Chapter 1 *INTRODUCTION*

1. What is the purpose of this Environmental Impact Statement?

The purpose of this environmental impact statement (EIS) is to assist in decision making – "to help public officials make decisions that are based on understanding of environmental consequences, and take actions that protect, restore, and enhance the environment (43 CFR Section 1500.1, CEQ Regulations). The EIS will insure that the policies and goals defined in the National Environmental Policy Act (NEPA) are adequately addressed in the U.S. Army Corps of Engineers (USACE) permit evaluation process. It will provide full and fair discussion of significant environmental impacts and shall inform decision makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment.

NEPA is a United States environmental law created in 1969 that established a U.S. national policy promoting the enhancement of the environment and also established the President's Council on Environmental Quality (CEQ). NEPA ensures that relevant environmental information is available to public officials and citizens before decisions are made and actions are taken. The Act requires federal agencies to conduct an EIS for major actions that could have significant impacts on the quality of the human environment. Under NEPA, "environment" includes the natural and physical environment (such as air, water, geography, geology) as well as people's relationship with the environment (such as health, safety, jobs, schools, housing, and aesthetics). An EIS looks at both short-term and long-term effects and considers possible mitigation measures, if needed.

This Environmental Impact Statement document has also been developed in accordance with the requirements of the State Clearinghouse review process under the North Carolina Environmental Policy Act (NCEPA, G.S. 113A-1). Upon the development and submittal of the Final EIS, additional filing under the NC EPA will not be required.

Each alternative presented in this document will be evaluated for its ability to satisfy the stated project goals and objectives, as well as the environmental, economic, and social consequences associated with each alternative. This evaluation process will help lead to the selection the least environmentally damaging practicable alternative (LEDPA) that meets the project needs and objectives while resulting in minimal negative environmental impacts.

2. What is the NEPA EIS process and how does it relate to Figure "8" HOA's proposed project?

This EIS will be prepared in a series of steps: gathering government and public comments to define the issues that should be analyzed in the EIS (a process known as "scoping"); gathering available data, preparing the draft EIS document and releasing it to the public requesting feedback; receiving and responding to public comments on the draft EIS; and preparing the subsequent final EIS. Decisions are not made in an EIS document; rather, the EIS primarily serves as an assessment of various project alternatives and their respective effects on the environment. Furthermore, the document is utilized to help evaluate and determine which of the project options is the LEDPA and meets the applicant's purpose and needs. This final evaluation will be made in the Record of Decision (ROD). The following describes the general concepts in the NEPA EIS process, which was used in evaluating Figure Eight Island Homeowners Association proposed project:

Scoping

Scoping is the process of identifying the key issues as they pertain to the proposed action. The USACE began the scoping process for this EIS by publishing a Notice of Intent (NOI) in the *Federal Register* to let the public know that it is considering an action and will prepare an EIS. During the scoping period, the public can provide comments on the proposed action, alternatives, issues, and environmental impacts to be analyzed in the EIS. Scoping may involve public meetings and other means to obtain public comments on the EIS.

Draft EIS

During scoping, information is collected and used for the preparation of a draft EIS. The draft EIS presents, analyzes, and compares the potential environmental impacts for the proposed action and alternatives and their implementation, and provides additional information on the methodologies and assumptions used for the analyses. A Notice of Availability (NOA) is published in the *Federal Register* announcing the release of the draft EIS for public review and comment. The NOA begins a 45-day comment period. Public comments on the draft EIS are considered in the preparation of the final EIS.

Final EIS

After the draft EIS commenting period is completed and through continuing scoping, a final EIS is prepared, published in the *Federal Register*, and released for any additional comments. All comments received during the commenting period will be addressed where applicable to prepare the final EIS.

Record of Decision

After the final EIS is published, a minimum 30-day waiting period is required before a ROD can be issued. The ROD notifies the public of the decision made on the proposed action and presents the reasons for that decision. The decision-making process may include consideration of factors such as cost, technical feasibility, agency statutory missions, and national objectives, as well as the potential environmental impacts of an action(s).

3. How has the public been involved?

In accordance with the National Environmental Policy Act (NEPA) and State Environmental Policy Act (SEPA) requirements, an early and open public forum process, identified as "scoping", was initiated to identify significant issues related to the proposed action and establish an appropriate scope of work for addressing those issues in the EIS document.

Appendix A, Subpart 1: Scoping Meeting and PDT Meeting Minutes

This appendix includes the minutes from the initial scoping meeting and subsequent PDT meetings. A list of meeting attendees in included.

In order to engage the general public, including residents of Figure Eight Island and all stakeholders, a Notice of Intent (NOI) was issued and published in the Federal Register (Volume 72, Number 31) on February 26, 2007. This Notice of Intent served to inform the public of the "intent to prepare a Draft Environmental Impact Statement (EIS) for the development of an inlet management plan that includes the repositioning and realignment of the main ebb channel of Rich Inlet and to use the material to nourish Figure Eight Island, north of Wilmington, New Hanover County, NC". The NOI provided the project description and described the proposed action, potential impacts, project alternatives, and the scoping process. Along with this issuance, a Public Notice (PN) containing similar information was released by the USACE on February 22, 2007. As announced in the NOI and PN, the initial scoping meeting was held at Eaton Elementary School, located at 6701 Gordon Road, on March 1, 2007.

In a continual effort to include the public, state and federal agencies, and all interested stakeholders in the process, a Project Delivery Team (PDT) was assembled. The PDT members were individually asked to: 1) provide input for the development of the EIS, 2) keep the public informed of project development, 3) discuss project-related concerns, and 4) to identify natural resources in the Permit Area. The PDT is comprised of a broad-based team of individuals who represent the following interests: local, state and federal government officials; business and property owners; non-governmental organizations; as well as the project design team (Table 1.1). PDT meetings were held on May 7, 2007, September 18, 2007, June 10, 2008, March 19, 2008, May 20, 2009, and August 11, 2010. See Appendix A, Subpart 1 for meeting minutes.

Table 1.1- Figure Eight Island Inlet and Shoreline Management Project PDT Members

NAME	AFFILIATION	E-MAIL ADDRESS
David Kellam	Figure 8 HOA	dkellam@bizec.rr.com
Bill Raney	Figure 8 HOA	waraney@bellsouth.net
Tom Jarrett	CPE	james.jarrett@shawgrp.com
Dawn York	CPE	dyork@coastalplanning.net
Brad Rosov	CPE	brad.rosov@shawgrp.com
Ken Willson	CPE	kenneth.willson@shawgrp.com
Bill Cleary	UNCW	wcleary@charter.net
David Webster	UNCW	webste@uncw.edu
Mickey Sugg	USACE	mickey.t.sugg@usace.army.mil
Brad Shaver	USACE	brad.e.shaver@usace.army.mil
Greg Williams	USACE	
David Ward	Hutaff Island	dlw@wardandsmith.com
David Rabon	USFWS	david_rabon@fws.gov
Howard Hall	USFWS	howard_hall@fws.gov
Becky Fox	EPA	fox.rebecca@epa.gov
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Jim Gregson	NC DCM	jim.gregson@ncmail.net
Robb Mair	NC DCM	robb.mair@ncmail.net
Doug Huggett	NC DCM	doug.huggett@ncmail.net
Noelle Lutheran	NC DWQ	noelle.lutheran@ncmail.net
Fritz Rohde	NC DMF	fritz.rohde@ncmail.net
Mike Street	NC DMF	mike.street@ncmail.net
Matthew Godfrey	NC WRC	godfreym@coastalnet.com
Steve Everhart	NC WRC	steve.everhart@ncmail.net
Susan Cameron	NC WRC	camerons@coastalnet.com
Todd Miller	NCCF	toddm@nccoast.org
Mike Giles	NCCF	capefearcoastkeeper@nccoast.org
Michelle Duval	Environmental Defense	mduval@environmentaldefense.org
Paula Bushardt	NE NHC Conservancy	
Harry Simmons	NCBIWA	ncsbpa@mindspring.com
Gary McSmith	New Hanover County	gmcsmith@nhcsgov.com
Dave Weaver	New Hanover County	dweaver@nhcsgov.com
Tom Walker	USACE	william.t.walker@usace.army.mil
Molly Ellwood	NCWRC	molly.ellwood.ncwildlife.org
Walker Golder	Audubon Society	wgolder@audubon.org
Jack Spruill	Pender Watch	jspruill@aol.com
Don Ellson	Figure 8 HOA	ellsond@bellsouth.net
Paul Parker	Pender County	
Lori Brill	Pender County	
Mike Giles	NCCF	mikeg@nccoast.org
Steve Underwood	NCDCM	steve.underwood@ncmail.net
Scott Geis	NCDCM	scott.geis@ncdenr.gov

4. How have government agencies been involved?

Participation in the EIS process by federal, state, and local government agencies and other interested organizations and persons has been encouraged. The USACE will be conducting additional consultation efforts with the U.S. Fish and Wildlife Service (USFWS) under the Endangered Species Act and the Fish and Wildlife Coordination Act; with the National Marine Fisheries Service (NMFS) under the Magnuson-Stevens Act and Endangered Species Act; and with the North Carolina State Historic Preservation Office (NCSHPO) under the National Historic Preservation Act. Specifically, the USACE will consult with the USFWS regarding species listed under the Endangered Species Act (ESA) via the development of a Biological Assessment (BA). NMFS will be consulted regarding essential fish habitat via the development of an Essential Fish Habitat (EFH) assessment. Additionally, because this EIS assesses the potential water quality impacts pursuant to Section 401 of the Clean Water Act, coordination efforts are being made with the North Carolina Division of Water Quality (DWQ), and a DWQ Section 410 water quality certification is required. Furthermore, the USACE has worked closely with the North Carolina Division of Coastal Management (DCM) through the development of this EIS to ensure the process complies with all State Environmental Policy Act (SEPA) requirements and to determine consistency with the Coastal Zone Management Act (CZMA).

As stated above, representatives of the relevant federal agencies have been involved in the scoping meeting and the subsequent PDT meetings. Their input has been integrated into this EIS document.

5. What is the Figure Eight Island Shoreline Management Project and where is it located?

The Figure Eight Beach Homeowners Association (F8 HOA) is seeking Federal and State permits to allow development of a management plan for Rich Inlet that would mitigate chronic erosion on the northern portion of Figure Eight Island so as to preserve the integrity of its infrastructure, provide protection to existing development, and ensure the continued use of the oceanfront beach along the northernmost three miles of its oceanfront shoreline.

Figure Eight Island is located in northeastern New Hanover County. It is an unincorporated privately developed residential barrier island with 465 homes and 93 undeveloped lots. The island is bordered to the south by Mason Inlet and Wrightsville Beach and to the north by Rich Inlet and Hutaff Island, an undeveloped, privately-owned island (Figure 1.1). Hutaff Island is one of the few remaining undeveloped and vehicle-free barrier islands on the North Carolina coast. It is among the largest near-pristine barrier island and salt marsh system in the region.

Figure Eight Island covers approximately 1300 acres, is approximately 5.0 mi long and approximately 0.4 mi wide. The proposed project is located along the oceanfront shoreline on the northeast end of the island, and within Nixon Channel and Rich Inlet.

Chronic erosion problems along the northern sections of Figure Eight Island have been directly linked to changes in the orientation and position of the main ebb channel through Rich Inlet (Cleary & Hosier, 1990; Cleary, 2001; Cleary & Knierim, 2006; Cleary & Jackson, 2004). When the main ebb channel of the inlet is oriented toward the southeast or in the direction of

Figure Eight Island, and positioned close to the north end of the island, the shoreline immediately south of the inlet tends to accrete. The accretion is associated with the wave sheltering ("breakwater effect") provided by the south side of the ebb tide delta, which also moves with the channel. During periods when the main bar channel migrates to the north toward Hutaff Island and is oriented in a northeasterly direction, the north end of Figure Eight Island erodes. The northward movement of the main ebb channel is accompanied by the northward shift of the south side of the ebb tide delta away from the north end of Figure Eight Island, thus removing the protection afforded by the south side of the ebb tide delta.

In addition to erosion issues along the ocean shoreline south of Rich Inlet, erosion is also prevalent along 548.8 m (1,800 ft) of the Nixon Channel shoreline extending from Rich Inlet northwest to the entrance to Nixon Creek. Between 1993 and 2005, the average rate of shoreline change along this segment of the Nixon Channel shoreline was -8.3 ft per year. The erosion of the Nixon Channel shoreline is associated with the proximity of the main flow channel to the shoreline.

To alleviate these problems attributed to erosion, several alternatives have been evaluated. Initially, relocation of the main channel within Rich Inlet was determined to be the Applicant's Preferred Alternative, as noted in the NOI and PN. This was prior to the passage of SB110 which allowed for the construction of a terminal groin. Since that time, the Applicant's Preferred Alternative includes the construction of a terminal groin 213 m (700 ft) in length with a 273m (900 ft) shore anchorage section to protect against possible flanking of the landward end of the structure. This structure is intended to control tidal current-induced shoreline changes immediately south of Rich Inlet. In addition to the construction of the terminal groin, several areas of the shoreline would be nourished with material excavated from the previously permitted area within Nixon Channel and from three upland dredge disposal sites located in proximity to the AIWW behind Figure Eight Island (pending approval of all landowners and receipt of a USACE consent for placement). Beach fill would be placed along 548.6 m (1,800 ft) of the Nixon Channel shoreline just south of Rich Inlet. In addition, material will be used to nourish 1,219 m (4,000 ft) of ocean shoreline extending from Rich Inlet south to the intersection of Beach Road and Bridge Road (Figure 1.1). The existing navigation feature in Nixon Channel would be maintained to its permitted depth of -2.7 m (-9 ft) MLW [or -3.5 m (-11.4 ft) NAVD] and permitted widths. Periodic nourishment of the beach fill would be accomplished in conjunction with maintenance dredging of the new channel and continued maintenance of the existing navigation feature in Nixon Channel.

What is a Terminal Groin?

A shoreline protection structure that reduces beach erosion by temporarily trapping sand before it reaches the inlet. Once the sand forms an "accretion fillet" to protect the shoreline, sand continues its normal flow by moving over, thru or around the structure.

As noted above, the Applicant's Preferred Alternative was modified from the initial project involving the relocation of Rich Inlet combined with beach nourishment to the alternative incorporating a terminal groin with associated beach nourishment. The passage of SB110 precipitated the exploration of a project involving a terminal groin as the legislation allows for the construction of up to four (4) terminal groins within the State of North Carolina. While the Figure Eight Homeowners Association states that the inlet relocation project meets its purpose

and needs, they have determined that the terminal groin alternative would result in an improved project in terms of economic benefits and reduced environmental impacts, as discussed in this document.

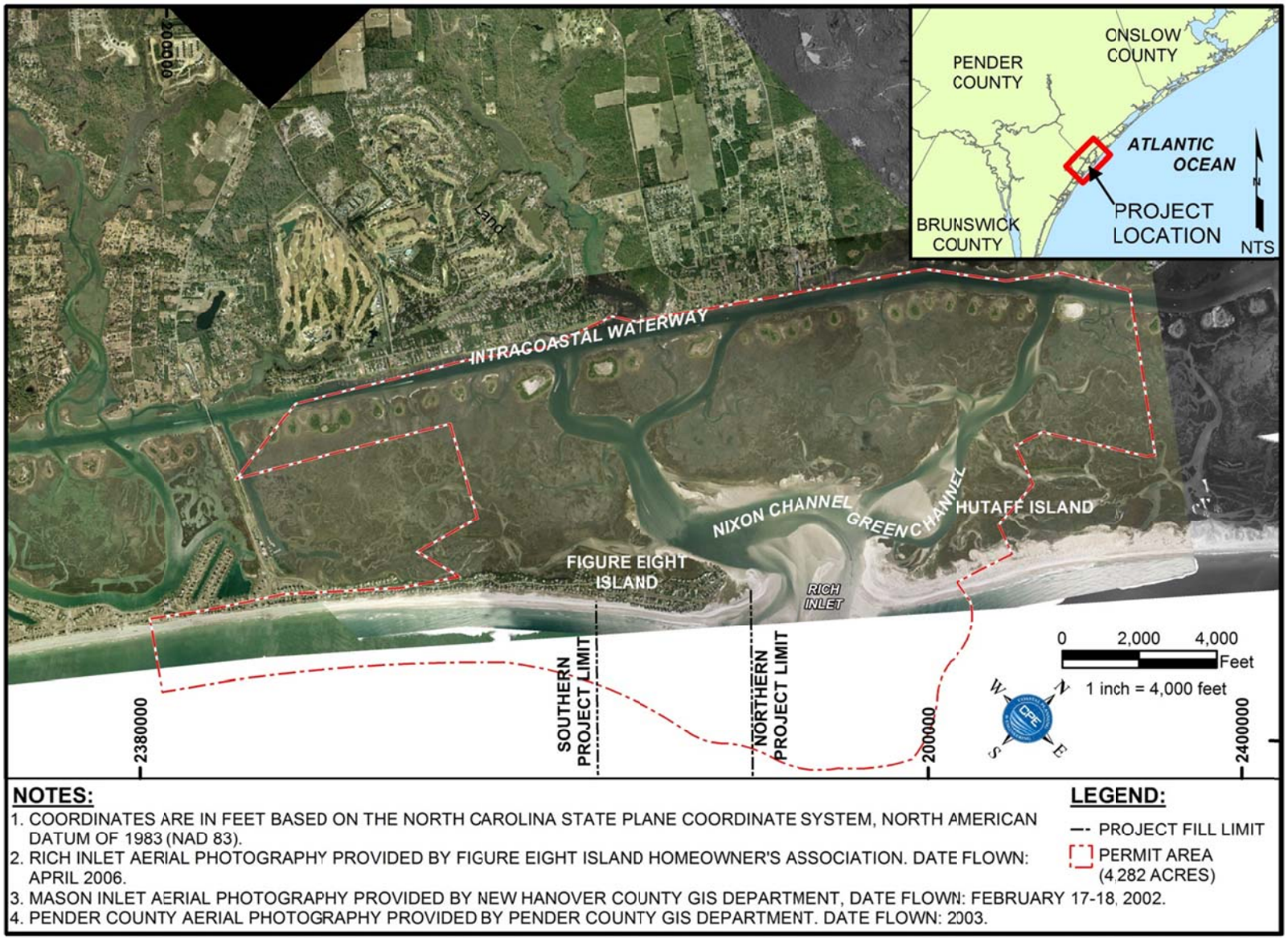


Figure 1.1- Figure Eight Island Inlet and Shoreline Management Project Location Map

6. What issues were identified as part of scoping?

During scoping (through public meetings and written comments), several issues were identified in association with the proposed project, including: funding concerns, impacts to environmental resources within the inlet complex, sand quality and compatibility, and concerns with the use of a terminal groin. Additional written correspondence has been provided in Appendix A - Subpart 2 (Pertinent Correspondence).

Appendix A, Subpart 2: Pertinent Correspondences

This appendix includes various emails and letters submitted by agencies, stakeholders, and the general public regarding relevant information pertaining to the project.

Summaries of the public scoping meetings and PDT meetings held to date are listed below. Minutes to the PDT meetings are to be found in Appendix A, Subpart 1.

- The March 1, 2007 Public Scoping Meeting convened on March 1, 2007 at Eaton Elementary School in Wilmington, NC. The scoping meeting was designed to solicit comments from the public, Federal, State and local agencies and officials, and other interested parties to identify issues to be addressed in the EIS document. Attendees included local residents, resource agencies, and representatives of the Figure 8 HOA, and Coastal Planning & Engineering, Inc. (CPE). Concerns expressed from the attendees are documented in Appendix A – Subpart 1.

