline change thresholds are exceeded, the Figure "8" Beach HOA would be responsible for taking mitigative and/or corrective measure to offset the negative impacts. Given the past variability in the behavior of the shoreline on both sides of Rich Inlet as demonstrated above, the shoreline change thresholds presented below include conditions that would reduce the possibility of premature reaction to short-term shoreline changes yet still provide a reasonable basis for determining if negative impacts are occurring. However, since the thresholds would not totally eliminate possible misinterpretations of the cause of excessive negative shoreline impacts, there will be some risk that the permit applicant may be required to mitigate for shoreline impacts that are not totally related to the installation of the terminal groin.

Given the influence Rich Inlet has on the behavior of the ocean shorelines of Figure Eight Island and Hutaff Island, and the recent tendency for the inlet's ocean bar channel to be situated near the south end of Hutaff Island, the measured shoreline changes for the 1974 to 2007 time period were used to establish the shoreline change thresholds. Specifically, the expected future changes in the shoreline within each transect group are based on the 1974-2007 linear regression shoreline change rates with allowances included to account for past variability in shoreline behavior over shorter time increments.

Expected Future Shoreline Changes.

The expected future shoreline changes within each transect group in the absence of any impacts associated with the terminal groin are defined by the linear regression rate computed for the 1974-2007 time period. For example, the linear regression shoreline change rate for transect group T1-T5 on Figure Eight Island is -2.7 feet/year and the expected change in the shoreline position after 30 years would be a recession of 81 feet. Given the variability in the behavior of the shorelines, an allowable variation in the shoreline change, or threshold boundaries, was based on 90% confidence limits associated with the 1974-2007 linear regression rate. The 90% confidence limit refers to the likelihood future shoreline changes for each transect group will be within the specified confidence interval, i.e. 90%. For transect group T1-T5, the computed 90% confidence interval for the shoreline change rate has an upper limit of +0.1 foot/year and a lower limit of -5.5 feet/year. Therefore in this example, the future change in the shoreline position for transect group T1-T5 would be expected to fall within a range of 3 feet of accretion to 165 feet of erosion at the end of 30 years with a 90% degree of confidence. The 90% confidence limits for the 1974-2007 linear regression shoreline change rates for all transect on Figure Eight Island and Hutaff Island are provided in Table 6.3.

Table 6.3. 90% Confidence intervals for the 1974-2007 linear regression shoreline change rates for each transect group on Figure Eight Island and Hutaff Island.

Transect Group	1974-2007 Linear Regression Rate & 90% Confidence Limits		
	Upper Limit ft/yr	Linear Regression Rate ft/yr	Lower Limit ft/yr
Figure Eight Island			
T1-T5	+0.1	-2.7	-5.5
T6-T9	+4.3	+1.1	-2,1
T10-T11	+3.8	-0.1	-4.0
T12-T13	+3.0	-1.8	-6.5
T14-T15	+1.2	-5.5	-12.2
T16-T19	-7.9	-16.8	-25.6
T20	+22.2	-0.4	-23.0
Hutaff Island			
T21-T25	+9.2	+3.7	-1.8
T26-T30	-3.1	-4.9	-6.7
T31-T35	-5.8	-7.8	-9.8
T36-T41	-5.0	-8.7	-12.5

The linear regression shoreline change rate for each transect group was used to project expected shoreline changes within each transect group over a 30-year period following the installation of a terminal groin on the north end of Figure Eight Island. These expected shoreline changes are provided on Figures 6.17 to 6.27. An envelope covering a range of possible variations in the shoreline changes was also determined using the upper and lower 90% confidence limits for the shoreline change rates given in Table 6.3. The resulting expected shoreline changes along with the 90% upper and lower limits of these expected changes are plotted on Figures 6.17 to 6.27. In each of these plots, future shoreline changes begin with the construction of the terminal groin and extend 30 years into the future.

Following the construction of the terminal groin, cumulative shoreline changes within each transect group would be determined based on the results of the shoreline monitoring program described below. The post-construction shoreline changes would be compared to the expected future shoreline change based on the pre-project shoreline change rates. As an example of how measured shoreline changes post-terminal groin construction would be compared to the expected shoreline change and the 90% confidence interval, the shoreline changes observed on Figure Eight Island and Hutaff Island between 1974 to 2007 were used to develop theoretical observed shoreline changes within each transect group following construction of the terminal groin. These "observed" shoreline changes are superimposed on Figures 6.17 to 6.27.

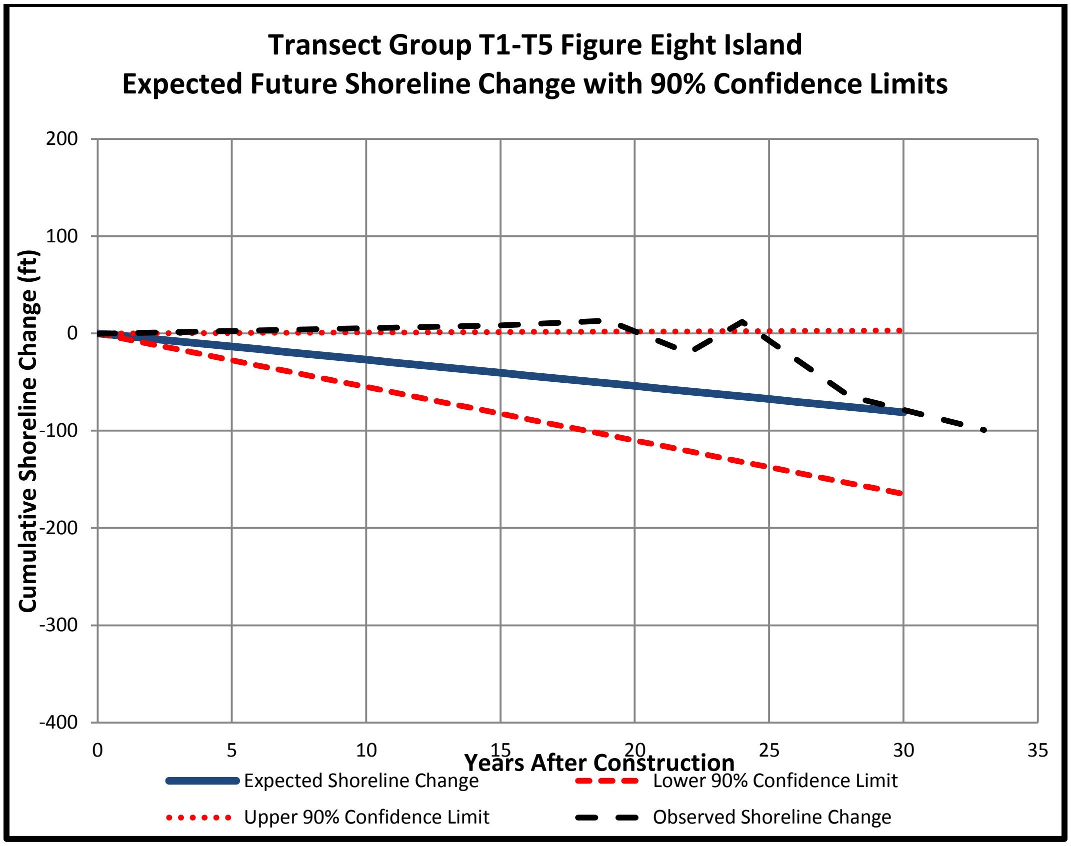

Figure 6.17. Transect Group T1-T5, Figure Eight Island – Expected future shoreline change.

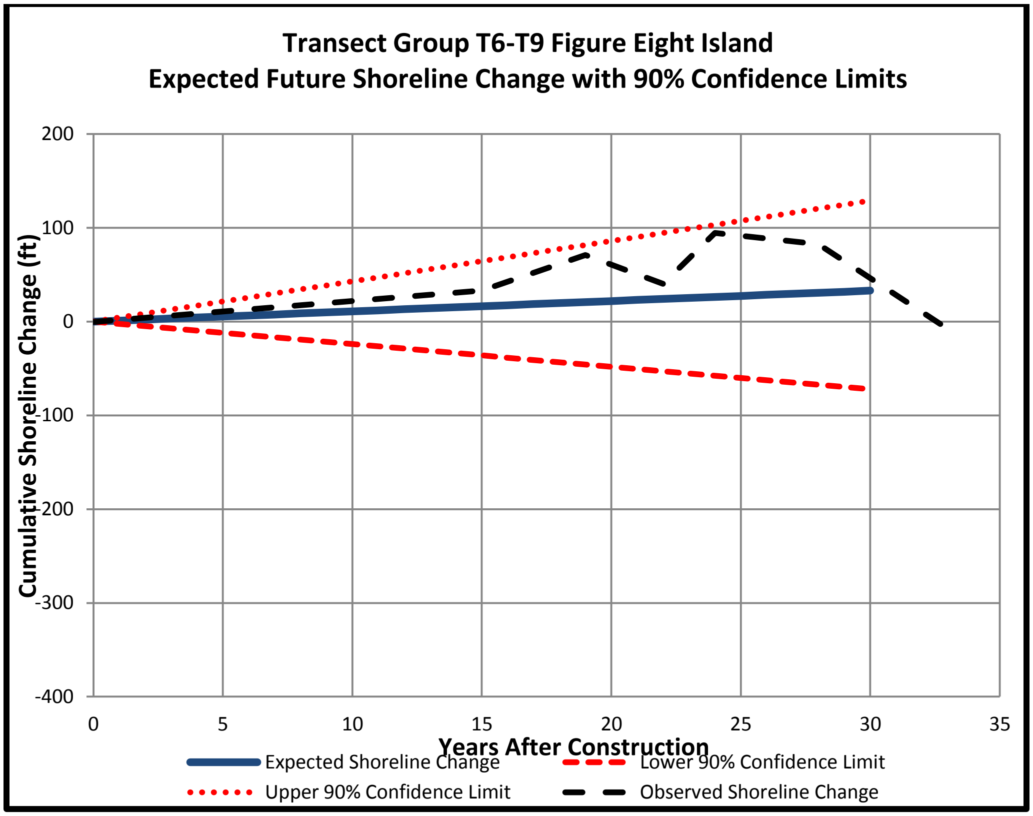

Figure 6.18. Transect Group T6-T9, Figure Eight Island – Expected future shoreline change.

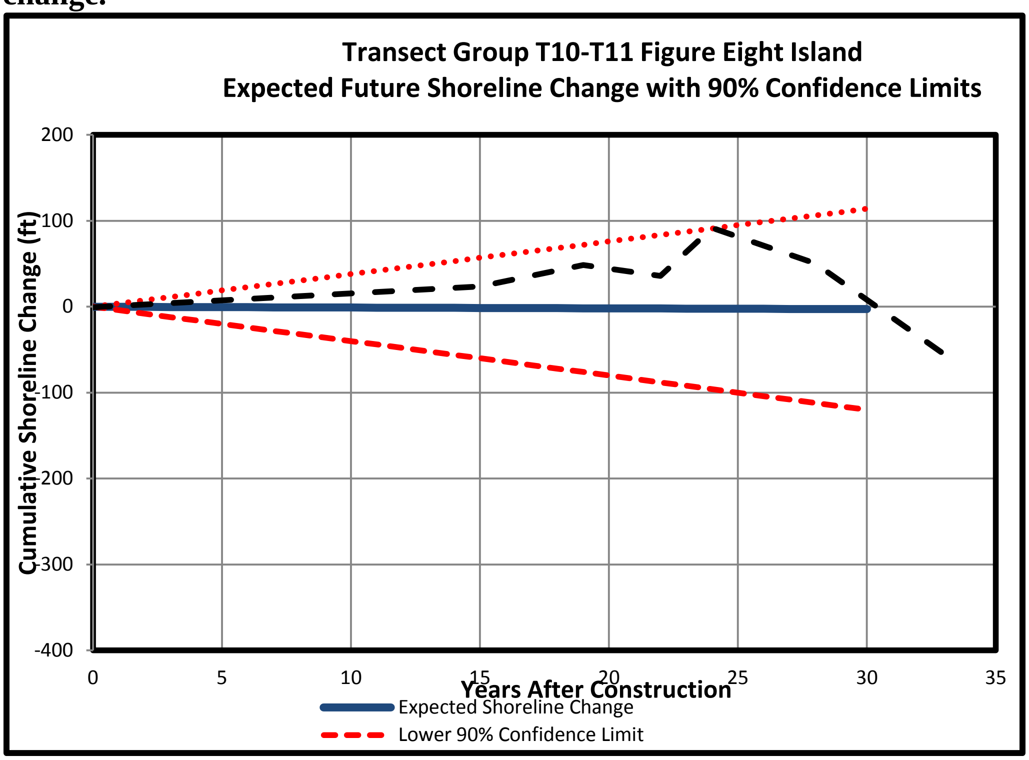

Figure 6.19. Transect Group T10-T11, Figure Eight Island – Expected future shoreline change.

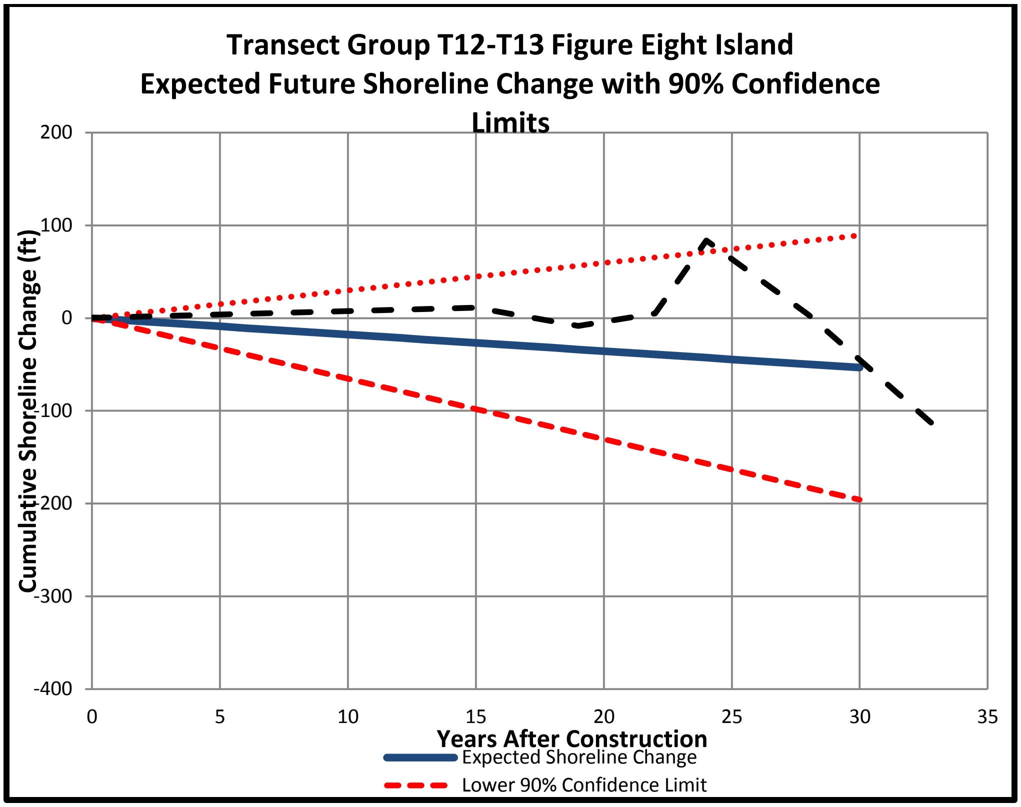

Figure 6.20. Transect Group T12-T13, Figure Eight Island – Expected future shoreline change.

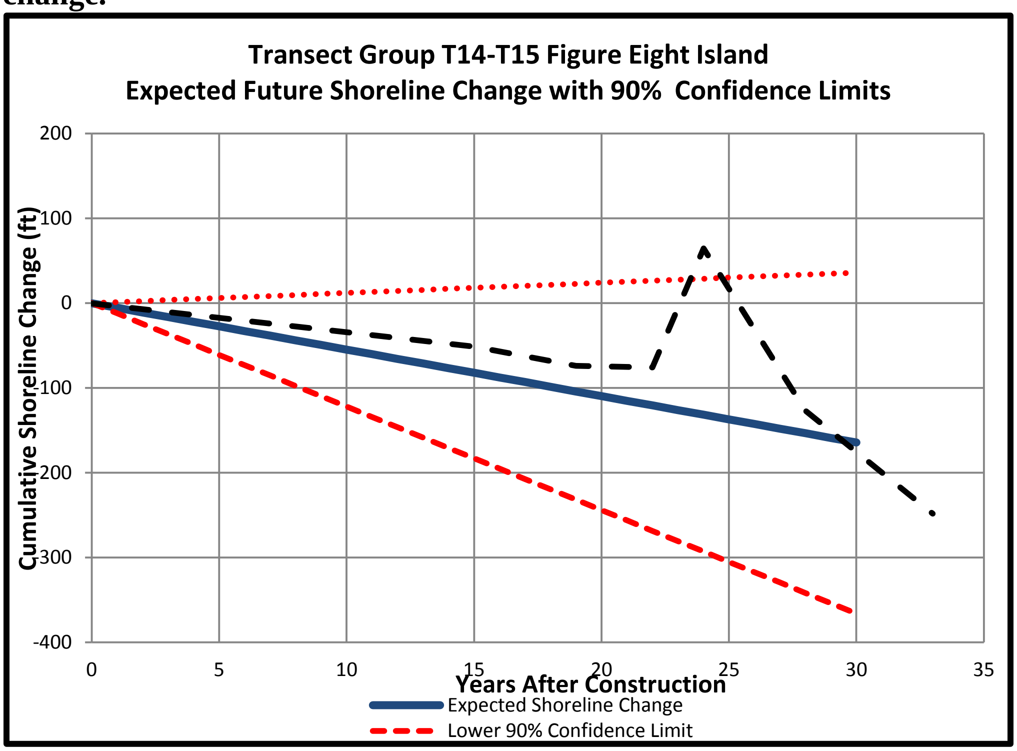

Figure 6.21. Transect Group T14-T15, Figure Eight Island – Expected future shoreline change.

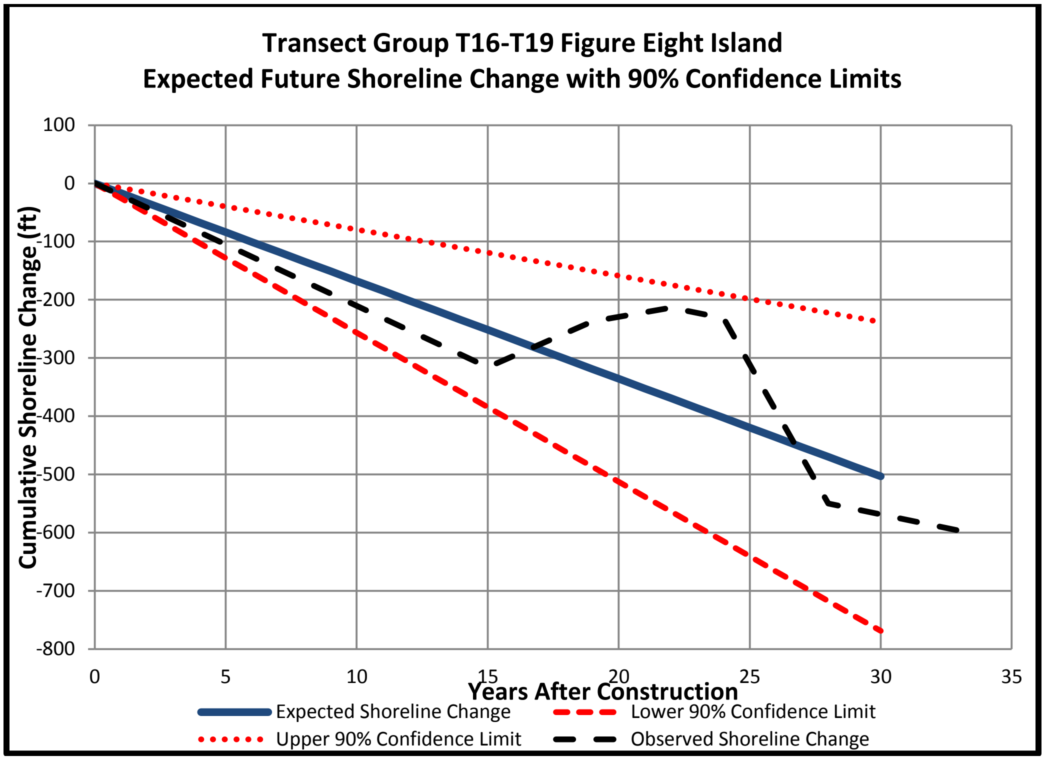

Figure 6.22. Transect Group T16-T19, Figure Eight Island – Expected future shoreline change.