- The May 7, 2007 PDT Meeting included the following: a presentation by CPE-NC coastal engineer Tom Jarrett regarding an overview of past nourishment projects on Figure Eight Island, a presentation by UNCW's Dr. William Cleary regarding the effects of Rich Inlet on adjacent shorelines, and update by CPE-NC geologist Ken Willson on geotechnical investigations, and a presentation by CPE-NC coastal biologist Dawn York regarding baseline biological resource investigations. The meeting format allowed for open discussions during and after the presentation.

- The September 18, 2007 PDT Meeting included a presentation by CPE coastal engineer Chris Day regarding Delft3D modeling results on the project alternatives. Discussions included the newly developed State Sediment Criteria and the need for hardbottom investigations. The meeting format allowed for open discussions during and after the presentation.

- The June 10, 2008 PDT Meeting included in depth discussions regarding the details of each project alternative. This was followed by a presentation by CPE coastal engineer Chris Day focusing on the engineering analysis performed for the Applicant's Preferred Alternative. Mickey Sugg of the USACE provided an overview of the NEPA process and the format of EIS. The meeting format allowed for open discussions during and after the presentation.

- The March 19, 2008 PDT Meeting included a presentation by UNCW's Dr. Bill Cleary on updated findings on shoreline change for Figure Eight and Hutaff Islands, and estuarine shoreline change for Nixon and Green Channels between 1938 and 2007. CPE-NC coastal biologist Dawn York presented the baseline environmental data collected to date including

salt marsh, submerged aquatic vegetation (SAV), shellfish and bird and turtle nesting areas. The meeting format allowed for open discussions during and after the presentation.

- The May 20, 2009 PDT Meeting included a presentation by CPE-NC marine scientist Brad Rosov regarding the updated biological resource investigations which provide baseline conditions for the EIS. This presentation included information provided by UNCW's Dr. David Webster. CPE-NC coastal engineer Tom Jarrett presented modeling results for project alternatives including the terminal groin options. The meeting format allowed for open discussions during and after the presentation.

- The August 11, 2010 PDT Meeting included a presentation by CPE-NC coastal engineer Tom Jarrett regarding the updated Delft3D modeling results regarding project alternatives. Information regarding anticipated beach fill performance and shoreline change analysis was included in the presentation. The meeting format allowed for open discussions during and after the presentation.

7. What laws are involved?

The following section includes a description of applicable Federal and State laws associated with the Figure Eight Island Inlet and Shoreline Management Project. This EIS document has been prepared to satisfy both the National Environmental Policy Act (NEPA) and the North Carolina State Environmental Policy Act (SEPA) requirements in accordance with State and Federal law.

National Environmental Policy Act of 1969.

The National Environmental Policy Act (42 U.S.C. 4321; 40 C.F.R. 1500.1) includes six fundamental objectives that have been developed since its enactment in 1970. These objectives include: supplemental legal authority; procedural reform; disclosure of environmental information; resolution of environmental problems; foster intergovernmental coordination and cooperation; enhance public participation in governmental planning and decision making (Bass *et al*., 2001). A NEPA document is required when a project includes Federal action including the need for Federal permits, the use of Federal funding, or if the action is to take place on Federal lands.

Section 10 of the Rivers and Harbors Act of 1899

Pursuant to Section 10 of the Rivers and Harbors Act of 1899, certain structures or work in or affecting navigable waters of the US will be regulated under the purview of U.S. Army Corps of Engineers (33CFR 322.1). The Act states that "it shall not be lawful to excavate or fill…..alter or modify the course, location, condition, or capacity of, any port roadstead, haven, harbor, canal, lake, harbor of refuge, or enclosure within the limits of any breakwater, or of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War…." (USACE, 2006). The geographic jurisdiction of the Rivers and Harbors Act includes all navigable waters of the United States which are defined (33 CFR Part 329) as, "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible to use to

transport interstate or foreign commerce." This jurisdiction extends seaward to include all ocean waters within a zone three nautical miles from the coastline (the "territorial seas").

Clean Water Act of 1972

Section 404 of the Clean Water Act established a permit program under the purview of the U.S. Army Corps of Engineers, to regulate the discharge of dredged and fill material into waters of the U.S., including wetlands. These waters consisting of, but not limited to, “all waters which are currently used or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide” (33CFR 328.3(a)(1)). This program is jointly administered by Environmental Protection Agency and the U.S. Army Corps of Engineers (USEPA, 2006).

Section 401 of the Clean Water Act includes the delegation of Federal authority to the State of North Carolina to issue a 401 Water Quality Certification. The 401 Water Quality Certification is applicable to all projects that require a Federal permit (i.e., Section 404 Permit) for discharge of dredge material into waters and wetlands of the U.S. The 401 Water Quality Certification Program is administered by the North Carolina Division of Water Quality to prevent the degradation of waters in the State and to prevent any violations of the State water quality standards.

Endangered Species Act of 1973

The Endangered Species Act of 1973 (ESA) was signed on December 28, 1973, and provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. The ESA replaced the Endangered Species Conservation Act of 1969; it has been amended several times. The lead federal agencies for implementing ESA are the U.S. Fish and Wildlife Service (USFWS) and the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Service. The USFWS maintains a worldwide list of endangered species. Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees. Coordination with the USFWS and NOAA National Marine Fisheries Service (NMFS) includes consultation under Section 7 of the Endangered Species Act of 1973, as amended.

National Historic Preservation Act of 1966

The National Historic Preservation Act is legislation intended to preserve historical and archaeological sites in the United States of America. The act created the National Register of Historic Places, the list of National Historic Landmarks, and the State Historic Preservation Offices.

Senate Bill 3035, the National Historic Preservation Act, was signed into law on October 15, 1966. Several amendments have been made since. Among other things, the act requires Federal agencies to evaluate the impact of all Federally funded or permitted projects on historic properties (buildings, archaeological sites, etc.) through a process known as *Section 106 Review*.

Archival research, field work and coordination with the North Carolina State Historic Preservation Officer (SHPO), have been conducted in accordance with the National Historic Preservation Act of 1966 (Public Law 89-665), the National Environmental Policy Act of 1969 (Public Law 11-190), Executive Order 11593, the Advisory Council on Historic Preservation Procedures for the protection of historic and cultural properties (36 CFR Part 800) and the updated guidelines described in 36 CFR 64 and 36 CFR 66.

The North Carolina Office of State Archaeology (OSA) protects endangered archaeological sites on private or public lands through enforcement of the North Carolina Archaeological Resources Protection Act (G.S. 70, article 2), the North Carolina Archaeological Records Program (G.S. 70, article 4), and the “Abandoned Shipwreck Law” (G.S. 121, article 3).

Magnuson-Stevens Fishery Conservation and Management Act of 1996

The Magnuson Fishery Conservation and Management Act of 1976, amended Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) in October 1996 and also referred to as the Sustainable Fisheries Act, was enacted by the U.S. Congress to protect marine fish stocks and their habitat, prevent and stop overfishing and minimize bycatch. Congress defined Essential Fish Habitat (EFH) as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires that EFH be identified for all fish species Federally managed by the Fishery Management Councils and the National Marine Fisheries Service (NMFS).

Fish and Wildlife Coordination Act of 1958

The Fish and Wildlife Coordination Act of 1958, as amended, mandates that Federal and State agencies cooperate “to protect, rear, stock, and increase the supply of game and fur-bearing animals….[and] study the effects of domestic sewage, trade wastes, and other polluting substances on wildlife.” The Act also requires consultation with the Bureau of Fisheries, Fish and Wildlife Service and State fish and wildlife agencies where the “waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted…or otherwise controlled or modified” by any agency under a Federal permit or license. Additional amendments to the Act have “permitted lands valuable to the Migratory Bird Management Program to be made available to the State agency exercising control over wildlife resources (USFWS, 2006a).

Coastal Zone Management Act of 1972

Enacted by Congress in 1972, the Coastal Zone Management Act does not require, but encourages that each State preserve, protect, restore or enhance natural coastal resources including; wetlands, floodplains, estuaries, beaches, dunes, barrier islands and coral reefs, as well as the fish and wildlife that utilize these resources. Since this Act is voluntary, any State that implements a coastal management program as defined in this Act will receive Federal financial aid.

The North Carolina Division of Coastal Management has developed and enforces a coastal management plan with the rules and policies that supports the ideals and concepts of the CZMA. The North Carolina Division of Coastal Management enforces this Act using the rules and policies of the Coastal Area Management Act of 1974 (enabled and delegated in 1972; adopted and implemented in 1974).

North Carolina Environmental Policy Act (As Amended)

The North Carolina (or State) Environmental Policy Act of 1971 (SEPA) requires State agencies to review and report the environmental effects of all activities that involve an action by a State agency, an expenditure of public monies or private use of public land, and that may have a potential negative environmental effect on natural resources, public health and safety, natural beauty, or historical or cultural elements of the State. This Environmental Impact Statement has been developed in accordance with the requirements of the State Clearinghouse review process under the North Carolina Environmental Policy Act, based upon the agreement between the North Carolina Division of Coastal Management and the U.S. Army Corps of Engineers. Upon the development and submittal of the Final EIS, additional filing under the NC EPA will not be required.

North Carolina Coastal Area Management Act of 1974

The North Carolina Coastal Area Management Act (CAMA) (§ 113A-100) was implemented to preserve the physical, aesthetic, cultural and recreational values, including the management of land and water resources in North Carolina's 20 coastal counties. Under CAMA, permits are necessary for development type projects proposing work in any Areas of Environmental Concern (AEC) established by the Coastal Resources Commission. An AEC includes areas of natural importance such as 1) estuarine and ocean systems, 2) ocean hazard system, 3) public water supplies, and 4) natural and cultural resource areas. Under CAMA, the proposed work cannot cause significant damage to one or more of the historic, cultural, scientific, environmental or scenic values or natural systems identified in the AECs listed. In addition, significant cumulative effects cannot result from a development project (NCDCM, 2003).

North Carolina Dredge and Fill Law

Under CAMA (§ 113-229), the North Carolina Division of Coastal Management regulates projects that involve excavation or filling in any estuarine waters, tidelands, marshlands, or State-owned lakes. An applicant proposing work in such lands must obtain a permit from both the North Carolina Department of Environment and Natural Resources and the USACE (NCDCM, 2006a).

North Carolina Surface Water Quality Standards

The North Carolina Division of Water Quality Surface Waters and Wetlands Standards (North Carolina Administrative Code 15A NCAC 02B .0100 & .0200) was implemented for assigning and regulating water quality standards for waters in the State of North Carolina. The water column in the North Topsail Beach project area is classified as both SA waters and Outstanding

Resource Waters. Class SA waters are surface waters suitable for shellfishing for market purposes. Waters designated as Class SA have specific water quality standards that must be met, as well as the water quality standards assigned to both Class SB and SC waters. Outstanding Resource Waters (ORW) includes waters of exceptional water quality. Waters designated as ORW and/or Class SA waters are also classified as High Quality Waters (HQW) (NCDWQ, 2003).

Based on the above classifications, water quality standards applicable to the project area include: 1) "turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU)" 2) "changes in salinity due to hydrological modifications shall not result in the removal of the functions of a Primary Nursery Area (PNA)" 3) temperature "shall not be increased above the natural water temperature by more than 0.8^{o}C (1.44^{o}F) during the months of June, July or August nor more than 2.2^{o}C (3.96^{o}F) during other months, and in no cases to exceed 32°C due to the discharge of heated liquids" 4) dissolved oxygen cannot decrease below 5.0 mg/l, except in "poorly flushed tidally influenced streams or embayments, or estuarine bottom waters" which may have decreased values from natural causes and 5) pH levels "shall be normal for the waters in the area, which generally range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions" (NCDWQ, 2006).

Limitations on Erosion Control Structures, North Carolina General Statute § 113A-115.1

This law establishes limitations of erosion control structures along the ocean shoreline. The "ocean shoreline" is defined as "the Atlantic Ocean, the oceanfront beaches, and frontal dunes". Furthermore, the term "ocean shoreline" includes "an ocean inlet and lands adjacent to an ocean inlet but does not include that portion of any inlet and lands adjacent to the inlet that exhibits characteristics of estuarine shorelines". This statute defines such a structure as "breakwater, bulkhead, groin, jetty, revetment, seawall, or any similar structure". Terminal groins, or specifically a groin that is constructed at the end of a littoral cell or on the updrift side of an inlet to prevent sediment passage into the channel beyond, are included under this statute, as of the passing of Senate Bill 110. Senate Bill 110 allows a total of four terminal groins within the State as long as the applicant meets a suite of requirements. These requirements include the preparation of an Environmental Impact Statement, proof of financial assurance to cover post construction monitoring and mitigation (if warranted), and notification to adjacent property owners amongst other requirements.

Chapter 2 *PURPOSE AND NEEDS*

1. What are the purpose and needs of this project?

The main concerns of residents and owners at Figure Eight Island are economic losses resulting from damages to structures and their contents due to hurricane and storm activity and the loss of beachfront land due to the ongoing shoreline erosion along portions of the ocean and estuarine shoreline. Current shoreline management strategies have not been successful in providing the proper shoreline protection that the Figure "8" Homeowners Association seeks. With a total assessed tax value of property within the limits of Figure Eight Island of approximately $1,189,810,926 (based on the 2007 reappraisal), the Figure "8" Homeowners Association sees the need for an improved shoreline protection plan. This valuation includes the valuation of 463 residential structures and property along with 93 vacant lots.

The purpose and needs of the Figure Eight Island Inlet and Shoreline Management Project are as follows:

- Reduce or mitigate erosion along 3.77 km (2.34 mi) of Figure Eight Island oceanfront shoreline south of Rich Inlet and 0.55 km (0.34 mi) of backbarrier shoreline on Figure Eight Island along Nixon Channel;
- Provide reasonable short-term protection to imminently threatened residential structures over the next five years;
- Provide long-term protection to Figure Eight Island homes and infrastructure over the next 30 years;
- Acquire compatible beach material in compliance with the North Carolina State Sediment Criteria for shore protection project;
- Maintain navigation conditions within Rich Inlet and Nixon Channel;
- Balance the needs of the human environment with the protection of existing natural resources;
- Maintain existing recreational resources; and
- Maintain the tax value of the homes and infrastructure on Figure Eight Island.

2. How is the Figure Eight Island shoreline managed today?

During the past several decades, the F8 HOA have addressed the continuing erosion problems associated with Rich and Mason Inlets and the Nixon Channel erosion hot-spot located on the estuarine side of the island. The long-term chronic erosion on the island has been exacerbated by the recent increase in hurricane activity since the 1990s.

Since the mid-1980s, shoreline changes along a 3,000 ft segment of shoreline along the southern portion of Figure Eight Island has been in response to the migration of Mason Inlet to the south (Cleary and Jackson, 2004). In the fall and winter of 2001-2002, Mason Inlet was relocated approximately 2,500 ft to the north helping to alleviate severe erosion on the north end of Wrightsville Beach. The estuarine shoreline along the northern portion of the island has undergone significant changes since the mid-1980s when the Rich Inlet gorge began to migrate to the northeast from its southwest most position. The associated migration and deflection of Rich Inlet's ebb channel caused the thalwag to migrate toward the developed estuarine shoreline causing erosion problems which persist today. As described above, the migration of the channel within Rich Inlet to its current northwest position has influenced the current erosion on the oceanfront shoreline along the northern portion of the island. A detailed summary of the history of Rich Inlet followed by a summary of shoreline protection activities on Figure Eight Island is discussed below.

Category 3 and 4 Hurricanes Affecting the North Carolina Coast

Name	Year	Landfall Location
Unnamed	1933	Ocracoke
Great Atlantic Hurricane	1944	Cape Hatteras
Hazel	1954	NC/SC Border
Connie	1955	Portsmouth
Ione	1955	Morehead City
Helene	1958	Offshore Outer Banks
Donna	1960	Emerald Isle
Diana	1984	Cape Fear
Gloria	1985	Offshore Hatteras Island
Emily	1993	Hatteras Island
Fran	1996	Cape Fear

(Hurricane Research Division, 2008).

RICH INLET HISTORY

Dr. William J. Cleary of the University of North Carolina at Wilmington (UNCW) conducted a detailed geomorphic analysis of Rich Inlet. The geomorphic analysis of the Inlet was conducted through interpretation of ortho-rectified aerial photographs collected between 1938 and 2007, as well as corresponding shoreline changes along Figure Eight and Hutaff Islands.

This study indicated that unlike many inlets in the region, Rich Inlet has migrated within a relatively narrow corridor of approximately 500 m (1,600 ft) from 1938 to present. This relative stability can likely be attributed to the Inlet's large tidal prism of 18 x 10^6 m^3 (636 x 10^6 ft^3) (with positive correlation between an inlet's tidal prism and inlet stability), as well as the topography of the underlying Oligocene siltstone with Rich Inlet likely occupying an ancestral location of Futch Creek during a lower stand of sea-level (Cleary, 2009).

Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). Between 1938 and 1993, the main ebb-channel was oriented in a southeasterly direction between azimuths of approximately 112° to 181° (Figure 2.1). During this period, the Rich Inlet ebb-tide delta was aligned with the main ebb-channel in a more southerly orientation providing a wave sheltering effect for the north end of Figure Eight Island. This corresponded to the creation of a one-mile zone of accretion along the oceanfront shoreline immediately south of Rich Inlet.

From 1993 to 2000, the ebb-channel shifted to a more northeasterly alignment with a maximum azimuth of 83° in October 2000 (Figure 2.2). With this shift came a northward migration of the

ebb-tide delta, exposing the north end of Figure Eight Island to wave attack. During this period, extensive erosion occurred along northern 1,400 m (4,500 ft) of the Island with a maximum of 150 m (500 ft) of shoreline retreat. Subsequently, during this time period the northward migration of the ebb-tide delta provided wave sheltering to the south end of Hutaff Island leading to accretion of the shoreline with a maximum progradation of 120 m (390 ft).