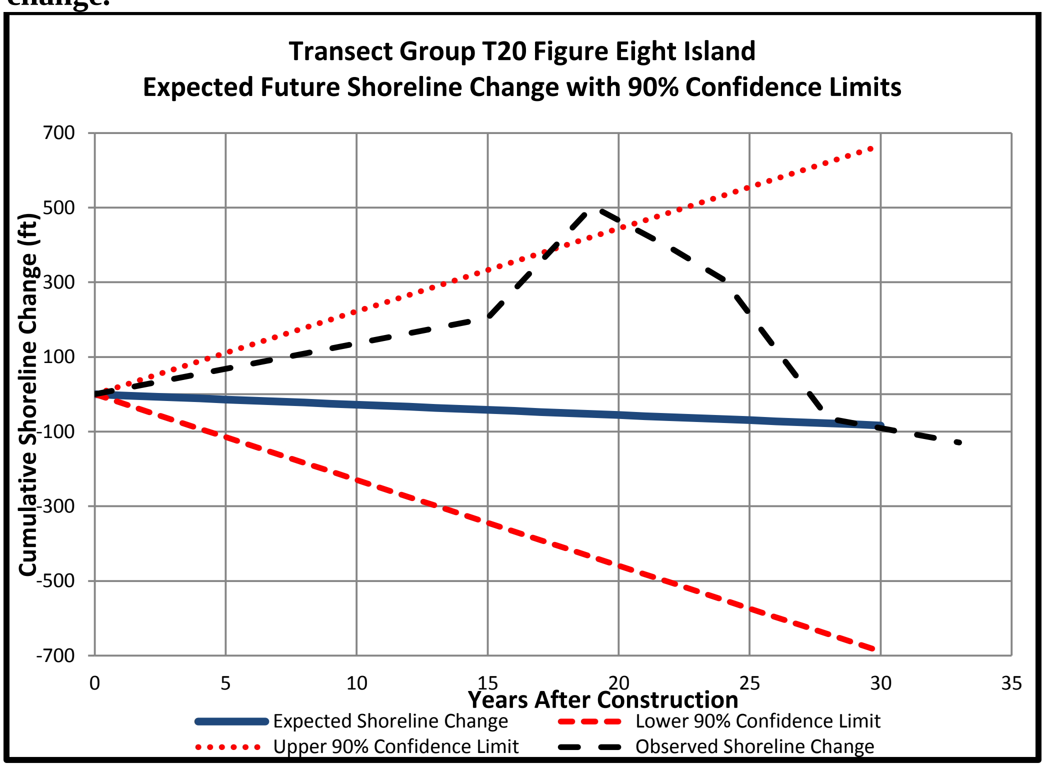

Figure 6.23. Transect Group T20, Figure Eight Island – Expected future shoreline change.

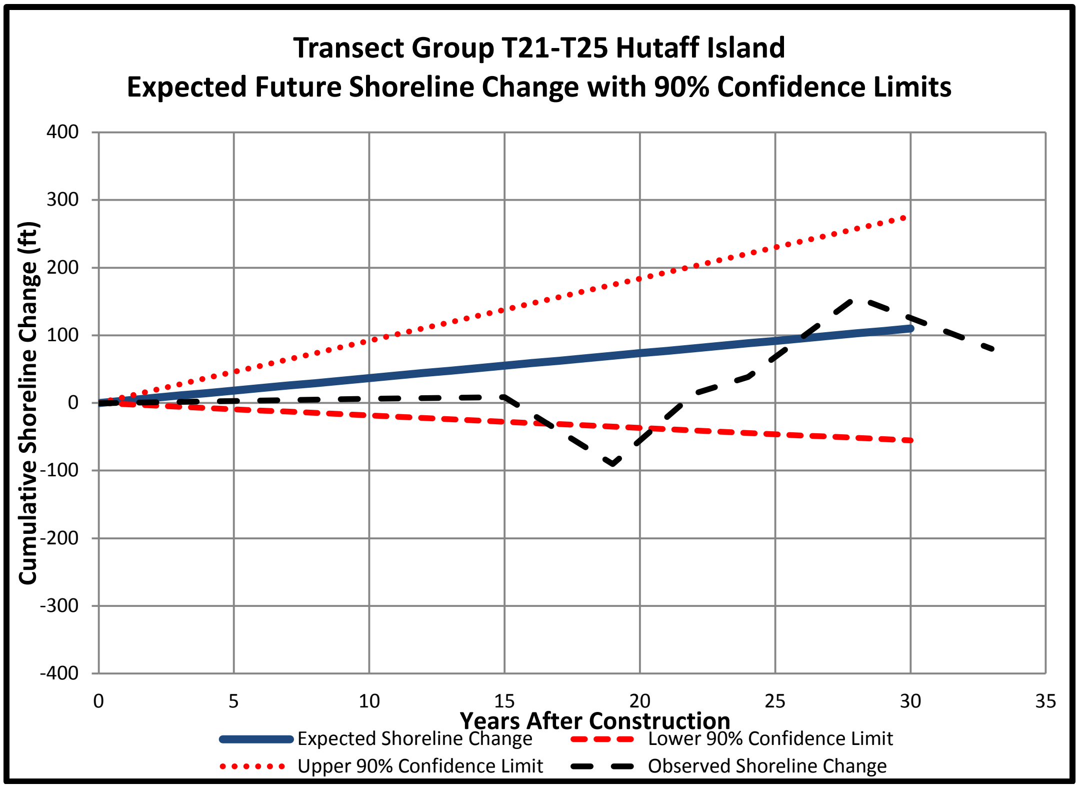

Figure 6.24. Transect Group T21-T25, Hutaff Island – Expected future shoreline change.

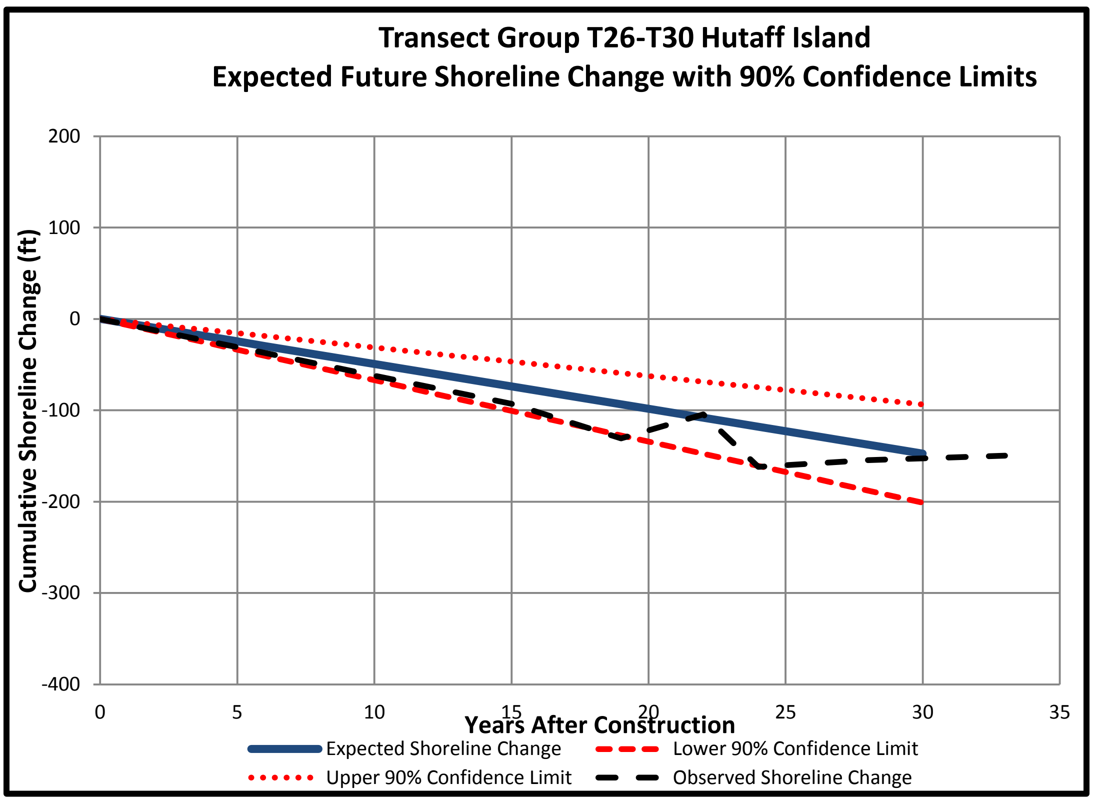

Figure 6.25. Transect Group T26-T30, Hutaff Island – Expected future shoreline change.

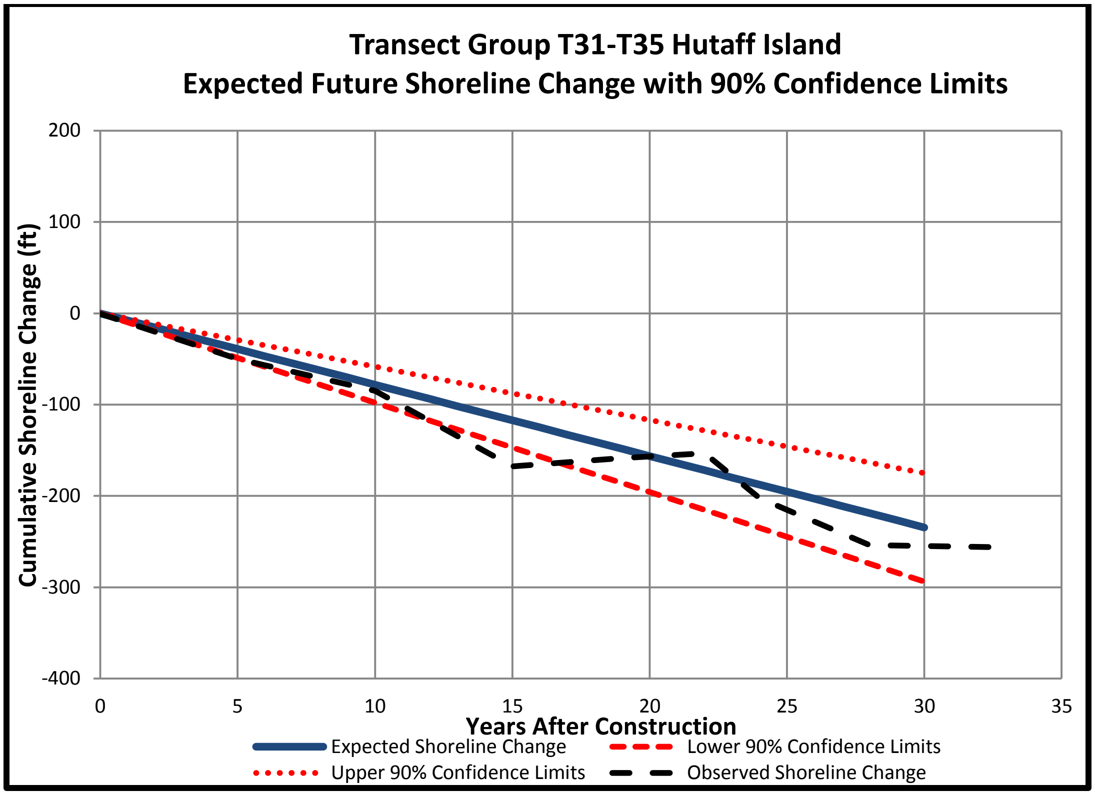

Figure 6.26. Transect Group T31-T35, Hutaff Island – Expected future shoreline change.

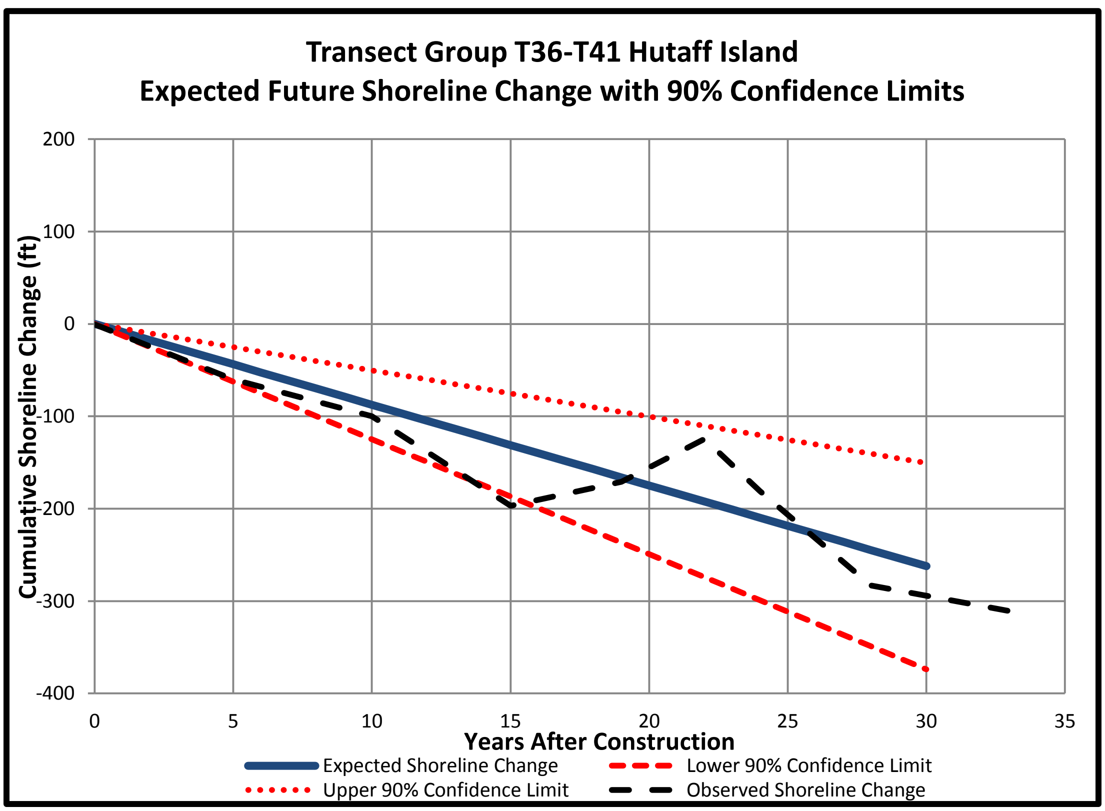

Figure 6.27. Transect Group T36-T41, Hutaff Island – Expected future shoreline change.

Response Trigger.

Should the cumulative shoreline changes within two adjacent transect groups exceed the lower 90% confidence limit, as is the case for transect groups T31-T35 and T36-T41on Hutaff Island used in the examples on Figures 6.17 to 6.27, the shoreline behavior would be deemed to have exceeded the shoreline change threshold for those two transect groups. However, given the known variability in the shoreline behavior, a verification period of two (2) years would follow to determine if the observed shoreline changes continue to exceed the lower 90% confidence limit in both transect groups. If the lower 90% shoreline change confidence limit continues to be exceeded for the entire 2-year confirmation period, then mitigative measures would be in order. If, however, the shoreline recovers and the cumulative shoreline change within either transect group becoming less than the lower 90% confidence limit any time during the 2-year confirmation period, the threshold would be re-set and no mitigation would be required.

Monitoring Plan.

Post-construction change analysis in the shorelines of Figure Eight Island and Hutaff Island would be accomplished twice a year for at least two years post-construction. At the end of two years, the monitoring analysis would be reassessed by the federal and state permitting agencies and a decision made as to whether or not to continue twice yearly surveys or decrease the coverage to once a year.

Shoreline changes would be measured from georectified aerial photographs with a scale of 1 inch = 200 feet. The shoreline would be defined by the wet/dry line on the photographs and measurements would be made at each of the same transects used to develop the shoreline change thresholds. Annual monitoring reports will be prepared and will include the aerial photographs, shoreline change results for each transect, average changes for each transect group, and plots of the cumulative post-construction shoreline changes superimposed on the shoreline change threshold curves. The report will identify if any of the thresholds for the transect groups have been exceeded and will indicate if a confirmation period has been initiated or if the shoreline change thresholds have been exceeded beyond a confirmation period. The monitoring reports will be provided to both the federal and state permitting agencies.

The aerial photographic analysis of shoreline changes will be supplemented by a continuation of the existing profile survey monitoring program being conducted by the Figure “8” Beach HOA. The existing profile monitoring program is conducted once a year and covers all of Figure Eight Island and the south end of Hutaff Island. Profile spacing is generally 1,000 feet, however, closer profile stationing of 250 feet is used for the north end of Figure Eight Island between baseline station 70+00 and Rich Inlet. The beach profiles extend from the dune seaward to approximately the 30-foot depth contour. The survey monitoring program also includes perpendicular and horizontal transects in Rich Inlet.

Mitigation Measures.

The general response for mitigating shoreline erosion impacts that exceed the shoreline change thresholds would be in the form of beach nourishment. The beach profile surveys described above would be used to determine the volume of material required to restore the post-construction shoreline change to a condition above the shoreline change threshold. Material needed to restore the shoreline would be derived from the existing permit area in Nixon Channel or possible the three northern upland disposal sites situated adjacent to the AIWW.

In the event the negative impacts of the terminal groin cannot be mitigated with beach nourishment or possible modifications to the design of the terminal groin, the terminal groin would be removed. Removal would entail the extraction of the sheet pile from the shore anchorage section and the complete removal of all stone, including bedding, underlayer, and armor stone as well as the entire structure seaward of the MHW line. All of the terminal groin construction materials would be transported off the island and placed in an appropriate storage site. The terminal groin material, particularly the sheet pile and stone, would have some salvage value; however the opinion on the cost for removal of the terminal groin, excluding any salvage value, is $2.5 million.

Attachment 1
Shoreline Change Thresholds

Table A-1

Figure Eight Island Shoreline Change Information	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T1 - T5 (2,000 ft)										
T1 incremental change		21	36	-155	-3	47	24	2	39	-26
fill width during time increment		0	0	0	0	42	36	27	99	0
T1 Incr. change adjusted for fill	0	21	36	-155	-3	5	-12	-25	-60	-26
T1 change since 1938		21	57	-98	-101	-96	-108	-133	-193	-219
T2 incremental change		30	16	-155	6	46	2	60	12	-31
fill width during time increment		0	0	0	0	42	36	27	99	0
T2 Incr. change adjusted for fill	0	30	16	-155	6	4	-34	33	-87	-31
T2 change since 1938		30	47	-109	-103	-100	-133	-101	-188	-218
T3 incremental change		-4	31	-143	16	56	-3	70	16	-42
fill width during time increment		0	0	0	0	42	36	27	99	0
T3 Incr. change adjusted for fill	0	-4	31	-143	16	14	-39	43	-83	-42
T3 change since 1938		-4	27	-116	-100	-87	-126	-83	-166	-208
T4 incremental change		-14	13	-117	11	56	-18	91	4	-30
fill width during time increment		0	0	0	0	42	36	27	99	0
T4 Incr. change adjusted for fill	0	-14	13	-117	11	14	-54	64	-95	-30
T4 change since 1938		-14	-1	-119	-108	-94	-148	-84	-179	-209
T5 incremental change		-52	18	-95	13	30	8	73	40	-44
fill width during time increment		0	0	0	0	42	36	27	99	0
T5 Incr. change adjusted for fill	0	-52	18	-95	13	-12	-28	46	-59	-44
T5 change since 1938		-52	-34	-129	-116	-128	-156	-110	-169	-213
Averages for T1 - T5										
Incremental Change		**-4**	**23**	**-133**	**9**	**47**	**3**	**59**	**22**	**-35**
fill width during time increment		**0**	**0**	**0**	**0**	**42**	**36**	**27**	**99**	**0**
Incremental change adjusted for fill	**0**	**-4**	**23**	**-133**	**9**	**5**	**-33**	**32**	**-77**	**-35**
Change since 1938-fill adjusted		**-4**	**19**	**-114**	**-106**	**-101**	**-134**	**-102**	**-179**	**-213**
Average incremental rate (ft/yr)		**-0.6**	**2.0**	**-7.1**	**0.6**	**1.5**	**-9.7**	**21.1**	**-19.2**	**-6.8**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T6 - T9 (2,000 ft)										
T6 incremental change		-82	20	-73	-2	30	47	45	25	-39
fill width during time increment		0	0	0	0	0	36	27	39	0
T6 Incr. change adjusted for fill		-82	20	-73	-2	30	11	18	-14	-39
T6 change since 1938	0	-82	-62	-135	-137	-107	-96	-77	-91	-130
T7 incremental change		-61	-3	-81	39	32	8	82	32	-56
fill width during time increment		0	0	0	0	0	36	27	39	41
T7 Incr. change adjusted for fill		-61	-3	-81	39	32	-28	55	-7	-97
T7 change since 1938	0	-61	-64	-145	-106	-74	-103	-47	-55	-151
T8 incremental change		-72	-6	-55	50	40	0	95	12	-65
fill width during time increment		0	0	0	0	0	36	27	39	41
T8 Incr. change adjusted for fill		-72	-6	-55	50	40	-36	68	-27	-106
T8 change since 1938	0	-72	-78	-133	-83	-43	-80	-12	-39	-145
T9 incremental change		-56	-17	-32	47	51	-34	103	39	-79
fill width during time increment		0	0	0	0	0	36	27	39	41
T9 Incr. change adjusted for fill		-56	-17	-32	47	51	-70	76	0	-120
T9 change since 1938	0	-56	-73	-104	-58	-7	-77	-1	-1	-121
Averages for T6 - T9										
Incremental Change		**-68**	**-2**	**-60**	**33**	**38**	**5**	**81**	**27**	**-60**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**31**
Incremental change adjusted for fill		**-68**	**-2**	**-60**	**33**	**38**	**-31**	**54**	**-12**	**-90**
Change since 1938-fill adjusted	**0**	**-68**	**-69**	**-129**	**-96**	**-58**	**-89**	**-34**	**-46**	**-137**
Average incremental rate (ft/yr)		**-9.9**	**-0.1**	**-3.2**	**2.2**	**11.2**	**-9.0**	**35.7**	**-3.0**	**-17.7**
T10 - T11 (1,000 ft)										
T10 incremental change		-5	-31	10	29	37	2	79	16	-58
fill width during time increment		0	0	0	0	0	36	27	39	41
T10 Incr. change adjusted for fill		-5	-31	10	29	37	-34	52	-23	-99
T10 change since 1938	0	-5	-36	-26	3	40	6	57	35	-64
T11 incremental change		9	-19	53	19	13	45	87	-21	-71
fill width during time increment		0	0	0	0	0	36	27	39	41
T11 Incr. change adjusted for fill		9	-19	53	19	13	9	60	-60	-112
T11 change since 1938	0	9	-10	43	62	75	84	144	84	-28