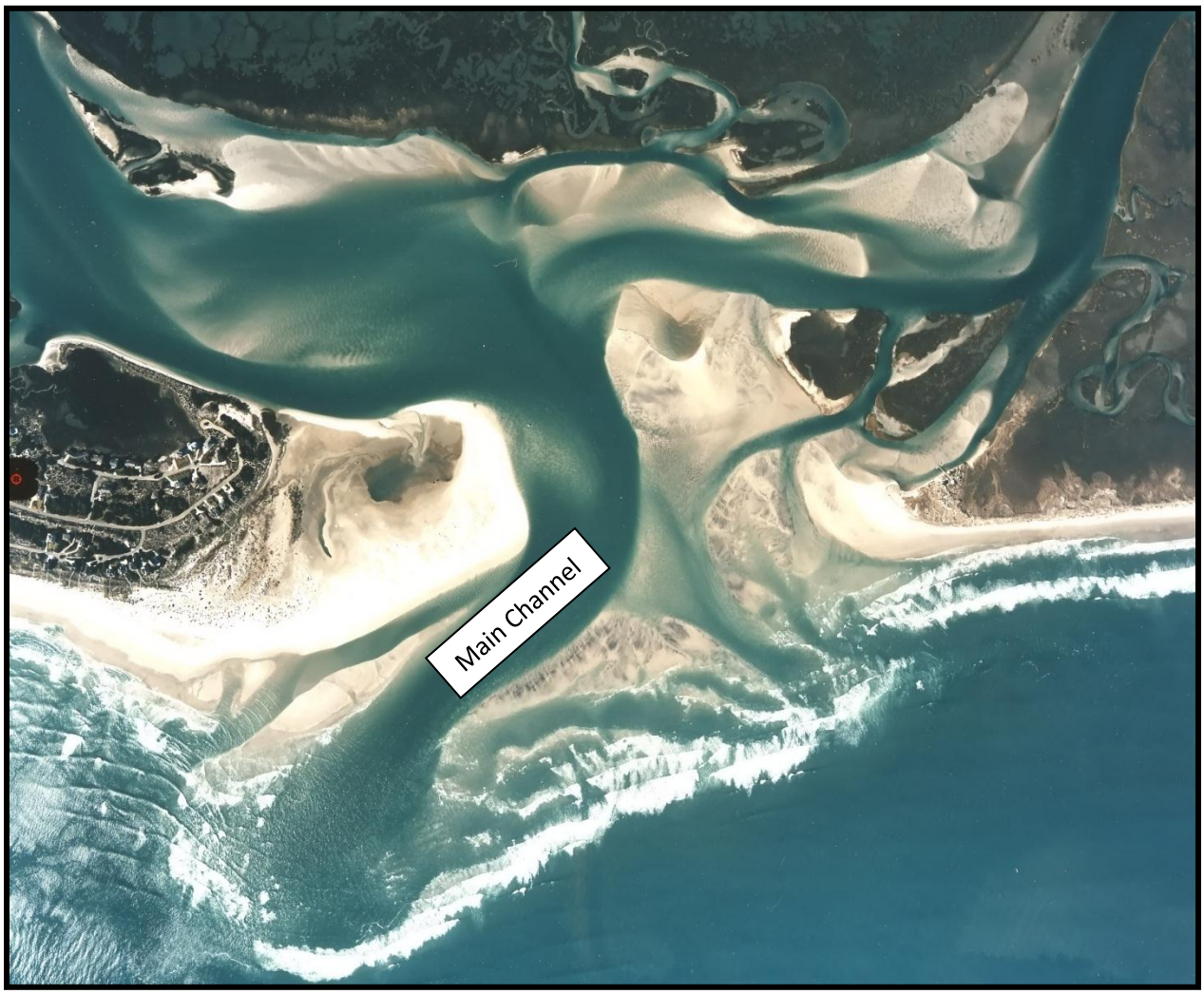


Figure 2.1- Southeasterly Orientation of the Main Channel within Rich Inlet as of November 1993

Figure 2.2- Northeasterly Orientation of the Main Channel within Rich Inlet as of March 1999

An ebb-tide delta breach in late 2000 resulted in a deflection of the main ebb-channel to a shore-normal position, with further southward deflection to an azimuth of 190° in 2003. Since March 2003 the throat segment of the ebb channel has reversed its migration direction and shifted to the southwest toward Figure Eight Island (Cleary, 2009). Since 2004, the general configuration of the ebb delta has changed slightly while the inlet has widened to its most expansive dimension since 1956. During the period between 2002 and 2007 erosion was the norm along the oceanfront shoreline of Figure Eight Island within the inlet hazard area despite shoreline armoring (sandbags) and the placement of 250,000 cubic yards of beach fill along the northernmost 6,100 ft of the island in March 2001.

Dr. William Cleary's analysis of inlet and shoreline geomorphology has shown that fluctuation of Rich Inlet's main ebb-channel can be well correlated to patterns of erosion and accretion along the adjacent shorelines. When the ebb-channel is deflected to the south, the ebb-tide delta migrates southward resulting in accretion along the northern portion of Figure Eight Island and erosion along the southern portion of Hutaff Island. However, severe northward deflection of the ebb-channel leads to erosion along the northern portion of Figure Eight Island and accretion along the southern portion of Hutaff Island.

SHORELINE PROTECTION HISTORY

At least 31 shoreline protection projects have occurred along Figure Eight Island since 1977 (Table 2.1). These projects have included beach nourishment events, beach scraping (bulldozing to form protective berms and dunes), bulkheading, and the installation of sandbags. The material utilized for the majority of the beach nourishment projects was acquired from the maintenance of Mason Inlet, Nixon Channel, the Intracoastal Waterway (AIWW), and Banks Channel.

Nourishment activities have increased since the mid to late 1990's due to changes to Mason and Rich Inlet systems and the frequency of storm activity. However, the change to the orientation of Rich Inlet along with recent storm activity have exasperated the long-term chronic erosion occurring along the northern extremity of the developed oceanfront downdrift of Rich Inlet, the southern 2,500 ft of developed shoreline updrift of Mason Inlet, and the 1,000 ft long developed estuarine shoreline fronting Nixon Channel (Cleary and Jackson, 2004).

In response to the accelerated erosion rates, the Figure Eight HOA nourished the area north of Bridge Road six (6) times between 1993 and 2011, with the cumulative volume of all six (6) fills totaling approximately 1.8 million cubic yards. The timeframe of these recent events corresponds with the start of the increased erosion rate associated with the shifting of the ebb tide channel to a more northerly direction. Due to the extremely high erosion rates just south of Rich Inlet, the beach fills placed in this area did not provide long-lasting protection and eventually forced the oceanfront property owners on Surf Court, Inlet Hook Road, and Comber Road to install temporary sandbag revetments. Based on the permit conditions, all of the temporary sandbag revetments were to be removed by April 2008; however, statewide legal challenges to the rule have delayed their removal.

The ineffectiveness of the past beach nourishment attempts along the extreme north end of Figure Eight Island emphasizes the need to address the inlet related process that impact the area (Figures 2.3 and 2.4). Without some change in the inlet's impact, future nourishment operations on the extreme north end of Figure Eight Island will suffer the same fate as the past efforts. Shoreline management issues south of Bridge Road on Figure Eight Island are being addressed through actions associated with the maintenance of the Mason Inlet Relocation Project and the periodic disposal of material removed to maintain the navigation channel in Banks Channel.

In total, the aforementioned shoreline protection projects along Figure Eight Island have placed well over 4 million cubic yards of material along the oceanfront shoreline along Figure Eight Island.

Table 2.1 - Shoreline Protection Project History on Figure Eight Island

Project Date	Type of Project	Volume (c.y.)	Source	Region
June 1977	Dredge/Fill and Bulkhead	13,000	Banks Channel	Mason Inlet
June 1983	Dredge and Nourishment	90,000	Nixon Channel and Rich Inlet	North End*
March 1985	Dredge and Nourishment	46,300	Mason Inlet Connecting Channel	South End
January 1986	Dredge and Nourishment	250,000	Mason Inlet and Banks Channel	South End
January 1987	Beach Scraping	N/A	N/A	South End
March 1987	Beach Scraping	N/A	N/A	South End
April 1987	Beach Scraping	N/A	N/A	South End
January 1990	Beach Scraping	N/A	N/A	Island-Wide**
November 1992	Dredge and Nourishment	343,000	Banks Channel near Mason Inlet	South End
February 1993	Beach Nourishment	274,000	Nixon Channel	North End*
December 1994	Beach Scraping	N/A	N/A	Island-Wide**
November 1996	Beach Scraping	N/A	N/A	Island-Wide**
January 1997	Storm Recovery	250,000	Nixon Channel	North End*
March 1998	Channel Dredging	450,000	Banks Channel and Middle Sound	Island-Wide**
September 1998	Beach Scraping	N/A	N/A	Middle of Island
March 1999	Beach Nourishment	785,000	Cameron Disposal Island and Banks Channel	South End
January 2000	Sandbag Placement	N/A	N/A	North End*
March 2000	Beach Scraping	N/A	N/A	North End*
September 2000	Beach Scraping	N/A	N/A	North End*
October 2000	Beach Scraping	N/A	N/A	North End*
November 2000	Beach Scraping	N/A	N/A	North End*
November 2001	Beach Scraping and Sandbags	N/A	N/A	North and South End
March 2001	Beach Nourishment	350,000	Nixon Channel	North End*
Jan.-Feb. 2002	Mason Inlet Relocation	390,000	Mason Inlet	South End
March 2003	Channel Dredging	50,000	Banks Channel & AIWW	South End
March 2003	Beach Nourishment	30,000	Banks Channel & AIWW	South End
February 2005	Channel Dredging	183,000	Mason Inlet	South End
November 2005	Beach Nourishment	261,235	Nixon Channel	North End*
February 2006	Beach Nourishment	179,175	Banks Channel	South End
April 2006	Beach Nourishment	148,969	Mason Creek & AIWW	South End
February 2009	Beach Nourishment	295,000	Nixon Channel	North End*

Spring 2009	Channel Dredging	176,000	Mason Inlet	South End
Jan-Mar 2011	Channel Dredging	275,000	Nixon Channel	North End*

*North end is defined as the area between the inlet gorge shoulder to Bridge Road
**Island wide includes the majority of the oceanfront shoreline at Figure Eight Island

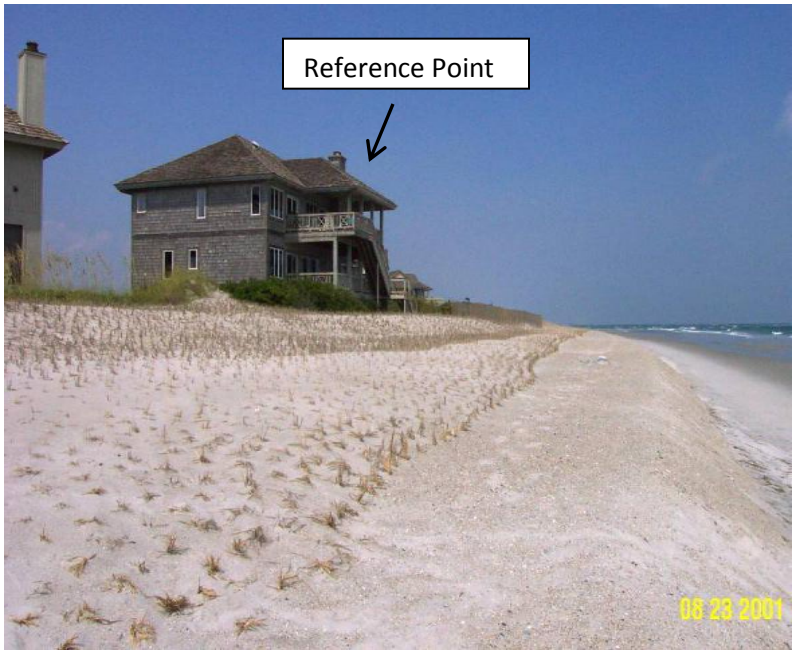


Figure 2.3. North End of Figure Eight Island after Nourishment Event in 2001

Figure 2.4. Evidence of Rapid Erosion Approximately One Month Following 2001 Nourishment

According to the F8 HOA, sandbag revetments were installed around 20 homes on the north end of Figure Eight Island between 2003 and 2010, however, one of the homes, located at 13 Comber Road, was relocated in 2010 leaving 19 homes along the north end of the island with sandbag revetments. These structures are considered to be imminently threatened as defined by State

Standard Rule 15A NCAC 7H .0308 (NCDCM, 2007a) (Figure 2.5). The basic premise of this rule is that a structure in the Ocean Hazard Area is considered imminently threatened when its foundation is less than 6.1 m (20 ft) from the toe of the erosion scarp (see Figure 1.2 as depicted in the North Carolina CAMA Handbook [2003]). Figure 2.6 depicts the location of each residential structure on Figure Eight Island protected by sandbags. As of 2008, the potential loss of these threatened structures would reduce the total tax base by $23.8 million (Table 2.2).

Sandbags protecting a home along the northern portion of Figure Eight Island, March 18, 2008

(Jarrett, 2008)

The area north of Bridge Road contains 116 oceanfront parcels and 134 non-oceanfront parcels. Presently, there are only ten (10) undeveloped oceanfront parcels and thirty-one (31) undeveloped non-oceanfront parcels north of Bridge Road. As of 2008, the total tax value of all the oceanfront parcels north of Bridge Road (structure and land) is approximately $237 million. The 27 oceanfront parcels located on Surf Court, Comber Road, and Inlet Hook Road- the area directly impacted by the changes in Rich Inlet- have a total tax value of $48.4 million. At the current tax rate for New Hanover County, all the oceanfront parcels would generate approximately $1 million/year in ad valorem taxes.

In general, Beach Road North is not in any immediate danger of being lost to long-term erosion, however, the road is expected to continue to be subjected to storm overwash and occasional washouts during severe storm events. Surf Court, Comber Road, and Inlet Hook Road, all located within 915 m (3,000 ft) south of Rich Inlet, could eventually be damaged or lost to long-term erosion, particularly once the oceanfront property owners remove the existing sandbag revetments (see Figure 2.6). Surf Court lies approximately 76 m (250 ft) from the shoreline while Comber Road and Inlet Hook Road are only 38 m (125 ft) and 33 m (100 ft) from the shoreline, respectively. Given the shoreline recession rates observed between 1999 and 2007, Inlet Hook Road and Comber Road could be undermined within the next five (5) years and Surf Court undermined within the next ten (10) years.

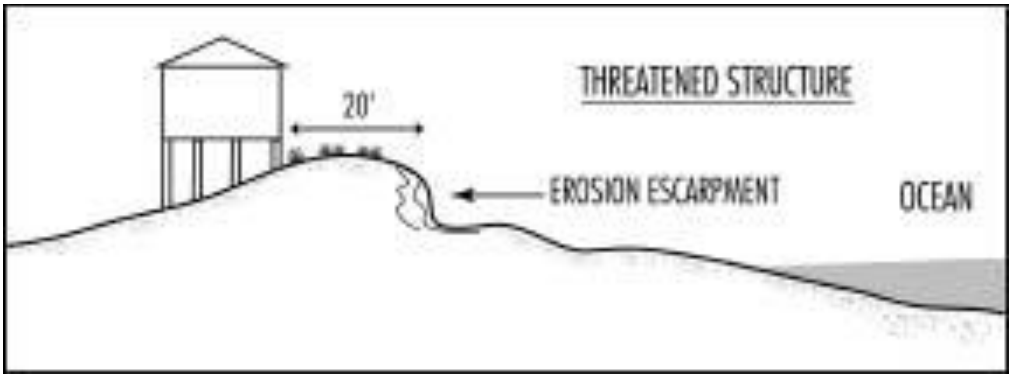


Figure 2.5 - Diagram Depicting Imminently Threatened Structures (NCDCM, 2003a)

Table 2.2 - Analysis of Threatened Structures on Figure Eight Island

Address	Property Value [a]	Structure Value [a]	Total Value
5 Comber	$283,075	$631,373	$914,448
6 Comber	$600,955	$668,381	$1,269,336
7 Comber	$70,482	N/A[b]	$70,482
8 Comber	$501,885	$591,277	$1,093,162
9 Comber	$564,230	$579,393	$1,143,623
10 Comber	$579,000	$684,674	$1,264,664
11 Comber	$601,176	$793,188	$1,394,364
12 Comber	$598,306	$695,096	$1,293,402
14 Comber	$541,488	$596,334	$1,137,822
15 Comber	$515,248	$461,591	$976,839
16 Comber	$509,135	$679,188	$1,188,323
17 Comber	$532,750	$418,515	$951,265
3 Inlet Hook	$426,268	$403,295	$829,563
4 Inlet Hook	$540,690	$689,188	$1,229,878
5 Inlet Hook	$1,177,453	$769,422	$1,946,875
6 Inlet Hook	$1,264,385	$929,181	$2,193,566
7 Inlet Hook	$1,306,408	$691,137	$1,997,545
8 Inlet Hook	$732,465	$696,815	$1,429,280
544 Beach Road North	$711,005	$724,983	$1,435,988
Total	**$12,056,404**	**$11,703,031**	**$23,760,425**

[a] Property and Structure value information was provided by the New Hanover County GIS database (http://etax.nhcgov.com/Main/Home.aspx).
[b] N/A denotes those structures in which a value was not provided in the Town's tax database or through the New Hanover County GIS database.

Figure 2.6 – Location of Imminently Threatened Residential Structures on Figure Eight Island

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 Maintenance of the Nixon Channel Navigation Channel and Connector Channel
- Alternative 5B - Terminal Groin with Beach Fill From Other Sources

A description of each alternative is provided below which includes detailed discussions of what each alternative entails, how it was formulated, and the economic cost to implement. An assessment of the economic impact on the existing island development and infrastructure and other consequences of each alternative are provided in Chapter 5.

Alternative 1: No Action

Sandbag revetments along the northern portion of Figure Eight Island

Description. Under Alternative 1, the Figure Eight HOA and individual property owners would continue to respond to erosion threats in the same manner as in the past. These measures include beach scraping (or bulldozing) to create and/or repair damaged dunes, intermittent beach nourishment, and the deployment of sandbags. These erosion control measures became increasingly necessary as Rich Inlet's ebb-channel shifted to a more northeasterly alignment beginning in 1993 (Cleary, 2009). With this shift came a northward migration of the ebb-tide delta, exposing the north end of Figure Eight Island to wave attack. During this period, extensive erosion occurred along northern 1,400 m (4,500 ft) of the Island with a maximum of 150 m (500 ft) of shoreline retreat. Sandbag revetments were installed around 20 homes on the north end of Figure Eight Island between 2002 and 2007, however, one of the homes, located at 13 Comber Road, was removed in 2010 leaving 19 homes along the north end of the island with sandbag revetments.

NCDCM regulations generally allow sandbag revetments to remain in place between 2 and 5 years depending on the size of the structure. In 2002, a Coastal Resource Commission (CRC) rule took effect that allows property owners in communities making headway toward beach nourishment to keep their sandbags until May 2008. The CRC, established in 1974, establishes policies for the N.C. Coastal Management Program and adopts implementing rules for both

CAMA and the N.C. Dredge and Fill Act. The sandbags located on Figure Eight Island were originally installed when homes immediately downdrift of the inlet were threatened by the retreating shoreline, which reached a critical level in January 2000 (Cleary, 2009). In 2003, a variance was granted by the CRC that allowed a group of homeowners on Figure Eight Island to reinforce existing sandbags and increase the height of the sandbag structure. The majority of the sandbags were placed on the northern portion of the Figure Eight Island ocean shoreline in 2003 following the natural shift in alignment of Rich Inlet to the north. In August 2009, the NC Legislature passed House Bill 709 which imposed a moratorium on the removal of temporary erosion control structures if a community was actively pursuing a beach nourishment project or an inlet relocation project. This moratorium, which was applicable to the sandbag revetments on the north end of Figure Eight Island, has expired.

The existing CRC regulations allow sandbags to remain for a period of 5 years after approval if a community is actively pursuing a beach nourishment project and 8 years if the sandbags are located in an inlet hazard area and the community is actively pursuing an inlet relocation project. While the Figure 8 HOA, by virtue of this document, is working on a response to its critical shoreline erosion problem along the north end of the island as discussed below. For purposes of describing Alternative 1, these actions, as they relate to the existing sandbag revetments, are excluded. As a result, given the expiration of the existing permits for the sandbag revetments coupled with the high rates of erosion in the area from Surf Court to Inlet Hook Road, the existing bag structures were assumed to either fail or be removed within approximately five (5) years.

What is NAVD?

The North American Vertical Datum (NAVD) is the vertical control reference used in surveying land elevation. Lines of elevation surveying beginning at the dune and continuing approximately 1 mile offshore are used to monitor sand movement in beach nourishment projects and measure project performance.

Continuation of the present rate of shoreline recession on the extreme north end of Figure Eight Island will imminently threaten an additional four (4) homes on Surf Court within the next 3 years and owners will likely pursue authorization for sandbag placement. Along Beach Road North just south of Surf Court, an additional seventeen (17) homes may become threatened within the next 15 to 25 years, if the channel continues to remain in the northeasterly orientation, and will be eligible for sandbag protection. Once the sandbags fail due to a continuation of the extremely high erosion rates or the sandbags reach the end of their permit period, the owners of the forty (40) structures that are presently or may become threatened over the 30-year analysis period will have to either demolish the structure or move it to another lot on Figure Eight Island.

Beach nourishment has been utilized to protect the homes along the north end of Figure Eight Island since the 1980's as shown in Table 1.1. The nourishment activities consist of dredging of a navigation channel and boat basin in Nixon Channel which shoals with material transported through Rich Inlet. 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.

Figure 3.1. Borrow area in Nixon Channel.

The depth for the previously permitted area within Nixon Channel is -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 cubic yards to 350,000 cubic yards, per event, with densities ranging from 26 cubic yards/linear foot to 133 cubic yards/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 cubic yards or an average of approximately 291,000 cubic yards for each event (Appendix B).

Implementation Cost. Over the thirty year analysis period, the total implementation cost associated with Alternative 1 would be about $115.7 million. This includes $25.7 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, $57.9 million for the loss of land, $0.8 million for temporary sandbag revetments, and $27.5 million for beach nourishment.

Alternative 2: Abandon/Retreat

Description. For Alternative 2, the Figure 8 HOA and the individual property owners would not take any action to slow erosion. This would include installation of new sandbags, beach scraping/bulldozing, or intermittent beach nourishment projects described above in Alternative 1. Also, the Figure 8 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. Twenty-three (23) oceanfront homes located on Surf Court, Comber Road, and Inlet Hook Road fall into this category and would have to 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, 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. Currently, Figure Eight Island has 93 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, 31 are on the located directly on the oceanfront. A total of 45 undeveloped lots are located on the sound side shoreline.

Implementation. Over the 30-year analysis period, the total implementation cost associated with Alternative 2 would be about $87.4 million. This total cost includes $25.7 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, and $57.9 million for the loss of land.

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 relocated from its present position immediately adjacent to the south end of Hutaff Island to a position closer to the north end of Figure Eight Island and oriented along an alignment essentially perpendicular to the adjacent shorelines. The relocation of the main ebb channel would be accompanied by new channels connecting the main ebb channel with Nixon Channel and Green Channel (Figure 3.2). Material removed to relocate the 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 548.6 m (1,800 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 new channel.

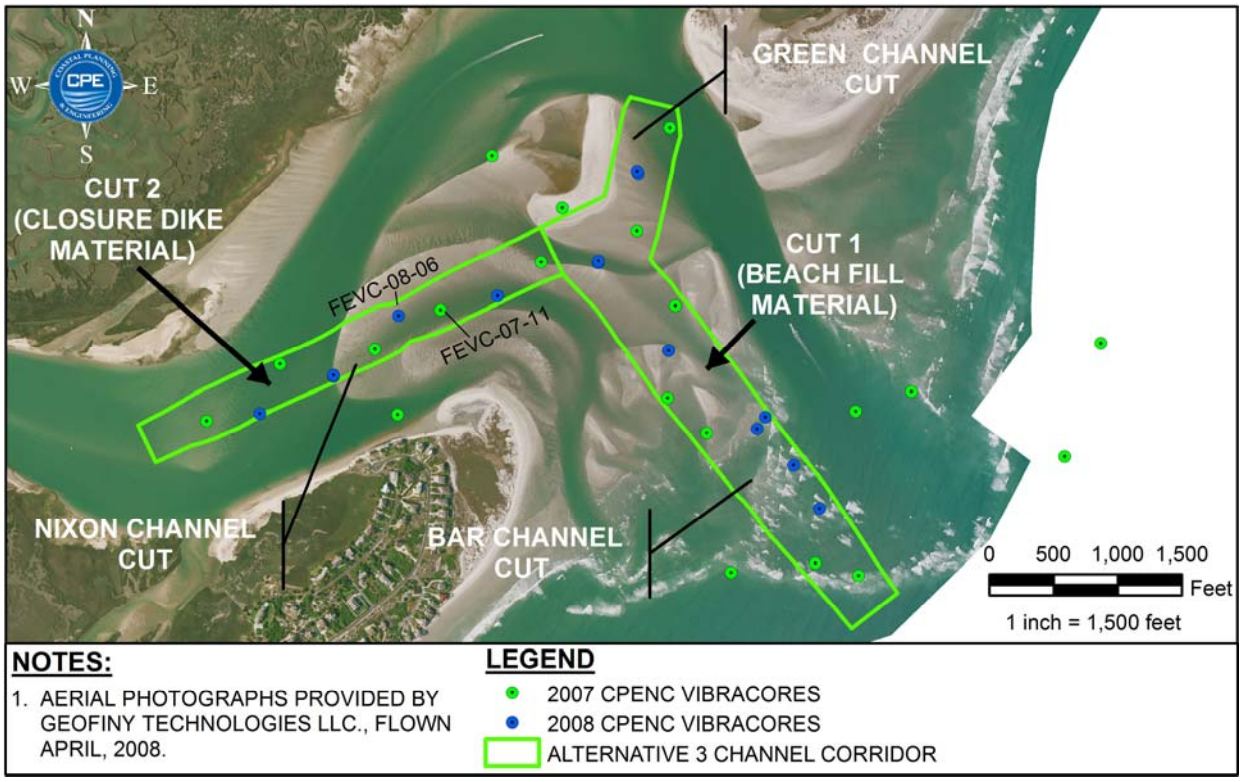


Figure 3.2. Map depicting the two different cuts designed for the Alternative 3 channel corridor. Note the locations of two vibracores (FEVC-07-11 and FEVC-08-06) in which clay material was contained.

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 new inlet bar channel position would be periodically maintained with maintenance episodes dictated by shoaling of the new 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 548.6 m (1,800 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. Under Alternative 3, the main ocean bar channel would be relocated to a position and alignment that would produce favorable shoreline changes on the extreme north end of Figure Eight Island. The relocated bar channel would be accompanied by 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 new bar channel.

The development of the recommended 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 existing entrance channel and interior channel depths of 5.2 m (-17 ft) NAVD, or the same depth as the inlet bar channel. Selection of an optimum 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 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 proposed for New River Inlet 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.

<u>Summary of the Optimal Channel Modifications</u>. The optimal modifications to Rich Inlet for oceanfront shoreline stability and protection 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)

Dredge Volume = 1,773,300 cubic yards + 150,400 cubic yards overdepth (based on the April 2006 survey)

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)
- Volume = 513,700 cubic yards (based on April 2006 survey)

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 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 3.1.

Table 3.1. Alternative 3 beach fill placement volumes and design berm widths

Shoreline Segment (Baseline Stations)*	Placement Volume (cy/lf)	Design Berm Width (ft)
105+00 to 100+00 (transition)	141.6 to 0	124 to 0
100+00 to 50+00	141.6	124
50+00 to 40+00 (transition)	141.6 to 51.4	124 to 46
40+00 to F100+00	51.4	46
F100+00 to F90+00 (transition)	51.4 to 0	46 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 station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments. The total volume of beach fill along the ocean shoreline, including 29,900 c.y. used to construct the dune, would be 1,152,300 cubic yards.

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 243.8 m (800 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 65,000 cubic yards.

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.

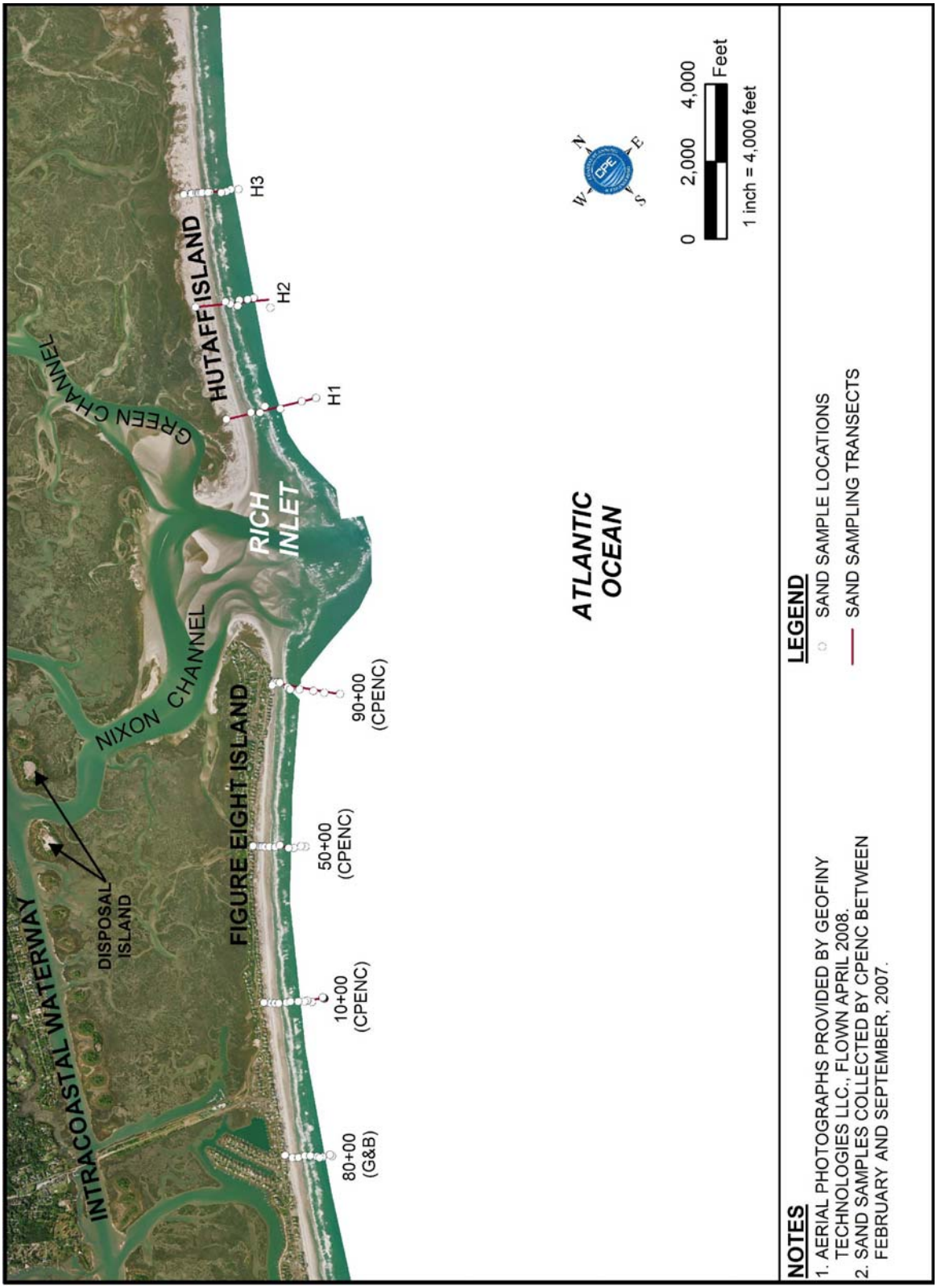


Figure 3.3. Map depicting the locations of sand samples collected on Figure Eight and Hutaff Island

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 3.2 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 3.2) 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 3.2- 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 and 3.4b 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 and 3.4b. The following depicts the appropriate amount of dredged material placed at each location:

Ocean Shoreline Beach Fill	1,152,300 cubic yards
Nixon Channel Beach Fill	65,000 cubic yards
Closure Dike	513,700 cubic yards
Upland Disposal (clay material)	29,700 cubic yards
TOTAL	1,773,300 cubic yards

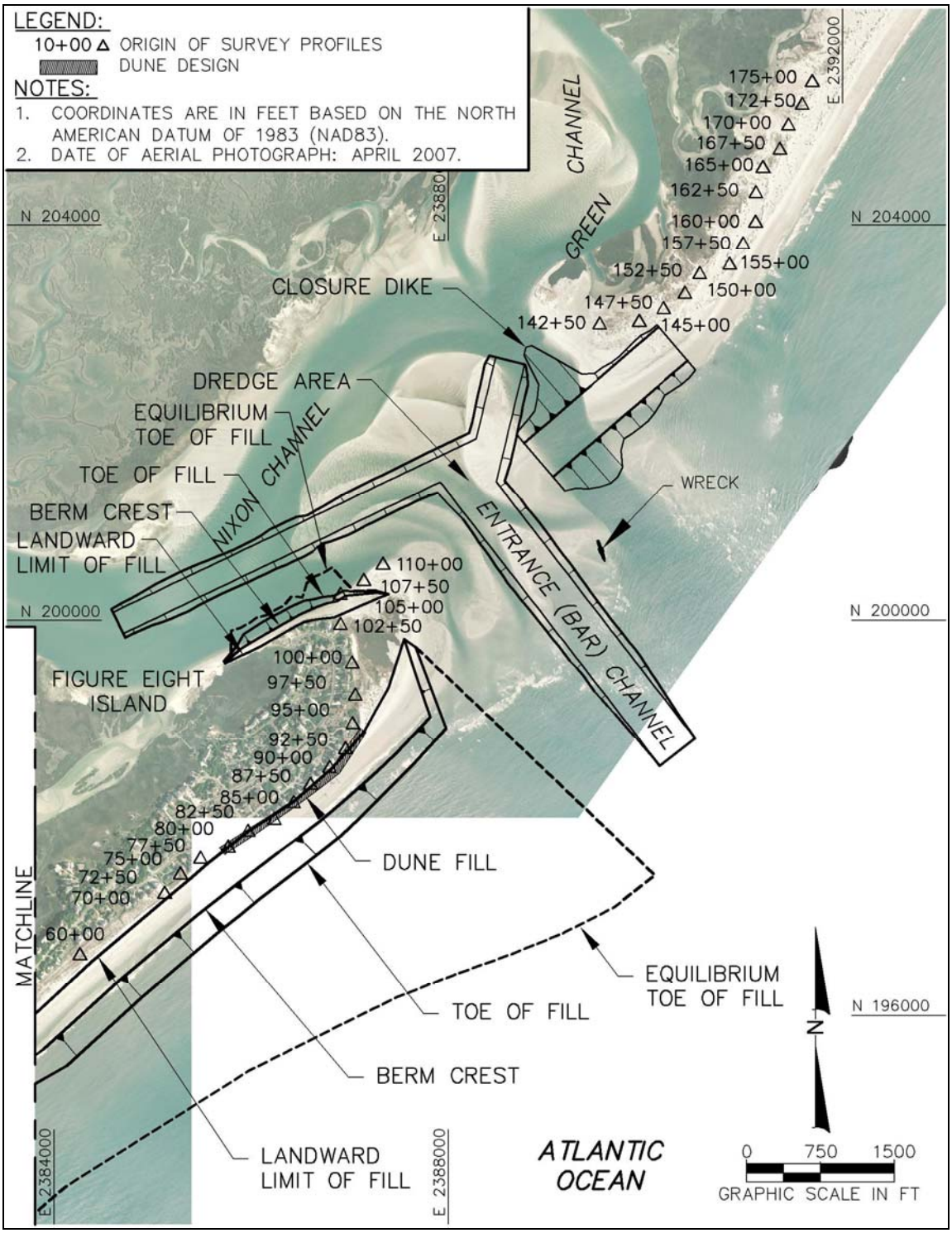


Figure 3.4a Alternative 3: Optimal channel design, closure dike, and northern portion of beach fill.

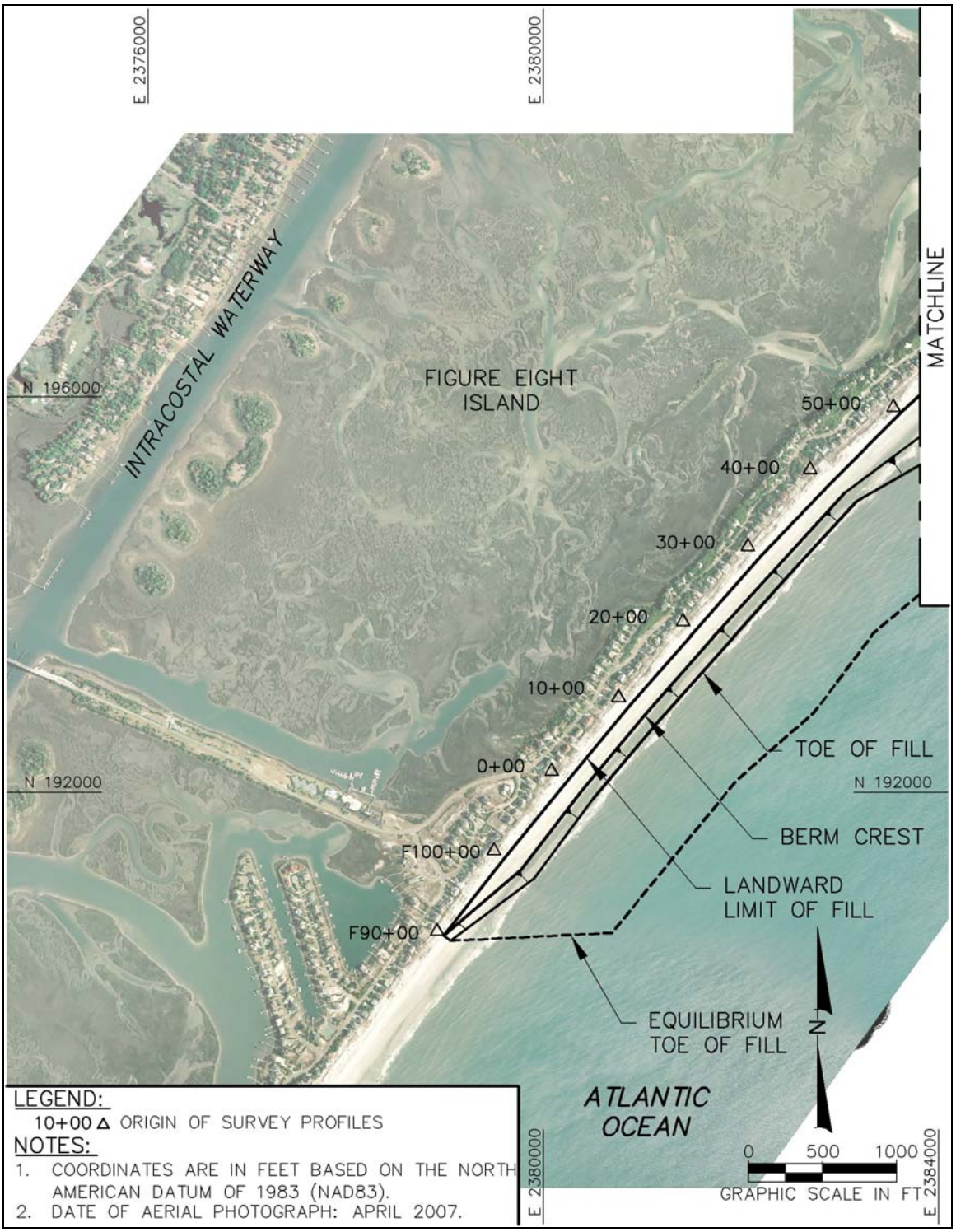


Figure 3.4b Alternative 3: Southern portion of beach fill.

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 3.3. 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. The initial construction volumes for the three channels are estimated to be 909,000 cubic yards for the bar channel, 599,400 cubic yards for Nixon Channel, and 264,900 cubic yards for Green Channel (April 2006 survey data).

Table 3.3. Estimated cumulative shoal volumes in each channel over the 5-year simulation for Alternative 3.

Year	Channel Shoal Volume (cubic yards)			
	Bar	Nixon	Green	Total
0	0	0	0	0
1	257,000	117,000	89,000	463,000
2	460,000	179,000	157,000	796,000
3	591,000	204,000	143,000	938,000
4	537,000	235,000	135,000	907,000
5	716,000	307,000	142,000	1,165,000

Initial volume removed: 909,000 cubic yards from the bar channel, 599,400 from Nixon Channel, and 264,900 from Green Channel (1,773,300 cubic yards in total)

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.