Averages for T10 - T11										
Incremental Change		**2**	**-25**	**32**	**24**	**25**	**23**	**83**	**-2**	**-65**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**2**	**-25**	**32**	**24**	**25**	**-13**	**56**	**-41**	**-106**
Change since 1938-fill adjusted	**0**	**2**	**-23**	**9**	**33**	**58**	**45**	**101**	**59**	**-46**
Average incremental rate (ft/yr)		**0.3**	**-2.3**	**1.7**	**1.6**	**7.3**	**-3.7**	**36.6**	**-10.3**	**-20.7**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T12 - T13 (1,000 ft)										
T12 incremental change		12	-8	90	14	-2	53	73	-5	-86
fill width during time increment		0	0	0	0	0	36	27	39	41
T12 Incr. change adjusted for fill		12	-8	90	14	-2	17	46	-44	-127
T12 change since 1938	0	12	4	95	109	106	124	170	126	-1
T13 incremental change		-14	43	112	8	-37	45	139	-78	-74
fill width during time increment		0	0	0	0	0	36	27	39	41
T13 Incr. change adjusted for fill		-14	43	112	8	-37	9	112	-117	-115
T13 change since 1938	0	-14	29	140	148	111	120	232	115	0
Averages for T12 - T13										
Incremental Change		**-1**	**18**	**101**	**11**	**-20**	**49**	**106**	**-41**	**-80**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-1**	**18**	**101**	**11**	**-20**	**13**	**79**	**-80**	**-121**
Change since 1938-fill adjusted	**0**	**-1**	**17**	**117**	**128**	**109**	**122**	**201**	**121**	**-1**
Average incremental rate (ft/yr)		**-0.2**	**1.6**	**5.4**	**0.7**	**-5.8**	**3.9**	**51.7**	**-20.0**	**-23.7**
T14 - T15 (1,000 ft)										
T14 incremental change		-26	114	140	-33	-36	14	195	-134	-88
fill width during time increment		0	0	0	0	0	36	27	39	41
T14 Incr. change adjusted for fill		-26	114	140	-33	-36	-22	168	-173	-129
T14 change since 1938	0	-26	88	228	195	159	137	306	133	4
T15 incremental change		-49	199	111	-69	-9	54	139	-171	-73
fill width during time increment		0	0	0	0	0	36	27	39	41
T15 Incr. change adjusted for fill		-49	199	111	-69	-9	18	112	-210	-114
T15 change since 1938	0	-49	150	261	192	183	201	313	103	-10

Averages for T14 - T15										
Incremental Change		**-38**	**157**	**125**	**-51**	**-23**	**34**	**167**	**-152**	**-80**
fill width during time increment		**0**	**0**	**0**	**0**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-38**	**157**	**125**	**-51**	**-23**	**-2**	**140**	**-191**	**-121**
Change since 1938-fill adjusted	0	-38	119	245	194	171	169	310	118	-3
Average incremental rate (ft/yr)		**-5.5**	**14.0**	**6.7**	**-3.4**	**-6.6**	**-0.5**	**91.9**	**-47.7**	**-23.7**

Table A-1

Figure Eight Island Shoreline Change Information

	Mar-38	**Jan-45**	**Mar-56**	**Dec-74**	**Oct-89**	**Mar-93**	**Aug-96**	**Feb-98**	**Feb-02**	**Apr-07**
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T16 - T19 (2,000 ft)										
T16 incremental change		-101	292	78	-42	19	63	83	-213	-68
fill width during time increment		0	0	0	179	0	36	27	39	41
T16 Incr. change adjusted for fill		-101	292	78	-221	19	27	56	-252	-109
T16 change since 1938	0	-101	191	269	48	67	95	151	-101	-210
T17 incremental change		-167	387	100	-97	69	78	20	-277	-4
fill width during time increment		0	0	0	179	0	36	27	39	41
T17 Incr. change adjusted for fill		-167	387	100	-276	69	42	-7	-316	-45
T17 change since 1938	0	-167	220	320	44	113	155	148	-168	-213
T18 incremental change		-251	531	140	-218	103	73	-36	-304	13
fill width during time increment		0	0	0	179	0	36	27	39	41
T18 Incr. change adjusted for fill		-251	531	140	-397	103	37	-63	-343	-28
T18 change since 1938	0	-251	280	420	24	127	164	101	-241	-270
T19 incremental change		-353	528	150	-192	124	24	-33	-322	36
fill width during time increment		0	0	0	179	0	36	27	39	41
T19 Incr. change adjusted for fill		-353	528	150	-371	124	-12	-60	-361	-5
T19 change since 1938	0	-353	174	324	-47	77	65	5	-357	-362
Averages for T16 - T19										
Incremental Change		**-218**	**434**	**117**	**-137**	**79**	**60**	**9**	**-279**	**-6**
fill width during time increment		**0**	**0**	**0**	**179**	**0**	**36**	**27**	**39**	**41**
Incremental change adjusted for fill		**-218**	**434**	**117**	**-316**	**79**	**24**	**-18**	**-318**	**-47**
Change since 1938-fill adjusted	**0**	**-218**	**216**	**333**	**17**	**96**	**120**	**101**	**-217**	**-264**
Average incremental rate (ft/yr)		**-31.9**	**38.9**	**6.3**	**-21.3**	**23.1**	**6.9**	**-12.1**	**-79.3**	**-9.2**

T20 (500 ft)										
T20 incremental change		**-478**	**342**	**-265**	**383**	**299**	**-76**	**-57**	**-333**	**-23**
fill width during time increment		**0**	**0**	**0**	**179**	**0**	**36**	**27**	**39**	**41**
T20 Incr. change adjusted for fill		**-478**	**342**	**-265**	**204**	**299**	**-112**	**-84**	**-372**	**-64**
T20 change since 1938	**0**	**-478**	**-136**	**-401**	**-197**	**103**	**-9**	**-94**	**-466**	**-530**
Average incremental rate (ft/yr)		**-69.9**	**30.6**	**-14.2**	**13.7**	**87.8**	**-32.6**	**-55.3**	**-92.8**	**-12.6**

Table A-1

Hutaff Island Shoreline Change Information

	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T21 - T25 (2,000 ft)										
T21 incremental change		371	-453	-202	79	-180	199	116	-27	-25
T21 change since 1938	0	371	-82	-283	-204	-384	-184	-69	-96	-121
T22 incremental change		221	-284	-239	43	-129	154	46	50	-50
T22 change since 1938	0	221	-63	-301	-259	-388	-234	-188	-138	-188
T23 incremental change		114	-171	-233	3	-88	90	55	132	-104
T23 change since 1938	0	114	-57	-290	-288	-375	-286	-231	-99	-203
T24 incremental change		29	-81	-234	-29	-60	50	-13	188	-90
T24 change since 1938	0	29	-52	-286	-314	-374	-324	-337	-149	-239
T25 incremental change		-44	-16	-206	-50	-40	28	-81	247	-112
T25 change since 1938	0	-44	-60	-266	-316	-356	-328	-409	-162	-273
Averages for T21 - T25										
Incremental change		**138**	**-201**	**-223**	**9**	**-99**	**104**	**25**	**118**	**-76**
Cumulative change since 1938	**0**	**138**	**-63**	**-285**	**-276**	**-375**	**-271**	**-247**	**-129**	**-205**
Average incremental rate (ft/yr)		**20.2**	**-18.0**	**-11.9**	**0.6**	**-29.1**	**30.3**	**16.1**	**29.4**	**-14.9**
T26 - T30 (2,500 ft)										
T26 incremental change		-47	-23	-197	-62	-31	12	-51	72	-36
T26 change since 1938	0	-47	-70	-266	-328	-360	-348	-399	-327	-364
T27 incremental change		-47	-34	-186	-59	-59	13	-56	49	-22
T27 change since 1938	0	-47	-81	-268	-327	-386	-373	-429	-379	-401
T28 incremental change		-52	-18	-192	-89	-53	44	-40	-39	15
T28 change since 1938	0	-52	-70	-262	-351	-404	-360	-399	-439	-424

T29 incremental change		-59	-13	-191	-119	-24	31	-73	-25	36
T29 change since 1938	0	-59	-72	-263	-382	-406	-375	-448	-472	-436
T30 incremental change		-38	-19	-179	-135	-24	33	-68	-20	31
T30 change since 1938	0	-38	-57	-236	-370	-394	-361	-430	-450	-419
Averages for T26 - T30										
Incremental change		**-48**	**-21**	**-189**	**-93**	**-38**	**26**	**-57**	**7**	**5**
Change since 1938	**0**	**-48**	**-70**	**-259**	**-352**	**-390**	**-363**	**-421**	**-414**	**-409**
Average incremental rate (ft/yr)		**-7.1**	**-1.9**	**-10.1**	**-6.3**	**-11.2**	**7.7**	**-37.7**	**1.8**	**0.9**