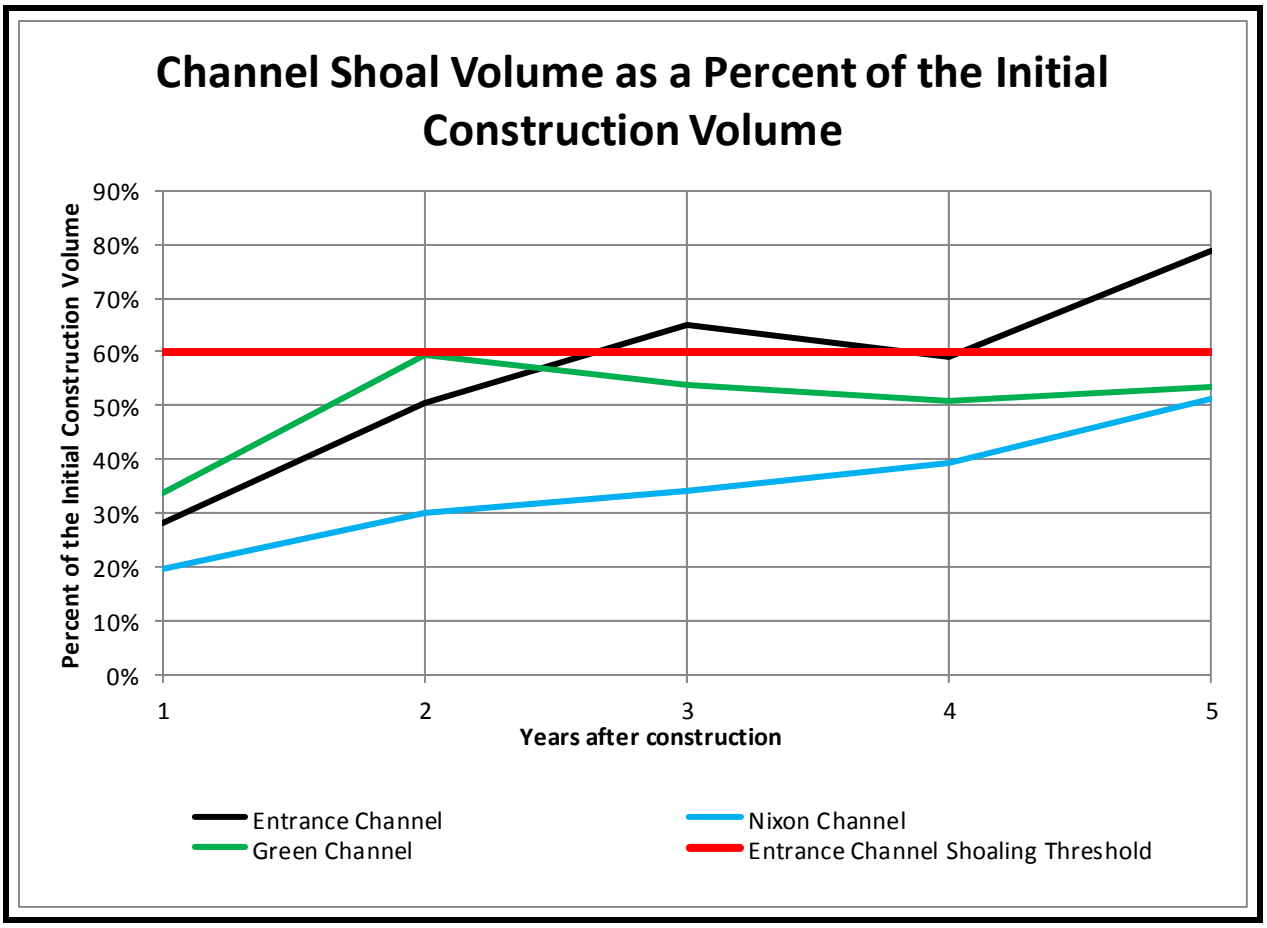


Figure 3.5. Alternative 3 - Cumulative channel shoal volumes over the 5-year model simulation expressed as a percent of the initial construction volume.

Figure 3.5 indicates shoaling of the Entrance Channel would approach the 60% shoaling threshold three years after initial construction. However, the shoaling percentage fluctuated around 60% between the third and fourth year after construction and did not exceed 60% until the fifth year of the simulation. The model indicated the new bar channel could breach the ebb tide delta and assume an alignment 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, as shown in Table 3.3 and on Figure 3.5, with this rapid shoaling 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, the Green Channel connector stabilized

with some slight scour occurring in the channel during years 3 and 4 of the simulation. The Nixon Channel connector also experienced some rapid shoaling during the first year, accumulating 117,000 cubic yards or about 20% of the initial construction volume. Beyond year 2, the rate of shoaling moderated to around 50,000 cubic yards/year over the final four years of the simulation. Even with the initial high rate of shoaling of the Nixon Channel connector, flow through Nixon Channel was concentrated toward the middle of Nixon Channel and away from the back side of Figure Eight Island. The reduced rates of shoaling in the two channel connectors indicate they had achieved some equilibrium and would probably not need to be maintained as frequently as the bar channel.

Periodic Nourishment – Alternative 3.

For planning purposes, future maintenance of the channels would be limited to just the bar channel with 716,000 cubic yards being removed every 5 years. 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 feet 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 30+00 with periodic nourishment of this segment only 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 main fill area between baseline stations 30+00 and 100+00 on a regular basis. The future need to nourish the area between F90+00 and 30+00 would be determined from the results of beach profile monitoring surveys.

The annual rate of erosion of the beach fill between stations 30+00 and 100+00 averaged 123,500 cubic yards/year over the 5 year simulation period. 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 617,500 cubic yards. Providing a transition or taper section between stations 100+00 and 105+00 would require 35,900 cubic yards which would increase the 5-year nourishment requirement along the ocean shoreline to 653,400 cubic yards. Nourishment of the Nixon Channel area would require an about 30,000 cubic yards which brings the total 5-year nourishment requirement to 683,400 cubic yards.

Regardless of the periodic nourishment requirement for the beach fill, 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 shift back toward Hutaff Island sometime between years 4 and 5. Consequently, the new channels would probably have to be maintained approximately every five years regardless of the nourishment needs along Figure Eight Island. The volume of material that would accumulate in the new entrance channel over the 5-year period was estimated to be 716,000 cubic yards.

Implementation Cost. Over the thirty year planning period, the total implementation cost for Alternative 3 would be about $61.7 million in current dollars. This total cost includes $15.3 million for initial construction of the new channels, sand dike, and beach fills and $46.4 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.

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 a beach fill under Alternative 4 used the same beach fill design as Alternative 3. However, as explained in Chapter 5 and in the Engineering Appendix (Appendix B), the Alternative 3 beach fill, which was dictated by the volume of material that would be removed to reconfigure the Rich Inlet bar channel and connecting channels, exceeded the fill volume needed to address shoreline erosion issues. Based on the modeled performance of the beach fill under Alternative 4, the Alternative 4 beach fill was redesigned resulting in a reduction in the initial beach fill volume between stations F90+00 and 80+00 and an increase in the design volume between 80+00 and 100+00 compared to that of Alternative 3. Also, due to the high rates of loss from the fill obtained from the model results for the area between 80+00 and 100+00, the beach fill design for Alternative 4 was based on a three-year periodic nourishment cycle. The total initial beach fill volume along the ocean shoreline from Rich Inlet to Bridge Road would be 864,300 cubic yards. The beach fill along Nixon Channel would be the same as Alternative 3 or 65,000 cubic yards. Periodic nourishment would occur every 3 years and would require a total of 670,000 cubic yards. Included in this total is 18,000 cubic yards to nourish the Nixon Channel shoreline and 50,000 cubic yards for the transition fill between stations 100+00 and 105+00 (Table 3.4).

Table 3.4. Alternative 4 beach fill placement volumes and design berm widths

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

The identified borrow sources for Alternative 4 include the previously permitted area within Nixon Channel as described in Alternative 1, three potential borrow sources located between 3 and 4 miles directly offshore of Figure Eight Island and three 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 cubic yards. The volume of material for each event was generally limited to less than 300,000 by the Figure 8 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 cubic yards every 4 or 5 years. Since the last maintenance dredging in Nixon Channel occurred in 2011, at least 400,000 cubic yards 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.

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.

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 3.6 each contain an estimated 4.6 million cubic yards 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.

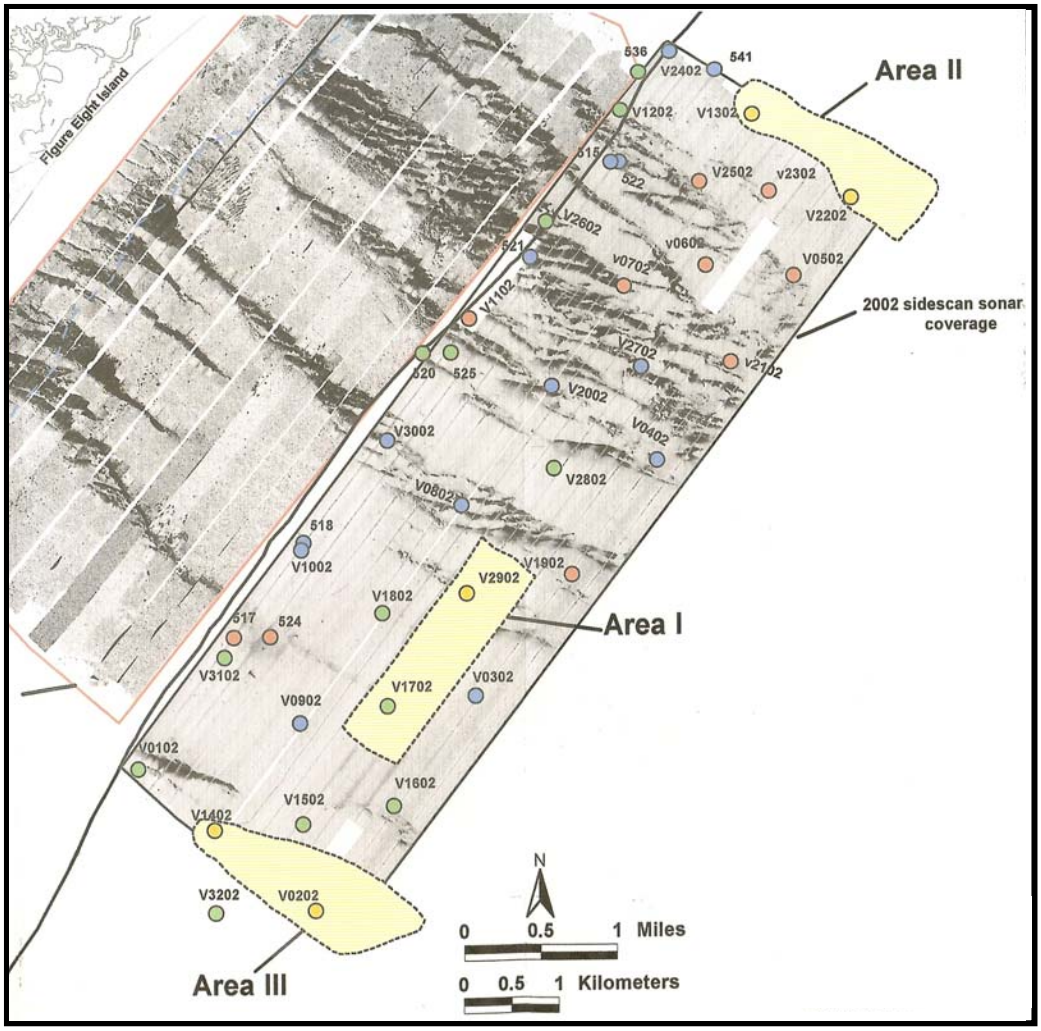


Figure 3.6. Potential offshore borrow areas identified by Dr. Cleary.

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

Three 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 northern disposal sites shown on Figure 3.7 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 3.7. Location of AIWW dredged material disposal sites 1, 2, and 3.

The Figure Eight 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 3.5.

Table 3.5. 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 cubic. Adjusting this total volume for silt content, approximately 527,000 cubic yards of sandy material is stored in the three 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 sources 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 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 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 rates for Alternative 4 indicated by the model results 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, the beach fill between stations F90+00 and 30+00 would not require periodic nourishment on a regular basis. North of baseline station 30+00, modeled losses from the fill over three years totaled 602,000 cubic yards with over one-half of the volume loss occurring north of station 80+00. Replacement of the transition section between 100+00 and 105+00 would require 50,000 cubic yards while nourishment of the Nixon Channel fill would require 18,000 cubic yards every three years. Thus, a 3-year nourishment cycle for Alternative 4 would be required at an amount of 670,000 cubic yards per event.

Implementation Cost. Over the thirty year planning period, the total implementation cost for Alternative 4 would be about $102.5 million in current dollars. This total cost includes $12.3 million for initial construction of the beach fills along the ocean and Nixon Channel shorelines and $90.2 million to nourish the beach fills every three (3) years. Initial construction is expected to take approximately 4 months.

Alternative 5: Beach Fill with Terminal Groin

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 permanent erosion control 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;…"***

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.

Two terminal groin options were considered with the difference in each option associated with where material would be obtained to construct the accompanying beach fill. Alternative 5A would use material from the existing and previously permitted in Nixon Channel and within an extension of this permit area that would connect into the gorge, or main channel, of Rich Inlet. Alternative 5B would use material from the previously permitted area within Nixon Channel supplemented with material from the three northern upland disposal sites. As discussed in Chapter 5, the periodic nourishment requirements for the beach fill along the ocean shoreline of Figure Eight Island would be significantly reduced by the addition of a terminal groin negating the need to use material from the offshore borrow sites. Additionally, in Chapter 5, information is provided to show why the other identified borrow sources were eliminated from further consideration.

Preliminary Delft3D model runs and engineering analysis were conducted to determine the desired terminal groin dimensions. In this regard, the terminal groin design goal was to create a

relatively stable beach south of the structure that encompassed the homes presently protected by temporary sandbag revetments.

Modeling runs evaluated the performance of a 700-foot long groin and a 1,200-foot long groin; with advanced beach fill within the fillet and without. Both terminal groins would include a 900-foot beach shore anchorage section above the mean high water line which would result in total groin lengths of 1,600 feet and 2,100 feet, respectively. Additionally, the 1200-foot groin option with advanced fill was modeled angled at 10, 20, and 30 degrees toward Figure Eight Island (see Appendix B for additional screening model results). Engineering analysis and the groin performance information generated by the Delft3D model determined that both the 700 and 1,200 foot long groins performed similarly and therefore the 700-foot option was considered the preferred design. The length of the terminal groin, as discussed for Alternatives 5A and 5B throughout this document, will be referred to as 700-feet long since the effective length, in terms of oceanfront shoreline, is limited to that portion seaward of the MHW.

Alternative 5A: Terminal Groin with Beach Fill from Maintenance of the Nixon Channel Navigation Channel and Connector Channel

A 700-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 3.8). The terminal groin would include a 900-foot shore anchorage section 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 shore anchorage section would essentially follow the 1970 inlet shoreline and terminate near the Nixon Channel shoreline (Figure 3.8). The total length of the terminal groin including the shore anchorage section would be 1,600 feet.

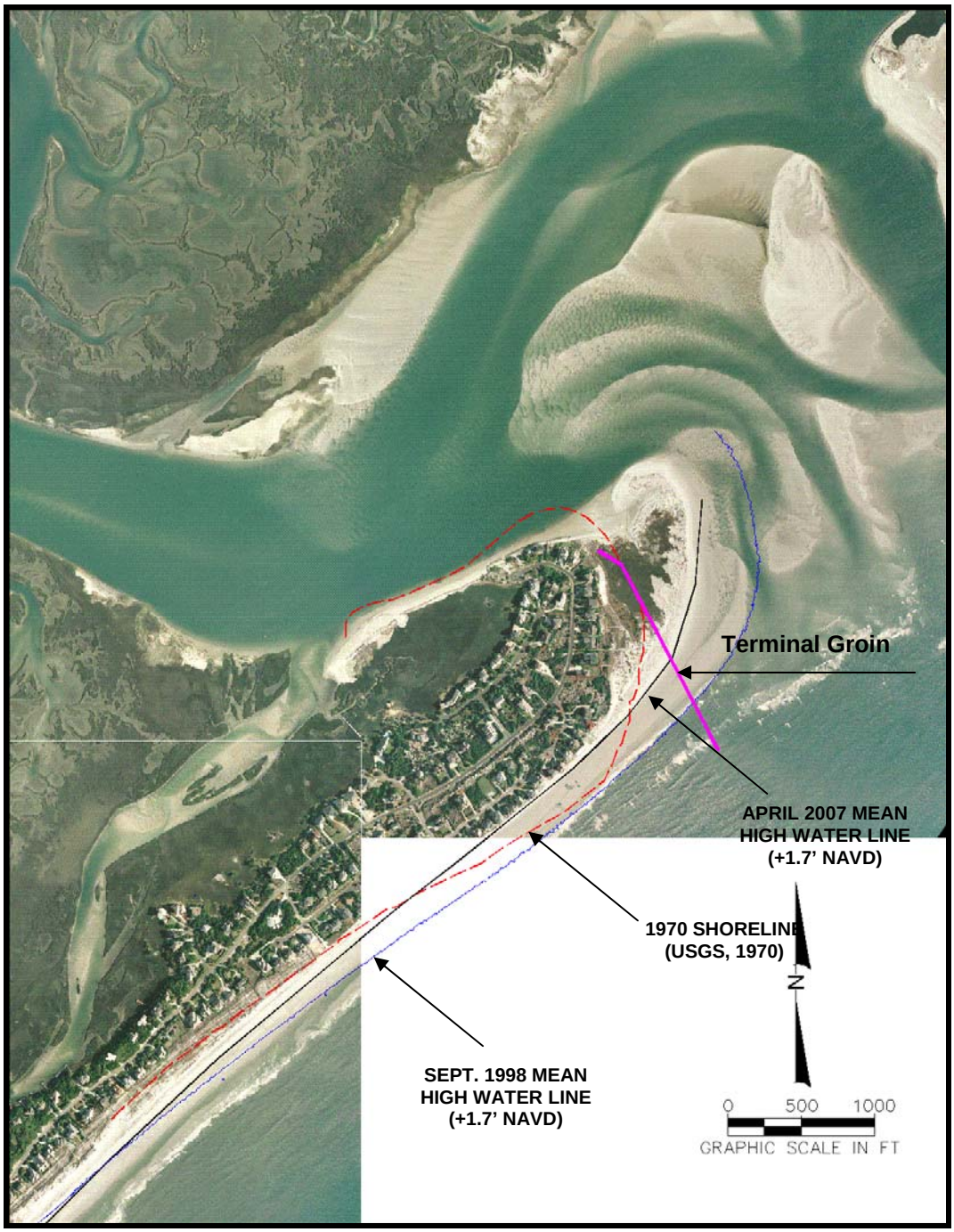


Figure 3.8. Terminal Groin Layout Based on 1970 and 1998 Shorelines

Alternative 5A includes a new channel that would connect the previously permitted area within Nixon Channel with the inlet gorge (Figure 3.9). 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. 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 cubic yards of material. Of this total volume, 319,600 cubic yards would come from the existing Nixon Channel permit area and the remaining 675,300 cubic yards excavated to construct the new channel connector.

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 77+50 to 95+00. Excavation of the material from the Nixon Channel and construction of the new connector into Nixon Channel would be accomplished by a 20-inch or smaller cutter-suction pipeline dredge.

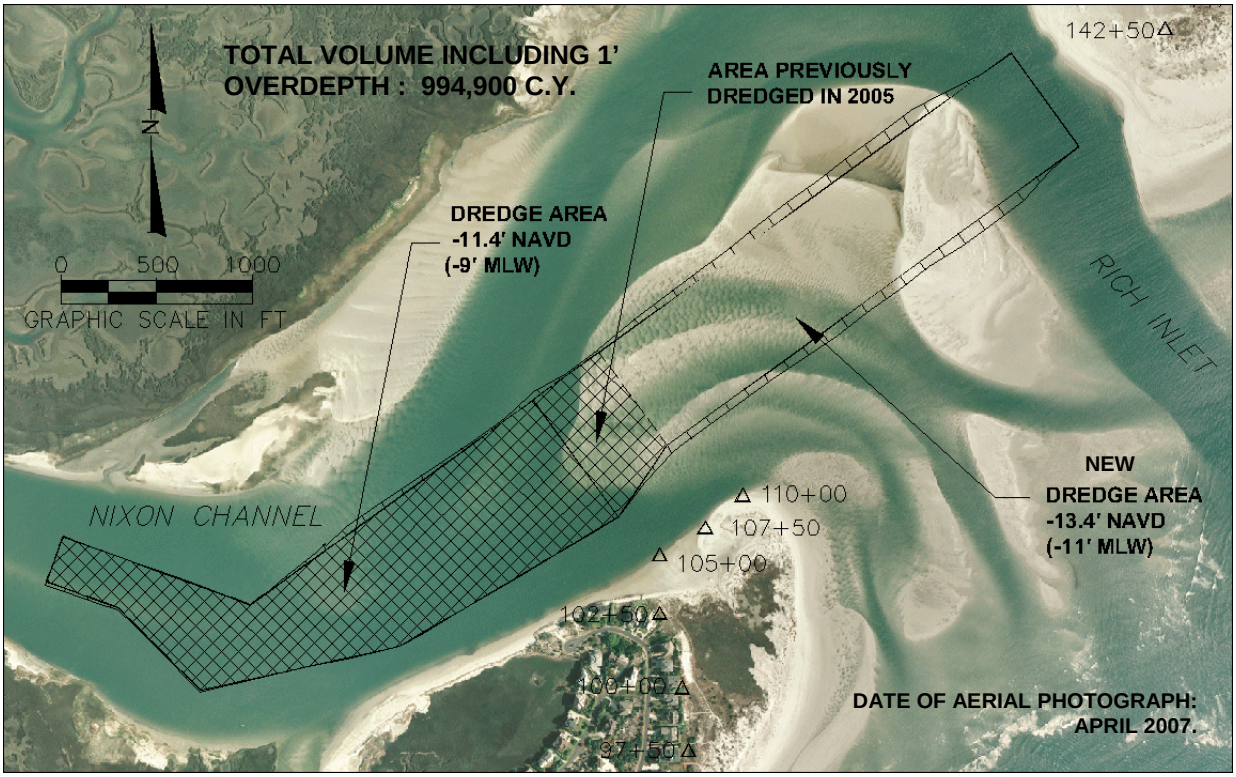


Figure 3.9. Alternative 5A, Terminal Groin with Beach Fill from New and Previously Dredged Cuts in Nixon Channel

As was the case for Alternative 3, the beach fill designs associated with Alternative 5A were based on the optimal distribution of the 994,400 cubic yards of material that would be removed to construct the new channel connector and maintain the previously permitted area within Nixon Channel. The volume of fill material placed along the 1,800-foot shoreline along Nixon Channel would be 65,000 cubic yards which is the same as Alternatives 3 and 4. The distribution of beach fill 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 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 3.6. An artificial dune, similar to Alternatives 3 and 4, would be provided in the existing sandbag area between stations 77+50 and 95+00. The total volume of beach fill along the ocean shoreline, including the dune fill, would be 913,000 cubic yards. The combined volume needed to construct the two beach fills is 978,000 cubic yards or 16,400 cubic yards less than the volume that would be excavated to restore the previously permitted area within Nixon Channel and construct the new Nixon Channel connector. Even though this "extra" volume is not needed to construct the two beach fills, the excess material would be evenly distributed along both fills to provide a limited amount of advanced nourishment.

Table 3.6 Alternative 5A beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
100+00 to 95+00	158.8 to 284.1	137 to 236
95+00 to 75+00	284.1 to 86.1	236 to 74
75+00 to 50+00	86.1	74
50+00 to 40+00 (transition)	86.1 to 32.1	74 to 28
40+00 to F100+00	32.1	28
F100+00 to F90+00 (transition)	32.1 to 0	28 to 0

Structural Design of the Terminal Groin.

The following description of the design of the terminal groin is based on preliminary design considerations and the latest survey information which are subject to change during the preparation of detailed plans and specifications. However, the size of the structures footprint and the required construction corridor presented below are representative of the final design.

The total length of the terminal groin would be around 1,600 feet of which only 700 feet would project seaward of the existing mean high water (MHW) shoreline. The landward 900 feet of the structure would be constructed with sheet pile, either steel or concrete, and would have a top elevation of +4 feet NAVD which is slightly below the existing ground elevation. The landward end of the groin would terminate near the existing Nixon Channel shoreline. To account for possible scour in this location, the landward portion of the sheet pile section would be protected by a rubble scour protection apron that would begin about 100 feet from the end of the structure and wrap around both sides. The toe apron would be installed at a depth of approximately 0 ft NAVD and would require the excavation of approximately 600 cubic yards. Material excavated for the toe apron would be used to bury the toe protection stone following placement. A total of 14,000 to 18,000 square feet of sheet pile would be required depending on the final design characteristics. The seaward 700 feet of the structure would be constructed with stone in a typical rubblemound fashion. A profile of the terminal groin is shown on Figure 3.10 with typical cross-sections of the rubblemound portion designated as Typical Cross-sections 1 and 2 shown in Figure 3.11 and 3.12, respectively. Typical Cross-section 1 would cover 400 feet of the structure beginning at a point approximately 200 feet landward of the MHW shoreline and would have a crest elevation of +6 feet NAVD. Typical Cross-section 2 would extend seaward of that point and terminate at a depth of approximately -6 feet NAVD based on the latest profile survey. The first 400 feet of Typical Cross-section 2 would have a top elevation of +6 feet NAVD and would slope down to a top elevation of +3.5 feet on the seaward end. Based on this preliminary design, construction of the rubblemound portion of the terminal groin would require around 16,000 tons of stone.

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, limiting its effective length to 700 feet, and constructing the structure with large voids between adjacent stones. While the seaward portion of the groin should be visible at

all stages of the tide, the seaward end of the terminal groin would be marked by a US Coast Guard approved navigation aid.

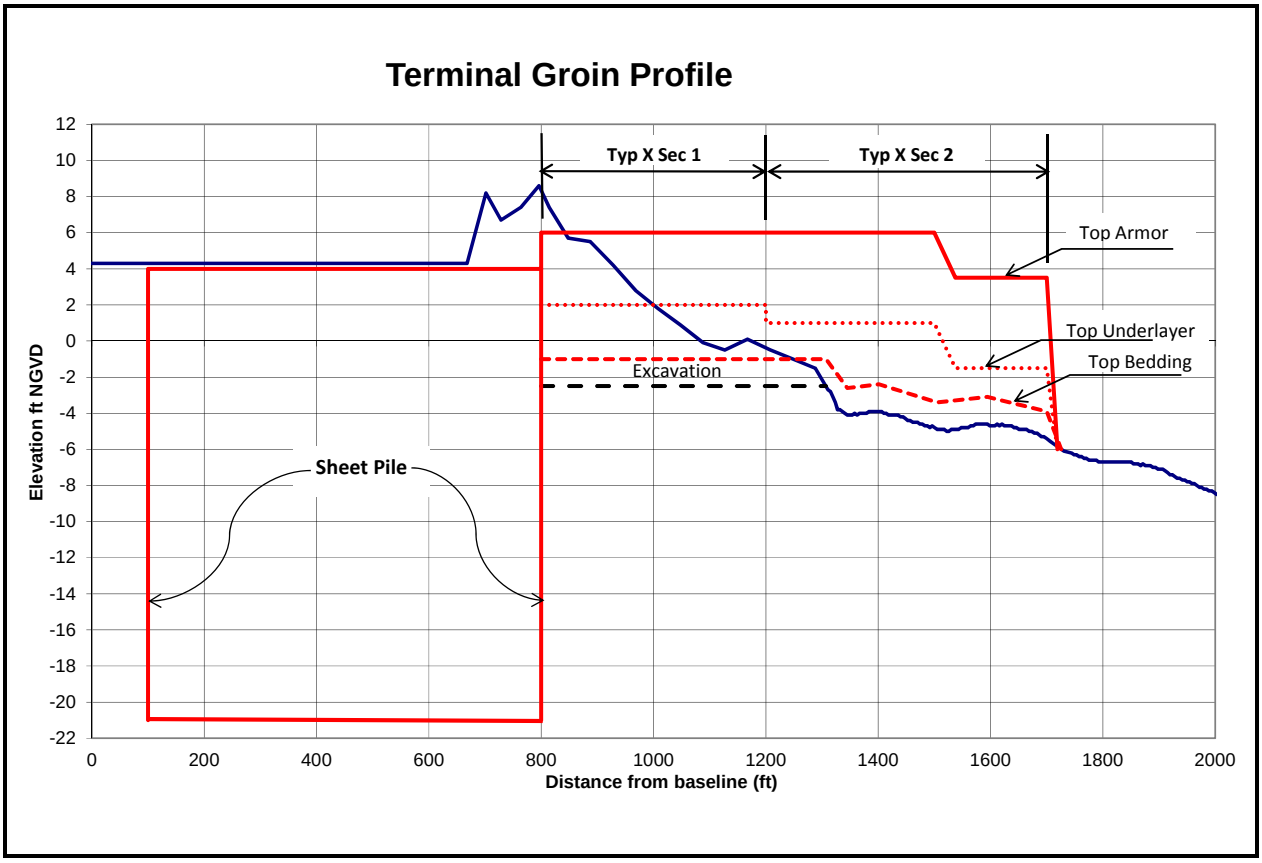


Figure 3.10. Profile of terminal groin.

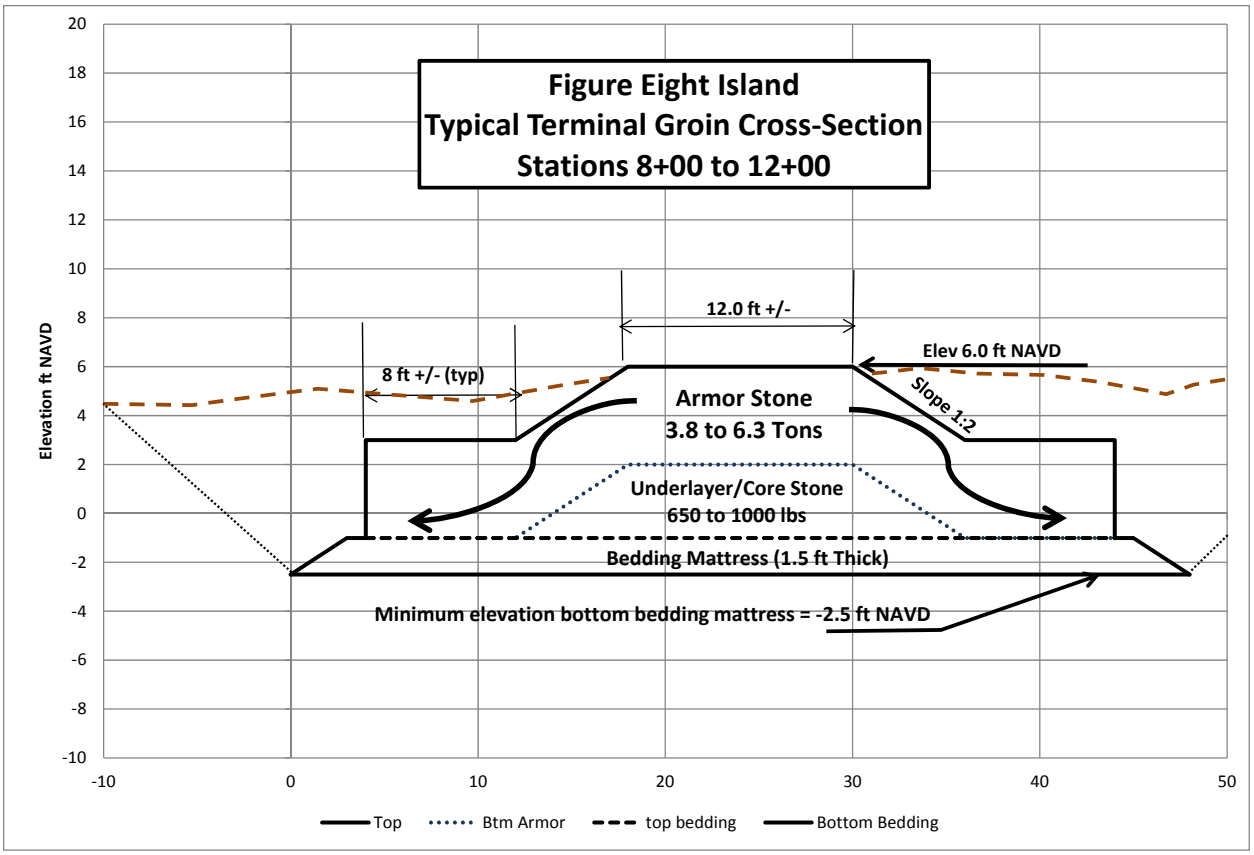


Figure 3.11. Typical terminal groin cross-section 1. Reference Figures 3.13a and 3.13b for station location.

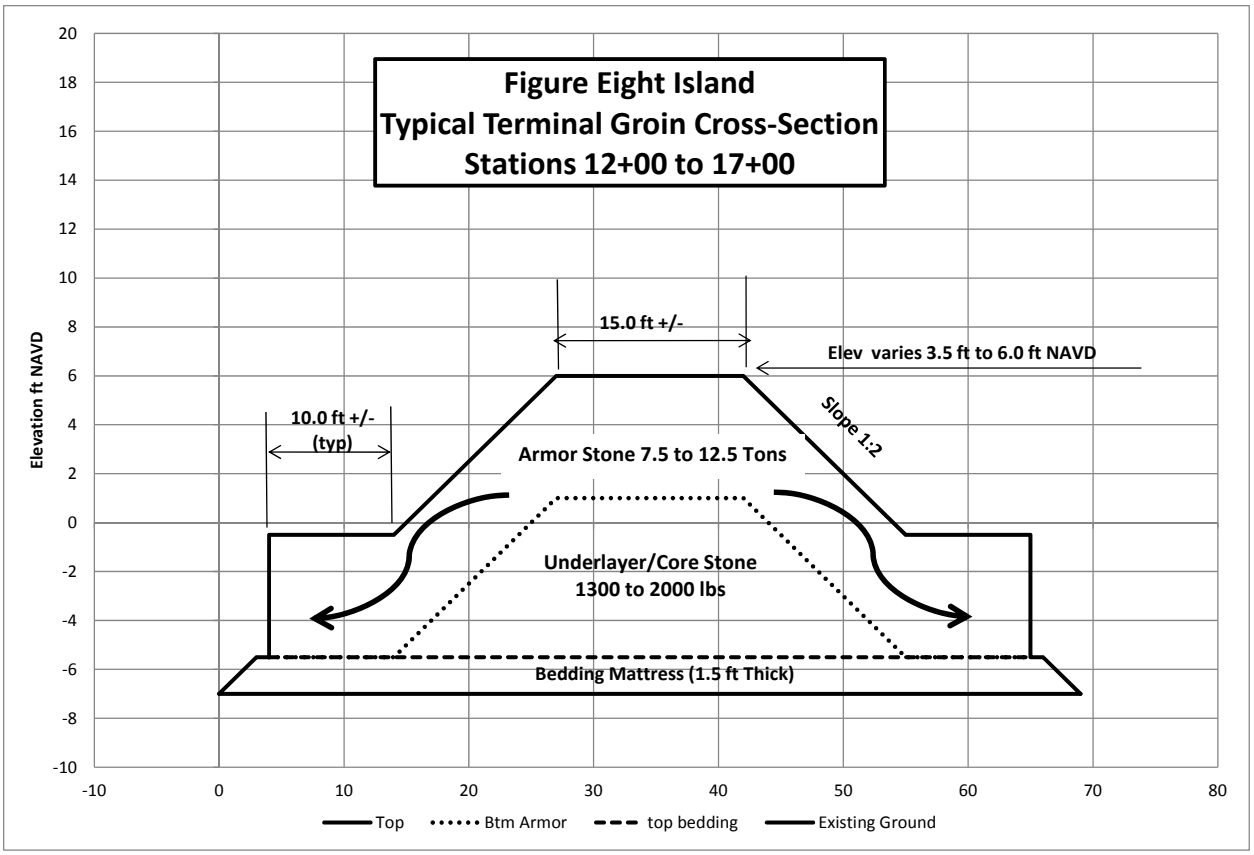


Figure 3.12. Typical terminal groin cross-section 2. Reference Figures 3.13a and 3.13b for station location.

The general layout of Alternative 5A showing the proposed location of the terminal groin, channel modification in Nixon Channel, and the distribution of the beach fill along both the ocean shoreline and Nixon Channel are shown on Figures 3.13a to 3.13b.

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, approved access locations and staging areas as well as 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 3.14, 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 varying in width from 100 feet to 200 feet would be established around the alignment of the terminal groin and all construction activity required to remain within the corridor (Figure 3.14). Along the construction corridor, backhoes or large cranes would excavate a trench varying in width from approximately 40 feet to 70 feet down to a depth of -2.5 feet NAVD for typical cross-section 1 and typical cross-section 2. Excavation of the trench would involve the temporary removal of 6,000 cubic yards with this material 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 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 the underlayer/core stone in the form of a trapezoidal mound, the side slopes of which would be covered with the armor stone. Once construction reaches the existing -2.5-foot NAVD depth contour in the ocean, the bedding stone (or mattress) would be placed directly over the existing bottom. Placement of the armor cap stones would be deferred until all of the bedding, underlayer/core stone, and side-slope armor stone has been placed along the entire length of the groin. At that point, the crane would back off the structure and place the cap stone as it moves back toward land. Prior to moving landward, the US Coast Guard approved navigation aid would be installed at the head of the groin.

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.

The bottom width of the terminal groin would vary between groin centerline stations (centerline stations shown on Figure 3.15) as follows:

Station 1+00 to 2+00 (sheet pile with toe apron)---20 feet
Station 2+00 to 8+00 (sheet pile)---------- 1 to 2 feet
Station 8+00 to 12+00 (rubblemound)---------- 40 feet
Station 12+00 to 15+37(rubblemound) ---------- 40 to 70 feet
Station 15+37 to 17+00 (rubblemound)---------- 70 feet

A schematic of the footprint of the terminal groin is shown in Figure 3.14. The total area bottom area of the terminal groin would be about 1.1 acres.