Table A-1

Hutaff Island Shoreline Change Information

	Mar-38	Jan-45	Mar-56	Dec-74	Oct-89	Mar-93	Aug-96	Feb-98	Feb-02	Apr-07
Incremental time period		**3/38-1/45**	**1/45-3/56**	**3/56-12/74**	**12/74-10/89**	**10/89-3/93**	**3/93-8/96**	**8/96-2/98**	**2/98-2/02**	**2/02-4/07**
Incremental years		**6.83**	**11.17**	**18.69**	**14.84**	**3.41**	**3.44**	**1.52**	**4.01**	**5.11**
T31 - T35 (2,500 ft)										
T31 incremental change		-44	-22	-157	-169	47	-21	-45	-56	33
T31 change since 1938	0	-44	-67	-224	-393	-345	-366	-411	-468	-435
T32 incremental change		-53	-7	-187	-140	26	-11	-16	-92	22
T32 change since 1938	0	-53	-60	-248	-388	-362	-373	-389	-481	-459
T33 incremental change		-33	-40	-164	-137	-27	5	-32	-66	0
T33 change since 1938	0	-33	-73	-237	-374	-400	-395	-428	-494	-494
T34 incremental change		-40	-47	-148	-196	4	24	-57	-28	-24
T34 change since 1938	0	-40	-86	-234	-430	-426	-402	-459	-486	-510
T35 incremental change		-35	-43	-152	-193	-7	29	-95	-16	-42
T35 change since 1938	0	-35	-78	-230	-422	-429	-400	-495	-511	-553
Averages for T31 - T35										
Incremental change		**-41**	**-32**	**-162**	**-167**	**9**	**5**	**-49**	**-51**	**-2**
Change since 1938	**0**	**-41**	**-73**	**-234**	**-401**	**-393**	**-387**	**-436**	**-488**	**-490**
Average incremental rate (ft/yr)		**-6.0**	**-2.8**	**-8.7**	**-11.3**	**2.6**	**1.5**	**-32.3**	**-12.8**	**-0.4**
T36 - T41 (3,000 ft)										
T36 incremental change		-35	-36	-171	-190	16	22	-39	-85	-16
T36 change since 1938	0	-35	-71	-242	-432	-416	-394	-433	-518	-533
T37 incremental change		-48	-54	-144	-208	36	29	-27	-112	-20
T37 change since 1938	0	-48	-101	-246	-454	-418	-389	-416	-528	-548
T38 incremental change		-54	-48	-143	-211	30	78	-94	-79	-25

T38 change since 1938	0	-54	-102	-245	-456	-426	-348	-442	-521	-545
T39 incremental change		-51	-51	-145	-207	44	65	-80	-91	-26
T39 change since 1938	0	-51	-102	-247	-454	-410	-346	-426	-517	-543
T40 incremental change		-62	-39	-149	-186	29	24	-39	-109	-47
T40 change since 1938	0	-62	-101	-249	-436	-407	-383	-422	-531	-578
T41 incremental change		-44	-31	-151	-177	2	62	-60	-138	-34
T41 change since 1938	0	-44	-75	-226	-402	-400	-339	-399	-537	-570
Averages for T36 - T41										
Incremental change		**-49**	**-43**	**-150**	**-196**	**26**	**46**	**-56**	**-102**	**-28**
Change since 1938	**0**	**-49**	**-92**	**-242**	**-439**	**-413**	**-366**	**-423**	**-525**	**-553**
Average incremental rate (ft/yr)		**-7.1**	**-3.9**	**-8.1**	**-13.2**	**7.6**	**13.5**	**-37.0**	**-25.5**	**-5.4**

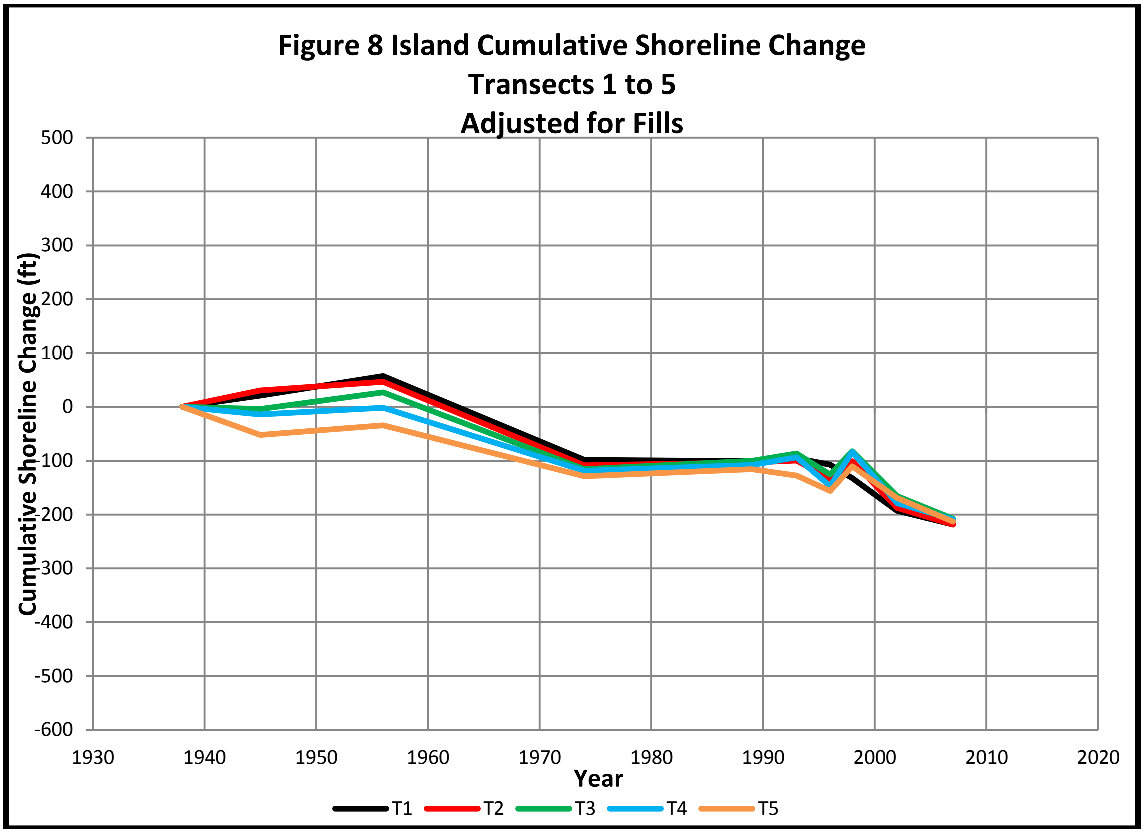

Figure A-1. Cumulative shoreline change Transects 1 to 5.

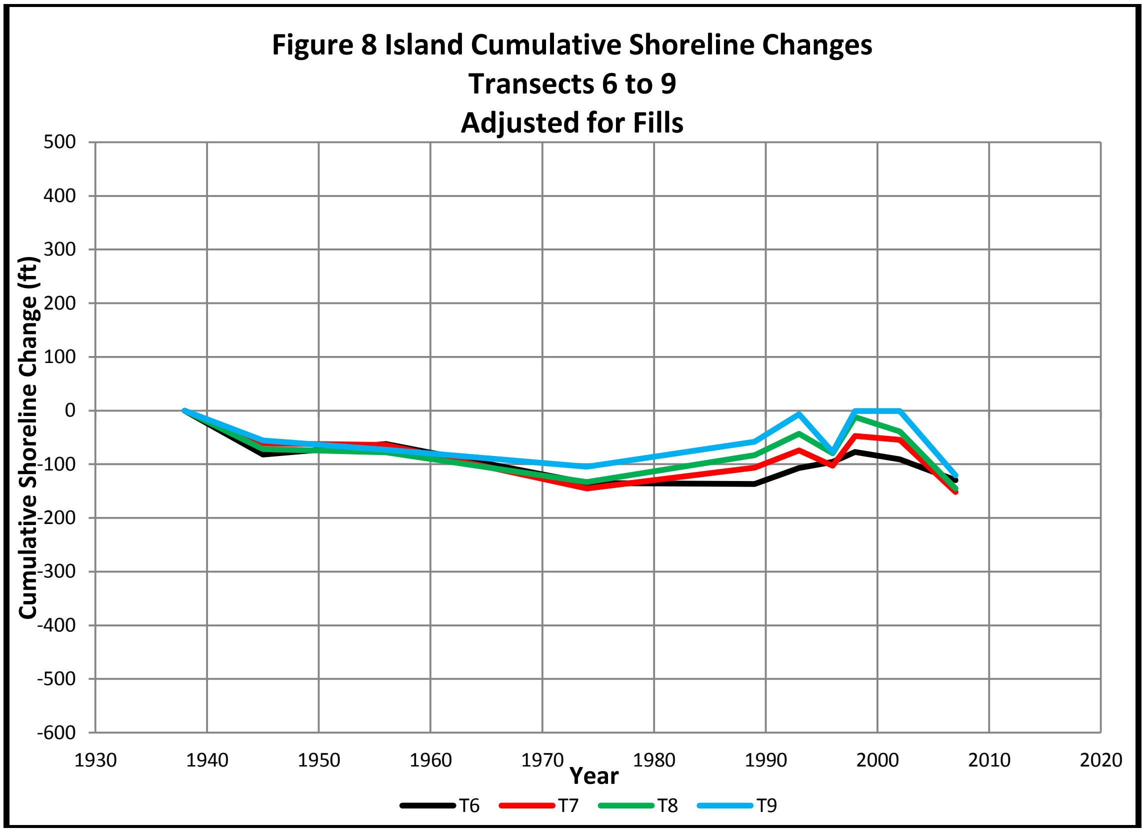

Figure A-2. Cumulative shoreline changes Transects 6 to 9.