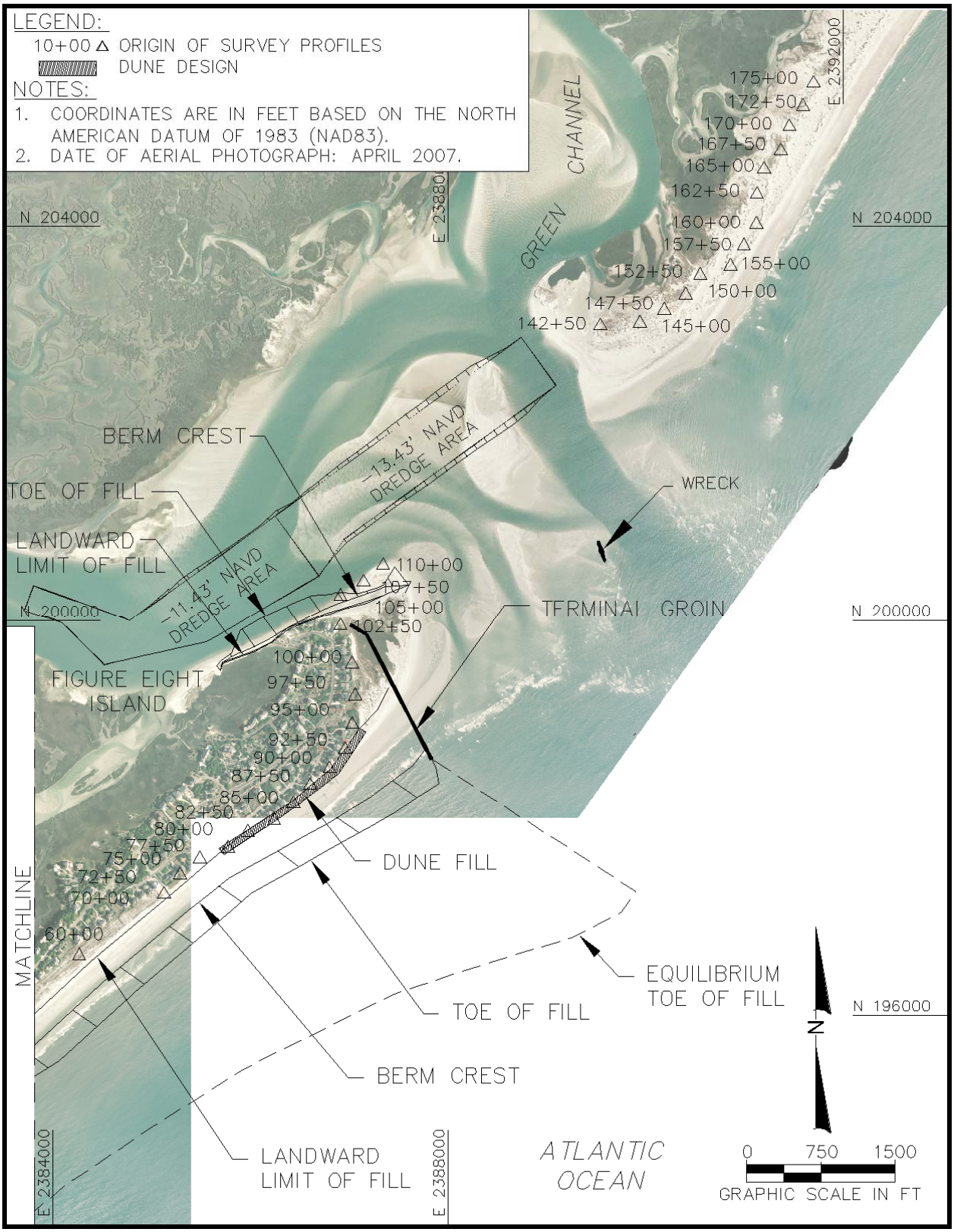


Figure 3.13a. Plan view of Alternative 5A

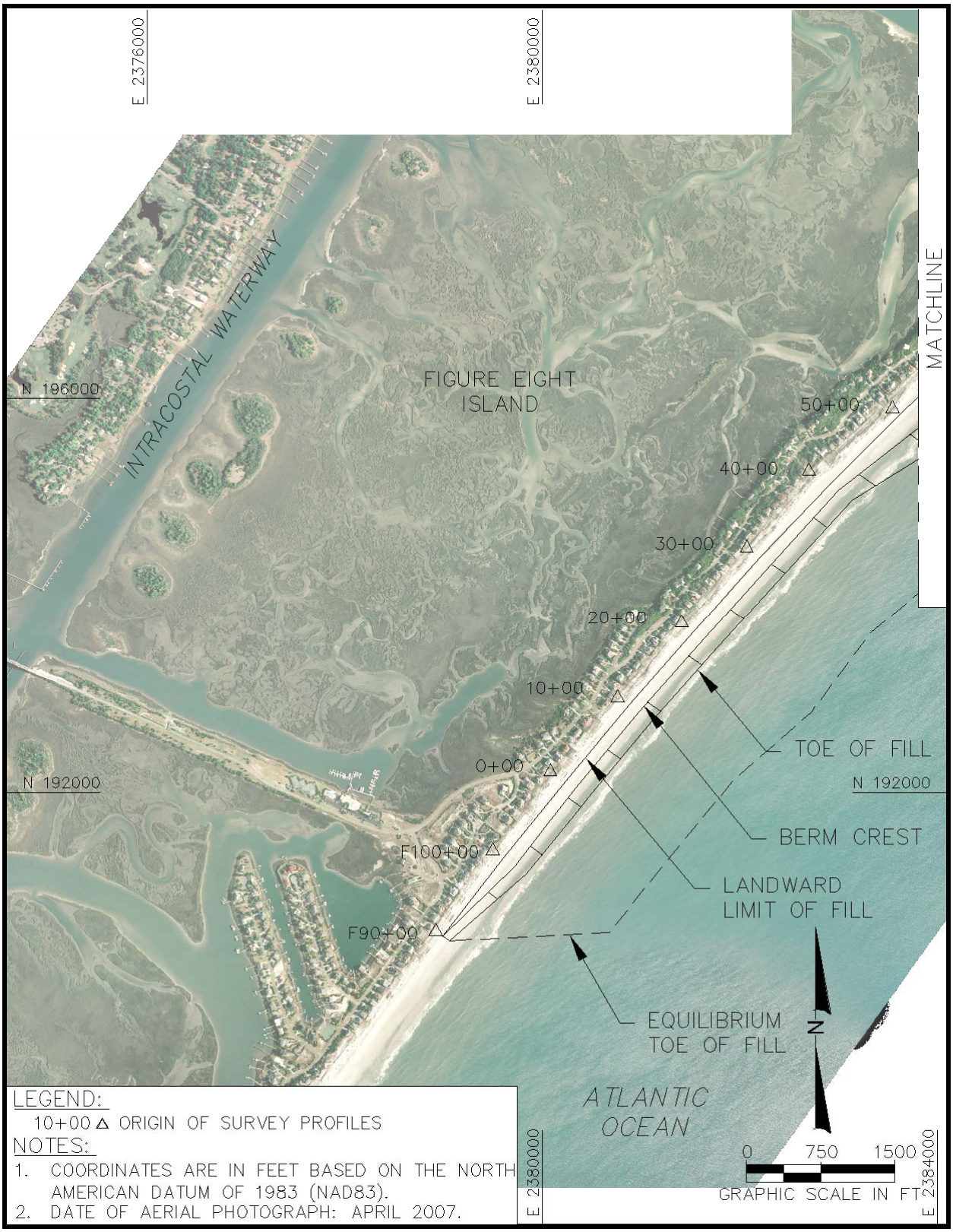


Figure 3.13b. Plan view of Alternative 5A

Figure 3.14. Footprint of the terminal groin, construction corridor, and offloading pier.

Numerical Model Evaluation of Alternative 5A

The functional design and performance of Alternative 5A was evaluated in the Delft3D model and included three different dredging options for the Nixon Channel connector, the selected 700-foot groin with beach fill, a 1,200-foot groin with beach fill, both the 700-foot and 1,200-foot groins without beach fill, and the 1,200-foot groin oriented toward Figure Eight Island at 10°, 20°, and 30°. A complete discussion of the model results for Alternative 5A is provided in Appendix B and a summary of the results included in Chapter 5.

Channel Maintenance Requirements.

Based on the results of the Delft3D model simulation for Alternative 5A, the rate of shoaling of the existing permit 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, the 5-year channel maintenance requirement would be 472,000 cubic yards.

Periodic Nourishment – Alternative 5A.

The beach area between F90+00 and 30+00 accreted during the 5-year simulation and would not require periodic nourishment. The computed volume losses from the fill between stations 30+00 and 100+00 averaged 85,500 cubic yards/year over the five year simulation period. Assuming periodic maintenance of the existing permit area in Nixon Channel and the proposed connecting channel is accomplished every five years, the nourishment requirement for the ocean shoreline would be 427,500 cubic yards. Nourishment of the Nixon Channel fill area would also require 30,000 cubic yards as with the other alternatives bringing the total five year nourishment requirement to 457,500 cubic yards.

Material for periodic nourishment of Alternative 5A would be derived from maintenance of the existing permit 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 472,000 cubic yards every 5 years or 94,400 cubic yards/year is approximately equal to the average annual amount of material removed to maintain the existing permit area since 1993. As mentioned previously, maintenance of the existing permit area removed about 1.75 million cubic yards between 1993 and 2011 which is equivalent to an annual rate of about 97,000 cubic yards/year. Therefore, based on both actual experience and model predictions, maintenance of the channels in Nixon Channel should be sufficient to satisfy periodic beach nourishment requirements for Alternative 5A.

Implementation Cost. 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 1,800 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 994,900 cubic yards. As presented above, the terminal groin would be constructed with both sheet pile and rubblemound. Armor stone sizes would range from approximately 4 to 12.5 tons.

The initial construction cost of the terminal groin is estimated to be $3,315,000 which includes engineering and design and construction oversight. Construction of the beach fills along Nixon Channel and the ocean shoreline using material from Nixon Channel and the new channel to the inlet gorge would cost $9,078,000. The total initial construction cost of Alternative 5A would be $12,393,000. The initial construction of Alternative 5A is expected to take approximately 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 $5,424,000 every five years.

The average annual equivalent cost for constructing and maintaining Alternative 5A would be $1,863,000. Over the 30-year planning period, the total implementation cost for Alternative 5A in current dollars would be about $39.5 million.

Terminal Groin Removal Cost. Session Law 2011-387, Senate Bill 110 includes the following requirement with regard to modification or removal of a terminal groin:

> Section 1. G.S. 113A-115-1(e)(6)c. reads as follows:
>
> *Proof of financial assurance…that is adequate to cover the cost of:*
>
> > *c. Modification or removal of the terminal groin as provided in the inlet management plan.*

In the event identifiable consequences of the terminal groin cannot be mitigated, the applicant must show financial capability to either modify the terminal groin or have it removed. Modification to the design of the terminal groin to address specific effects cannot be predicted prior to observing the actual performance of the structure. Therefore, as a worst case, the applicant must show the financial capability to have the terminal groin removed. In this case, removal of the terminal groin would entail extracting the sheet pile from the shore anchorage section and complete removal of all of the stone along the seaward portions of the structure including all bedding, underlayer, and armor stone and the transport of the material to a disposal site off of the island. Removal of the terminal groin would include the cost of labor and equipment minus the salvage value of the sheet piles and stone. The estimated cost of removal of the terminal groin is $1.0 million.

Alternative 5B (Applicant's Preferred Alternative): Terminal Groin with Beach Fill from Other Sources

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. 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. Since Alternative 5B does not include the excavation of a new connector channel into Nixon Channel, the beach fill for 5B was designed to address erosion protection needs.

The design of the beach fill for Alternative 5B was based on the Delft3D simulated behavior of the Figure Eight Island shoreline in response to the installation of a terminal groin without any accompanying beach fill and the need to prefill the beach immediately south of the terminal groin. The results of the terminal groin simulation without beach fill indicated the area south of station 60+00 to station 30+00 would experience very moderate erosion which would not pose any immediate threat to upland development. The shoreline segment from station 30+00 to station F90+00 accreted and would not need any initial beach fill. Based on this result and the modeled rate of beach fill retention under Alternative 5A, the beach fill for Alternative 5B would be limited to the area north of station 60+00 and would have the placement rates and design berm widths shown in Table 3.7. Even though the area south of station 60+00 to station F90+00 would not receive any initial nourishment, this area would be included in the project monitoring plan, presented in Chapter 6, with nourishment provided on an as-needed basis or in response to shoreline changes exceeding the shoreline change thresholds are also discussed in Chapter 6.

The beach fill would be constructed to an elevation of 1.8 m (6.0 ft) NAVD and would include an artificial dune similar to Alternatives 3, 4, and 5A between stations 77+50 and 95+00. A plan layout for Alternative 5B is provided in Figure 3.15. The total volume of beach fill along the ocean shoreline, including the dune fill, would be 224,800 cubic yards. The Nixon Channel beach fill would require 65,000 cubic yards bringing the total beach fill volume to 289,800 cubic yards.

Like Alternative 4, the material to construct the beach fill for Alternative 5B would be derived from maintenance of the existing permit area in Nixon Channel. Based on past maintenance operations in the existing permit area of Nixon Channel and anticipated shoaling rates indicated by the Delft3D simulations for the other alternatives, the volume of material available from the existing permit area would satisfy the volumetric requirements for Alternative 5B. The beach compatible material contained in the three 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 Nixon Channel permit area 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 3.7 Alternative 5B beach fill placement volumes and design berm widths.

Shoreline Segment (Baseline Stations)	Placement Volume (cy/lf)	Design Berm Width (ft)
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

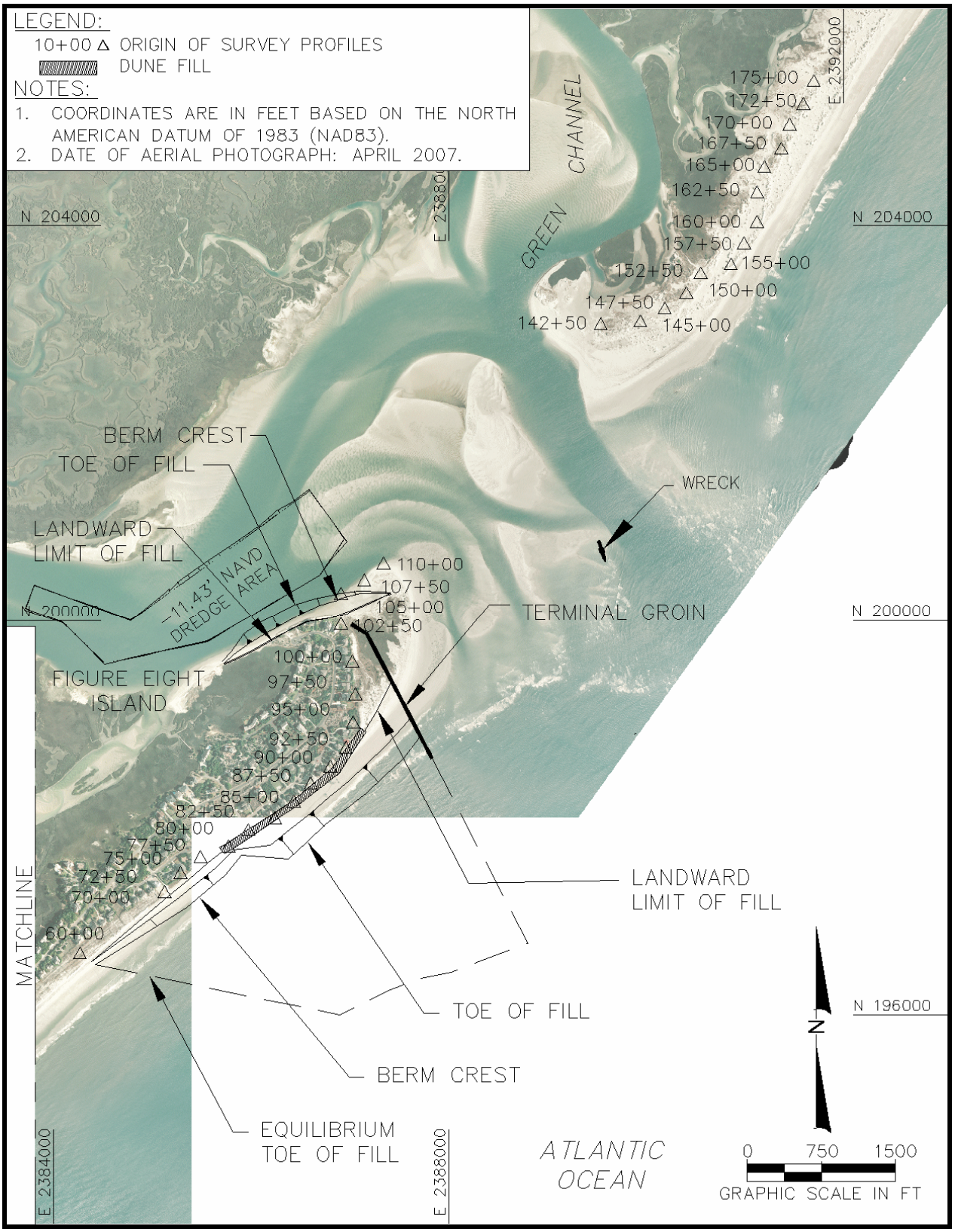


Figure 3.15. Alternative 5B Dredging and Groin Option and Beach Fill Layout.

Periodic Nourishment – Alternative 5B.

The periodic nourishment requirement for the Alternative 5B was based on the performance of the Alternative 5A beach fill north of station 60+00 in terms of the percent of initial fill remaining at the end of the 5 year simulation. Based on a fill retention rate between stations 60+00 and 80+00 for the Alternative 5A beach fill, the estimated loss from the Alternative 5B fill would be ~12,100 cubic yards at the end of five years. Similarly, the Alternative 5A fill retained 17% of the initial fill volume between stations 80+00 and 100+00. Assuming the Alternative 5B fill would experience the same rate of retention, losses from this area over 5 years would be 132,800 cubic yards. Thus, the total 5-year nourishment requirement for the Alternative 5B fill along the ocean shoreline would total approximately 145,800 cubic yards. Maintenance of the beach fill along Nixon Channel would require 30,000 cubic yards every 5 years resulting in a combined total 5-year periodic nourishment requirement of ~175,800 cubic yards.

Material for periodic nourishment of Alternative 5B would be derived from maintenance of the existing permit area in Nixon Channel. If needed, supplemental fill material could be obtained from one of the AIWW upland disposal areas. The maintenance dredging would be performed by a 16-inch to 20-inch cutter-suction pipeline dredge, or the same size dredge used for initial construction.

The removal of 175,800 cubic yards from the Nixon Channel existing permit area every 5 years is equivalent to a rate of about 35,200 cubic yards/year which is less than the average annual amount of material removed to maintain the existing permit area since 1993. Therefore, based on the actual maintenance dredging experienced for the existing Nixon Channel permit area, maintenance of Nixon Channel should be sufficient to satisfy periodic beach nourishment requirements for Alternative 5B. However, should the available shoal volume be less than needed to maintain the beach fill, some supplemental fill could be obtained from the upland disposal areas next to the AIWW.

Implementation Cost. Initial construction costs for the terminal groin would be 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 $2,615,000 resulting in a total cost for initial construction (beach fills and terminal groin) of $5,930,000. The initial construction of Alternative 5B is expected to take approximately 6.5 months. Maintenance of the existing permit area in Nixon Channel with disposal of the material along Nixon Channel shoreline and the ocean shoreline would cost $1,821,000 every 5 years. Over the 30-year planning period, the total cost for Alternative 5B in current dollars would be about $16.9 million.

Terminal Groin Removal Cost – Alternative 5B.

Like Alternative 5A, the cost for removing the terminal groin under Alternative 5B would be the same as Alternative 5A which is estimated to be $1.0 million.

In summary, the average annual economic impact of each alternative is expressed in Table 3.8. Table 3.9 presents a summary of the 30-year implementation costs for each alternative.