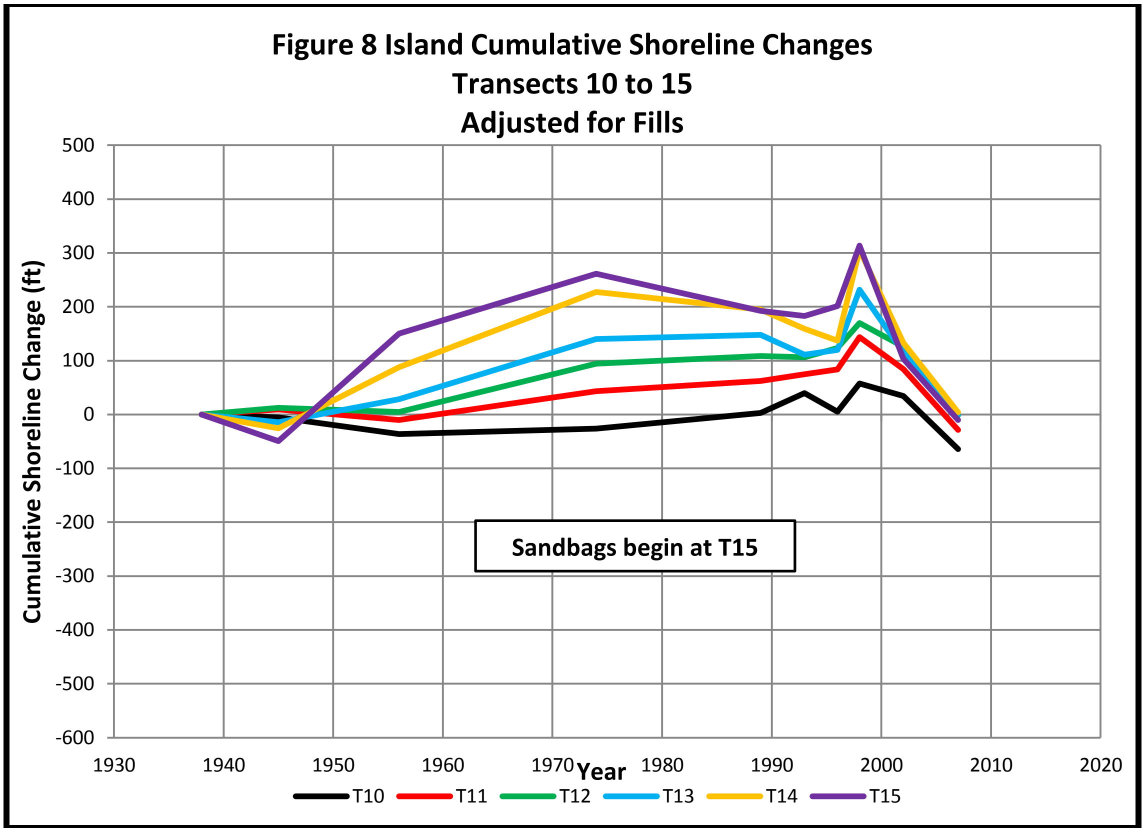

Figure A-3. Cumulative shoreline changes Transects 10 to 15.

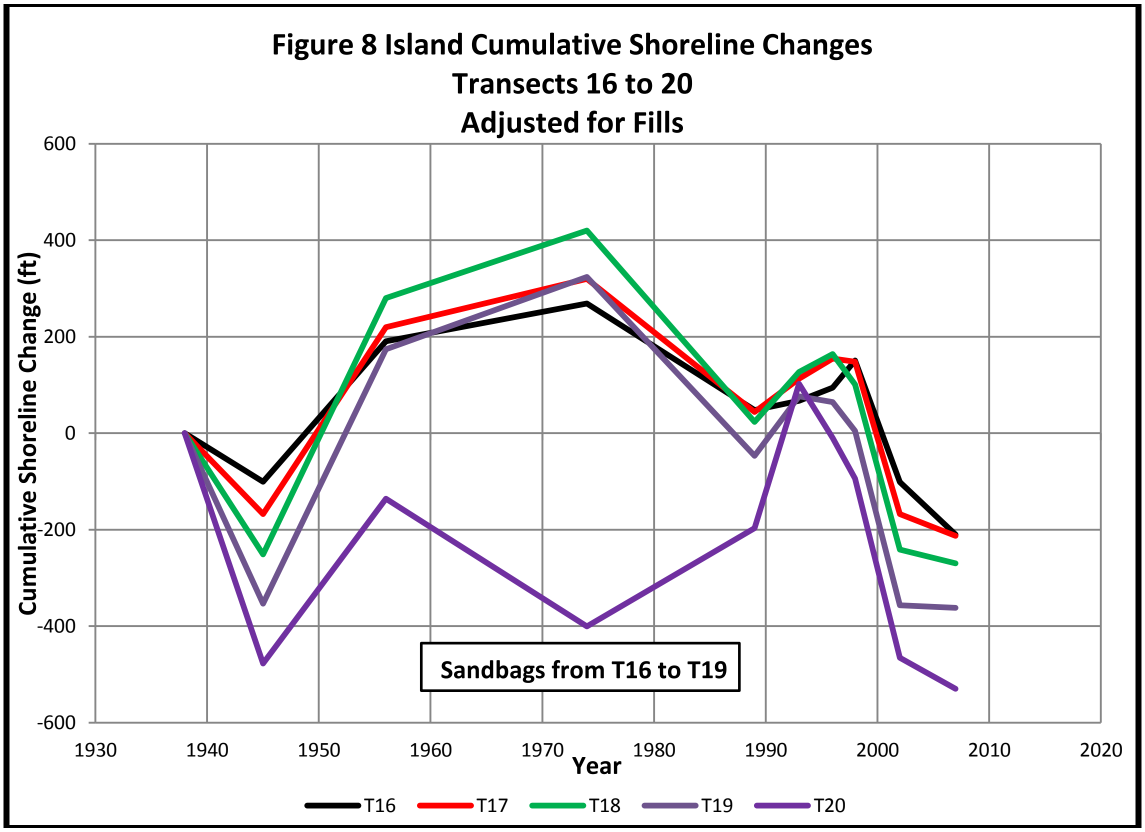

Figure A-4. Cumulative shoreline changes Transects 16 to 20.

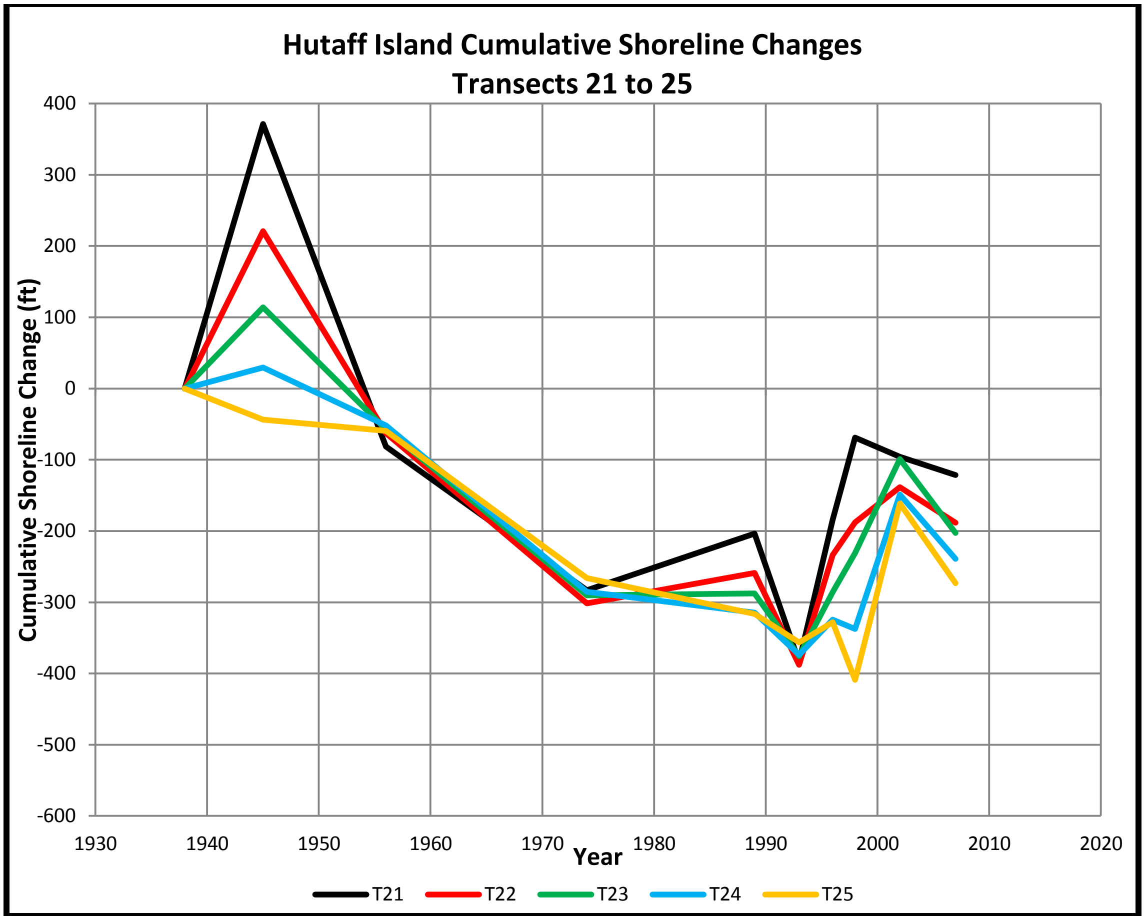

Figure A-5. Cumulative shoreline changes Transects 21 to 25.

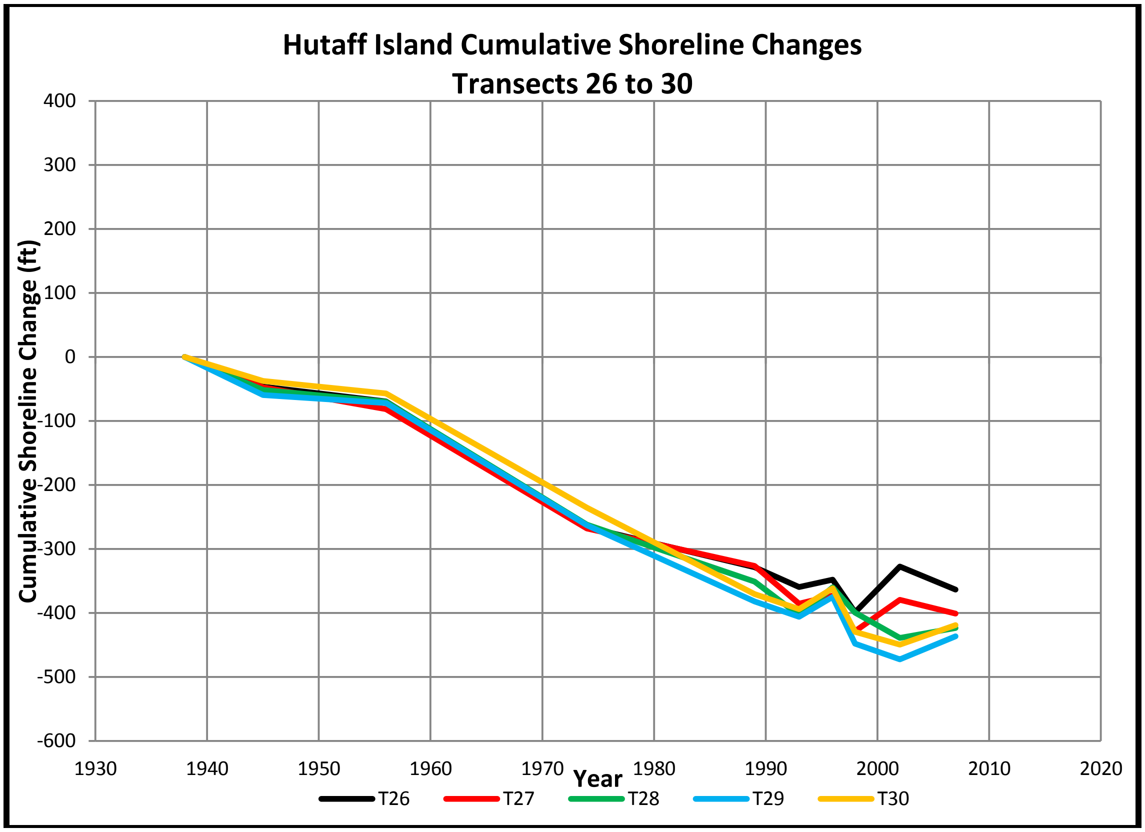

Figure A-6. Cumulative shoreline changes Transects 26 to 30.

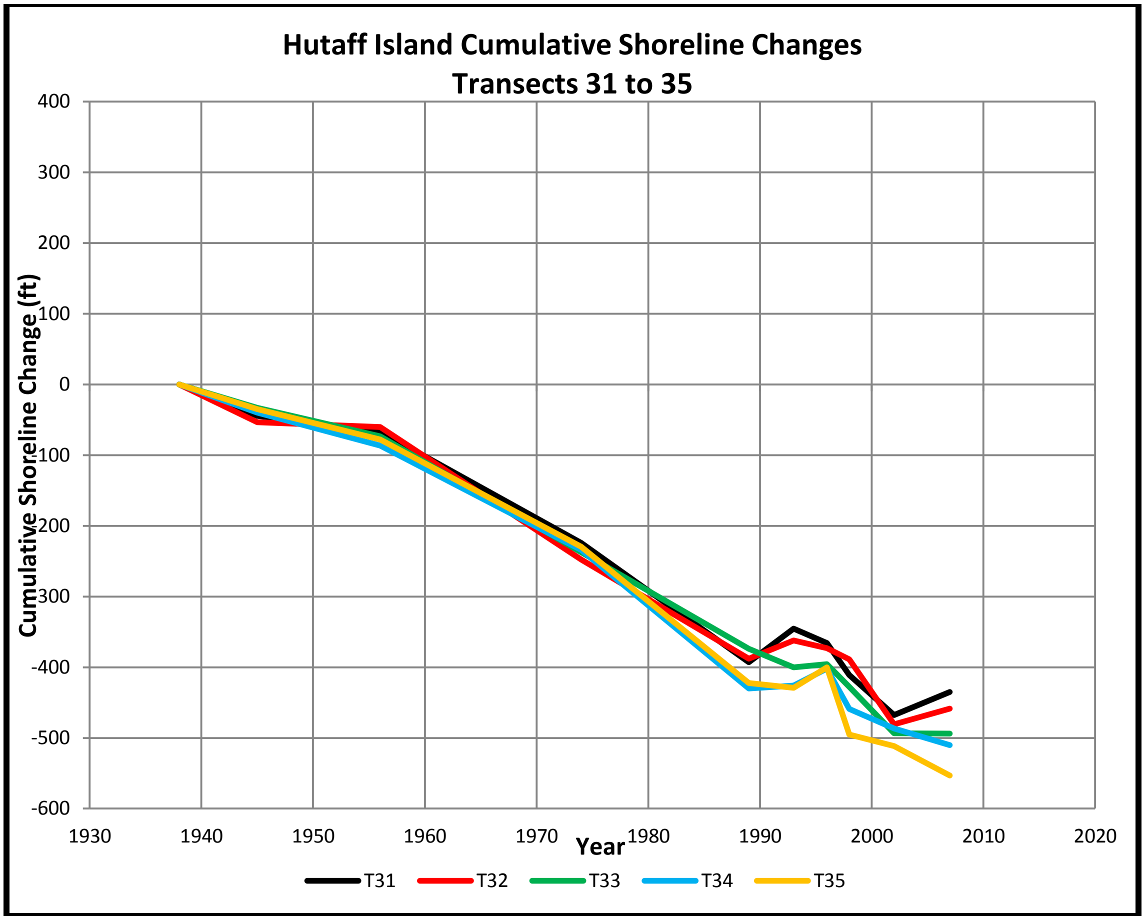

Figure A-7. Cumulative shoreline changes Transects 31to 35.

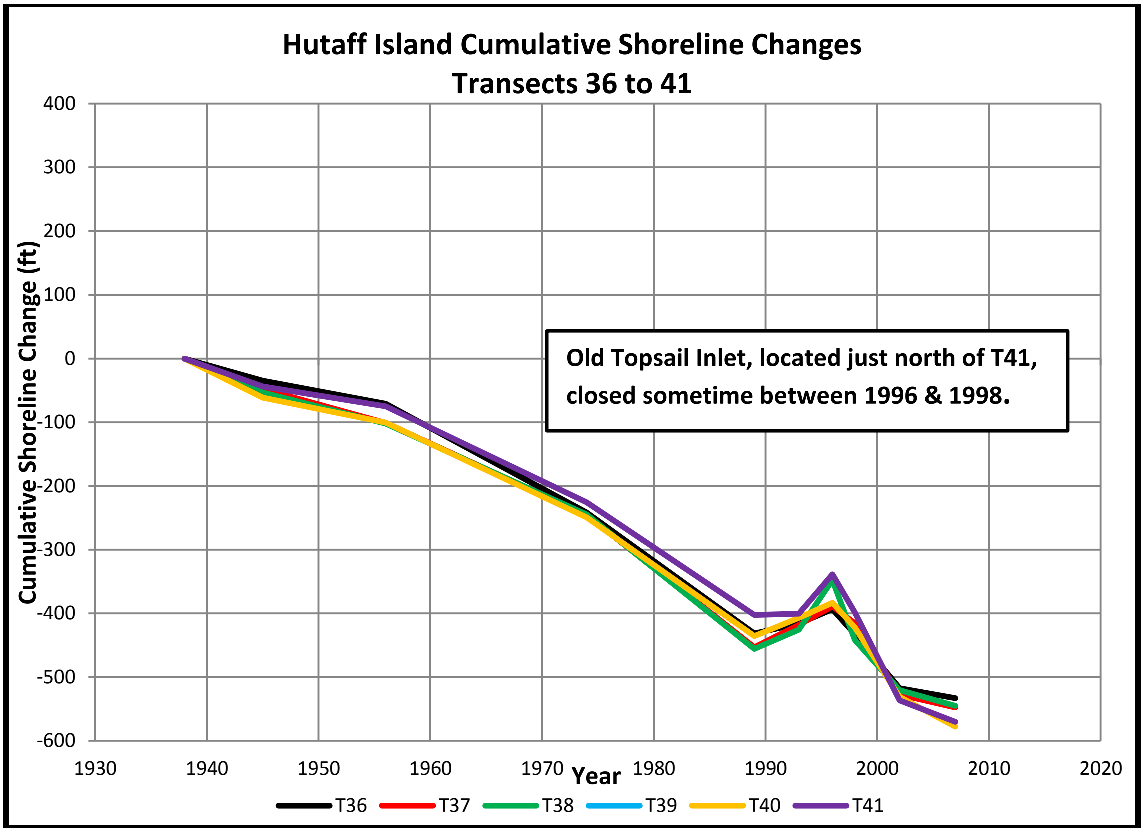

Figure A-8. Cumulative shoreline changes Transects 36 to 41.

3. How does the construction of the terminal groin relate to SB 110 and SB 151?

Senate Bill 110 and the amended terminal groin construction law in SB 151 contains a number of stipulations that the applicant must abide by to ensure that the Preferred Alternative is implemented within the law. Many aspects of the legislations are discussed in various sections of this EIS. Section 1. G.S. 113A-115-1(e)(6) of the legislation requires the applicant to provide financial assurance that is adequate to cover the cost of (a) long-term maintenance and monitoring of the terminal groin, (b) carry out mitigation measures provided in the inlet management plan, and (c) modify or remove the terminal groin if negative impacts cannot be mitigated. These financial assurances are addressed below.

The cost of monitoring the performance of the terminal groin and assessing impacts to the adjacent shorelines and inlet environment totals $480,000. This includes the acquisition of high resolution aerial photos of the inlet and adjacent shorelines, computation of shoreline change rates from the aerial photos, analysis of beach profile surveys along both Figure Eight Island and Hutaff Island, comparison of measured shoreline change rates to erosion thresholds, and measurements of changes in various habitats within the Permit Area. It is proposed that this monitoring will occur twice a year for the first two years following construction of the groin and, depending on the performance of the groin, it may be reassessed to determine if it would be appropriate to change to once a year thereafter for a total of 30 years. Depending on the performance of the structure, this long-term monitoring may be curtailed prior to the end of the 30-year period.

A cost to maintain the terminal groin is not anticipated based on the structural design parameters used for its design and the documented performance of both the Fort Macon and Pea Island terminal groins which have not required any maintenance since their initial construction.

Mitigation measures to address shoreline changes along Figure Eight Island and Hutaff Island that exceed the erosion thresholds would involve the placement of beach fill. Since the applicant's preferred alternative for Figure Eight Island includes periodic nourishment approximately every 5 years at an estimated cost of $2,718,000 for each operation, no additional shoreline mitigation is anticipated for Figure Eight Island. Mitigation beach fill for Hutaff Island is not anticipated due to the lack of private property and structures on the island.

Should removal of the terminal groin become necessary, the estimated cost for removal of the structure is estimated to be approximately $3.2 million. The construction of the terminal groin would be completed in stages. The first stage would only involve the seaward or rubblemound portion of the structure. The landward shore anchorage section would not be constructed until the need for the shore anchorage section becomes apparent. Before that occurs, monitoring of the seaward portion of the structure would establish if observed negative shoreline impacts can or cannot be mitigated. These impacts would be determined prior to the need to install the shore anchorage section. Therefore, if observed negative shoreline impacts cannot be mitigated, only the rubblemound portion of the terminal groin would be removed.

In summary, the financial assurances will be based upon:

- -$480,000 for shoreline monitoring
- -$0 for maintenance
- -$2,718,000 for beach nourishment on Figure Eight Island
- -$3,200,000 for the removal of the terminal groin

Based on these costs, the total amount of financial assurances provided by the Figure 8 Beach Homeowners Association will be $6,398,000. The instrument type or form of financial assurance has yet to be determined.