Table 3.8 Summary of Average Annual Economic Impact of Alternatives

Alternative	Long-Term Erosion Damages	Loss of Tax Revenues	Response/ Construction Cost	Total Economic Cost
1	$3,010,000	$290,000	$1,164,000	$4,464,000
2	$4,364,000	$844,000	$215,000	$5,423,000
3	0	0	$2,484,000	$2,484,000
4	0	0	$3,725,000	$3,725,000
5A	0	0	$1,863,000	$1,863,000
5B	0	0	$754,000	$754,000

Table 3.9 Summary of 30-year Implementation Costs of Alternatives

Alternative	30-Year Implementation Cost
1	$115.7 Million
2	$87.4 Million
3	$61.7 Million
4	$102.5 Million
5A	$39.5 Million
5B	$16.9 Million

Chapter 4 AFFECTED ENVIRONMENT

1. What is the environmental setting of this project?

Figure Eight Island is located on the northwest end New Hanover County, in southeastern North Carolina, approximately eight miles north of Wilmington. It is a private, gated residential barrier island with 463 homes and 93 undeveloped lots. The island is bordered to the south by Mason Inlet and Wrightsville Beach and to the north by Rich Inlet and Hutaff Island, an undeveloped, privately owned island. Figure Eight Island covers approximately 526.1 hectares (1300 acres) and is approximately 8.0 km (5.0 mi) long and approximately 0.6 km (0.4 mi) wide. The Permit Area encompasses 4,282 acres and includes a wide diversity of estuarine and nearshore habitat types supporting diverse ecosystems typically associated with a developed and undeveloped barrier island system in southeastern North Carolina. The proposed project is located on the northeast end of the island and within the channel and shoals in Nixon Channel and Rich Inlet.

The Permit Area, as shown in Figure 4.1, is defined as the boundary of where direct and indirect effects of the project will, or may likely occur. The Permit Area was identified and delineated based on the modeling results depicting potential sedimentation distribution in the inlet as a result of the realigned inlet channel proposed for Alternative 3 and the point of intercept calculated along the oceanfront shoreline from proposed nourishment activities. Since developing the Permit Area, Alternative 5B has become the applicant's preferred alternative. Because the extent of the beach fill and the anticipated sedimentation distribution within the inlet are similar to Alternative 3, the scope of the Permit Area will remain unchanged. It should also be noted that all borrow sources for Alternative 5B are within the Permit Area.

The Permit Area also includes portions of Hutaff Island, which is located to the northeast of Rich Inlet. Hutaff Island is one of the few remaining undeveloped and vehicle-free barrier islands on the North Carolina coast. It is the largest near-pristine barrier island and salt marsh system in the region. Natural communities that are found in the area include: dune grass, upland forest, scrub-shrub, salt marsh, and beaches and foredunes. The natural area supports a gull-tern-skimmer colony, and the upper beach provides habitat for seabeach amaranth (*Amaranthus pumilus*). Rare animals supported by the area include the loggerhead sea turtle (*Caretta caretta*), piping plover (*Charadrius melodus*), Carolina diamondback terrapin (*Malaclemys terrapin centrata*), black skimmer (*Rhychops niger*), least tern (*Sterna atillarum*), and eastern painted bunting (*Passerina ciris ciris*). The North Carolina Natural Heritage Program (NCNHP) has identified Hutaff Island as a Significant Natural Heritage Areas (SNHA) of statewide significance (NCNHP, 2006). This site is partly owned by the NC Division of Parks of Recreation; the remaining area is

What is the North Carolina Natural Heritage Program?

As part of the Office of Natural Resource Planning and Conservation within the NC Department of Environment and Natural Resources, the program serves to inventory, catalogue, and support conservation of the rarest and the most outstanding elements of the natural diversity within North Carolina. These elements of natural diversity include those plants and animals which are so rare or the natural communities which are so significant that they merit special consideration as land-use decisions are made.

privately owned (NCNHP, 2006a). In 2001, the United States Fish and Wildlife Service (USFWS) designated Hutaff Island as Piping Plover Critical Habitat. This area provides foraging and nesting grounds for the endangered piping plover (*Charadrius melodus*). The Piping Plover Critical Habitat Area extends beyond Hutaff Island through Rich Inlet and onto approximately the northern 305 m (1,000 ft) of Figure Eight Island (Figure 4.1).

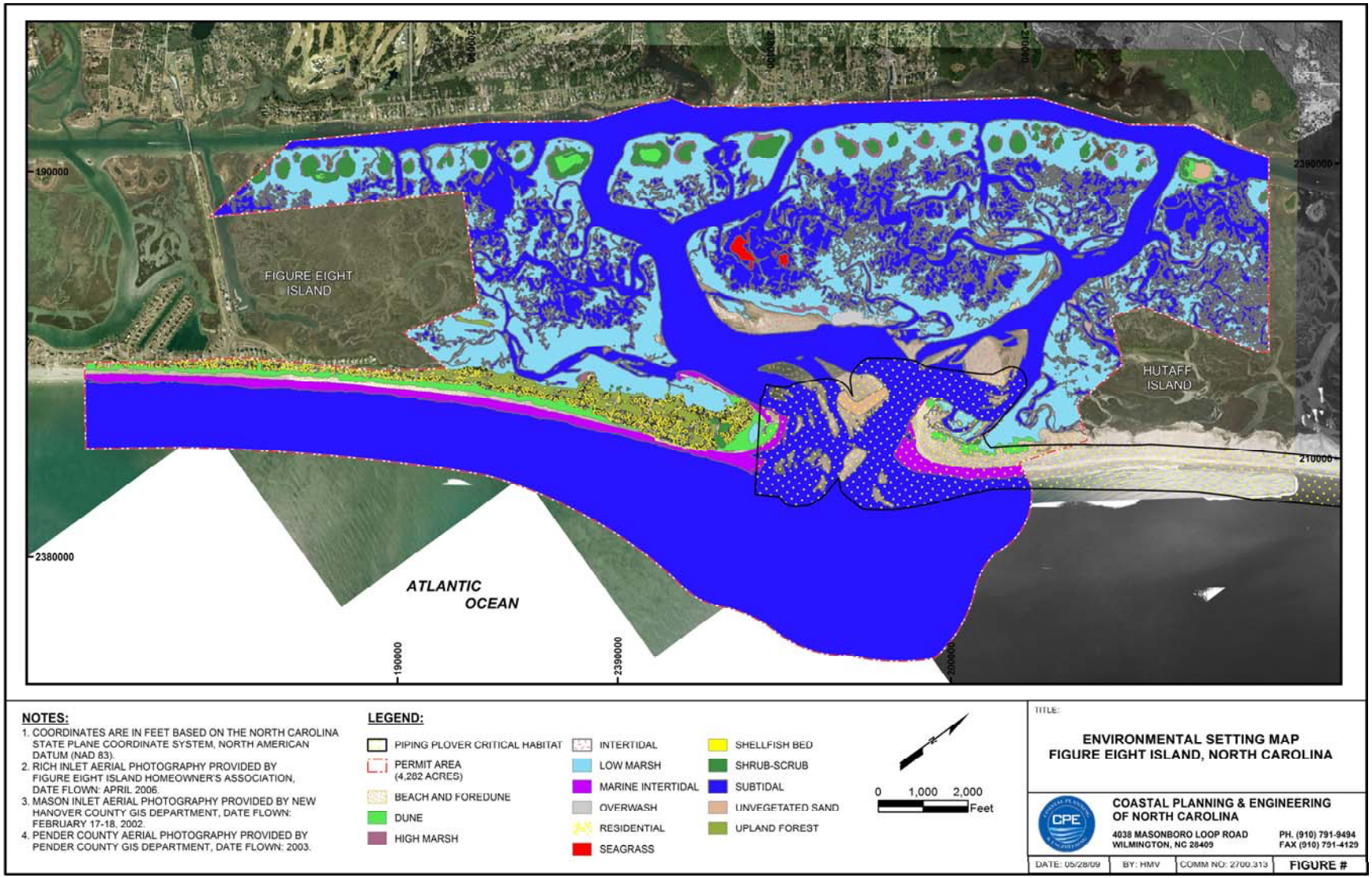


Figure 4.1. Figure Eight Island Environmental Setting Map within the Permit Area

The North Carolina Division of Marine Fisheries (NCCDMF) has designated about 595 km^2 (230 mi^2) of fishery nursery areas throughout North Carolina, dividing the habitats into three categories of nursery areas: Primary, Secondary and Special Secondary Nursery Areas (NCDMF, 2007). Primary Nursery Areas (PNAs) are usually shallow with soft muddy bottoms and surrounded by marshes and wetlands. PNAs are located within the Permit Area, specifically within the salt marsh habitat between the AIWW and the back side of Figure Eight Island and Hutaff Island. To protect juveniles, many commercial fishing activities are prohibited in these waters including the use of trawl nets, seine nets, dredges or any mechanical methods used for taking clams or oysters.

The geomorphology of the Permit Area is characterized by beaches, dunes, and marshes typical of a barrier island complex. The Atlantic Coastal Plain and Onslow Bay are both underlain by relatively flat-lying sedimentary units which gently dip and thicken as they move to the southeast.

Barrier islands, such as Figure Eight Island, are composed of unconsolidated fine- to medium-sized quartz and shell material that is in a constant state of flux due to wind, waves, currents and storms. The oceanfront beach and the backing dunes are deposits of sand that are constantly changing their shape, and hence position, with time as they respond to coastal processes.

Areas of Environmental Concern

Lands adjacent to coastal inlets that are vulnerable to natural processes including erosion and flooding are known as inlet hazard areas. These inlet hazard areas, as designated by the North Carolina Coastal Area Management Act (CAMA), are important Areas of Environmental Concern (AEC). Generally, the Inlet Hazard Areas AEC are natural-hazard areas especially vulnerable to adverse effects of sand, wind, and water, because of their proximity to dynamic ocean inlets (NCAC T15A 7H.0304(3)). The Inlet Hazard Area AEC boundaries were originally approved by the Coastal Resources Commission (CRC) in 1979. Presently, the inlet hazard AEC boundaries are more than 20 years out-of-date and have therefore been reviewed and updated with proposed new boundaries.

What are Areas of Environmental Concern?

The Coastal Resources Commission designates areas as AECs to protect them from uncontrolled development, which may cause irreversible damage to property, public health or the environment, thereby diminishing their value to the entire state. The CRC has set up four categories of AECs:

A. The Estuarine and Ocean System
B. The Ocean Hazard System
C. Public Water Supplies
D. Natural and Cultural Resource Areas

Many AECs have also been designated as SNHA by the NCNHP. The NCNHP has identified more than 2,000 SNHAs in North Carolina, which are defined as an area of land or water important for conservation of biodiversity. SNHA's contain one or more natural heritage elements such as high-quality or rare natural communities, rare species, and/or special animal habitats.

2. What are the characteristics of the various habitats found within the project area?

Barrier islands within North Carolina are dominated by wave and tidal processes, often with large flood and ebb tidal deltas. Like other inlets in southeastern North Carolina, Rich Inlet serves as the primary pathway of sediment transportation into its sound via Green Channel and Nixon Channel. These inlets historically migrated along the Outer Banks and were typically created by storm breaching. Many are now maintained by the USACE for navigation purposes. Historically, Rich Inlet has shown little tendency to migrate, however, the cyclical reorientation of the ebb channel can produce very rapid erosion on adjacent shorelines (Cleary and Pilkey, 1986). The Permit Area contains various habitat types such as salt marsh, upland hammocks, intertidal flats, shoals, dunes, and beaches (Figure 4.2).

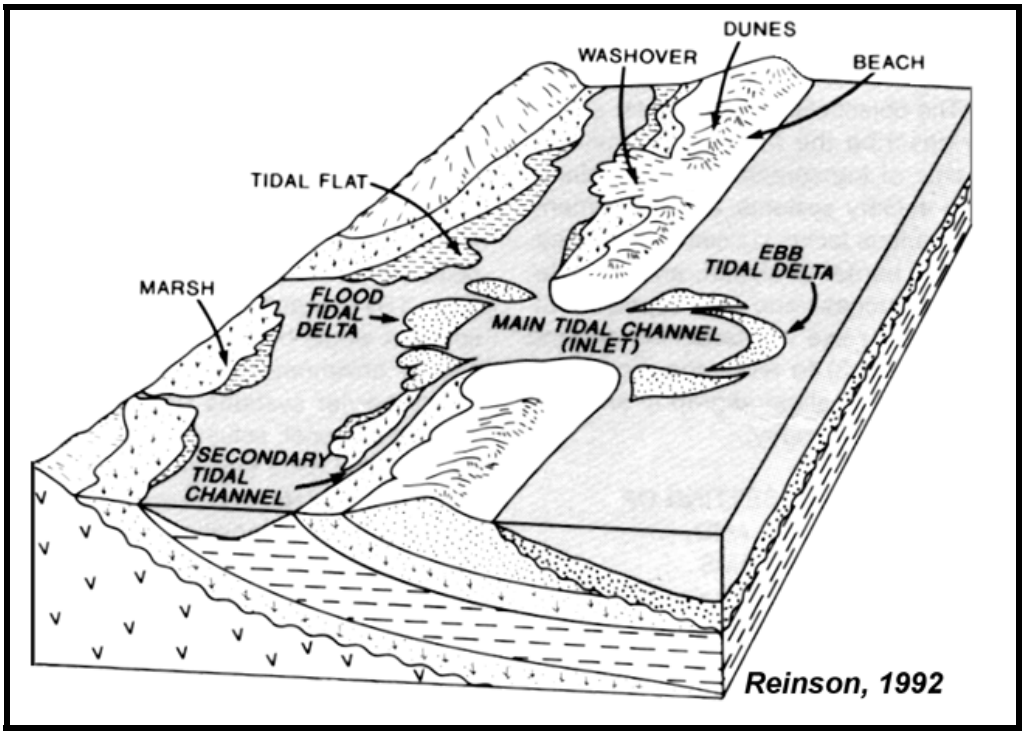


Figure 4.2. Schematic depicting various habitats associated with a barrier island

A. Estuarine Habitats

While estuaries are also often known as bays, lagoons, harbors, inlets, or sounds, the defining feature of an estuary is the mixing of fresh and saline water (32 to 36 parts per thousand [ppt]). Flush with nutrients and inhabited by resilient organisms, estuaries are among the most productive ecosystems on earth. They provide rich feeding grounds for coastal fish and migratory birds, and spawning areas for fish and shellfish (NPS, 2007). This section will characterize the following estuarine communities that are found, or have potential to be found, within the Permit Area including salt marshes, submerged aquatic vegetation (SAV), and shellfish areas.

1. Salt Marsh Communities

These community types are found in relatively flat and poorly drained topographic areas found along the North Carolina coastline and are subject to regular and irregular tidal flooding. These systems are extremely important for water filtration and water storage during flood events, as well as supplying food and providing habitat for a wide-array of flora and fauna. Coastal wetlands within the project vicinity include tidal salt marshes, and occur along the shoreline and island fringes along the backside of Figure Eight and Hutaff Island.

Salt Marsh Communities

In eastern North Carolina, salt marsh communities can be found along 4,500 miles of coastal shoreline, which encompasses 2.1 million acres of estuarine habitat (NCCF, 2007).

Estuarine systems, such as those characterized within the Figure Eight Island Permit Area, have been designated as AEC by the CRC. These areas have been identified as "sensitive and productive coastal lands and waters where uncontrolled development might cause irreversible loss of property, public health and the natural environment" (NCDCM, 2006b). Section 15A NCAC 07H .0205 of the North Carolina Administrative Code defines coastal wetlands as any salt marsh or other marsh subject to regular or occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses), provided this shall not include hurricane or tropical storm tides (NCDCM, 2008a). There are four kinds of coastal marsh habitats found in North Carolina; low marsh, high marsh, brackish marsh, and freshwater marshes. Of these kinds, the Permit Area contains low and high marsh.

Low salt marsh environments are regularly flooded with the tides and are characterized by organic mats with smooth cordgrass (*Spartina alterniflora*) as the dominant vegetative species. *S. alterniflora* marshes occur within the intertidal zone along the sounds and tidal creeks, and provide valuable nursery habitat for commercially valuable species of marine and estuarine organisms. The zonation of vegetation in salt/brackish marsh is largely determined by variations of salinity and drainage of sediment porewater. Some species are restricted in the low marsh because of high porewater salinity, frequent inundation, and high-sulfide porewaters associated with frequent inundation (Street *et al*., 2005). Smooth cordgrass can tolerate a wide range of environmental conditions, including pH levels from 5.4 to 7, salinities from 3% to 5%, and a water table four inches above ground level (ANHP, 2004). There have been 1,010 acres of low marsh delineated within the Permit Area, as determined through interpretation of high resolution aerial photography.

Cowardin (1979) classifies high marsh as an estuarine intertidal emergent wetland or palustrine, emergent wetland. High salt marsh environments are irregularly flooded lands where plant species such as saltmeadow cordgrass (*S. patens*), glasswort (*Salicornia* Spp.), salt (or spike) grass (*Distichlis spicata*), and sea lavender (*Limonium carolinianum*) may be found. Saltmeadow cordgrass grows at the seaward edge of the high marsh, just above the high water line, providing habitat for a variety of waterfowl and songbirds, as well as other types of wildlife indigenous to the area. This environment is important in stabilizing the shifting sands of the barrier islands. Eventually, over time, the high marsh habitat can transform as it becomes vegetated with dominant shrub species such as marsh elder (*Iva frutescens*), wax myrtle (*Myrica cerifera*), and yaupon holly (*Ilex vomitoria*). Twenty-eight acres of high marsh have been

delineated within the Permit Area, as determined through interpretation of high resolution aerial photography.

For both low and high salt marsh, the benthic communities consist of many faunal species. A 2007 wildlife utilization study conducted in the low salt marshes within the Bogue Inlet complex revealed high numbers of macroinvertebrates including fiddler crabs (*Uca puglator*), periwinkle snails (*Littorina irrorata*), oysters (*Crassostrea virginica*), and unidentified species of mud crabs, clams, and mussels (Rosov and York, 2007). Other common macro invertebrates in the salt marsh include blue crabs (*Callinectes sapidus*) and grass shrimp (*Palaemonetes* species) (Meyer, 1991).

Benefits of Salt Marsh Habitats to Shorebirds, Colonial Waterbirds, and other Waterbirds
Due to their biological productivity, estuaries provide ideal areas for migratory birds to rest and forage during their long migratory journeys. Various species of shorebirds utilize marsh habitats for wintering, as well as feed on fish, shrimp and fiddler crabs found in the salt marsh. Along with a number of shorebirds and waterbirds, various waterfowl including dabbling ducks, diving ducks, geese, swans and coots utilize the salt marsh (Cowardin 1979).

Colonial waterbirds that utilize marsh habitat include black skimmers, gull-billed terns, common terns, least terns, egrets (*Egretta* spp.), and green herons (*Butorides virescens*). Most of these species prefer sandy beaches and shoaling habitats for nesting. The green heron is a habitat generalist, frequenting most coastal freshwater bodies as well as some saltwater bodies. The green heron nests in coastal shrub thickets, upland and swamp forests, and salt marshes, as well as in suburbs where habitat is deemed suitable. This species is less colonial than other wading birds, and although it often nests in mixed colonies with other herons and ibis (*Plegadis falcinellus* and *Eudocimus albus*), the green heron will frequently nest singly or in colonies of a few pairs. Nests are typically elevated in trees or shrubs between five and 30 ft off the ground (Alsop, 2002).

Willets (*Catoptrophorus semipalmatus*), American oystercatchers *(Haematopus palliatus)*, piping plovers, Wilson's plovers, and killdeers (*Charadrius vociferous*) usually nest above the high tide line on coastal beaches, on sand flats at the ends of sand spits, in blowout areas behind dunes and in overwash areas. However these various shorebirds also utilize various estuarine habitats including intertidal-emergent and submerged vegetated areas, intertidal-unvegetated, managed wetlands, as well as inland habitats for feeding (Hunter *et al*., 2001; Brown *et al*., 2001).

A variety of other waterbird species that are not classified as shorebirds or colonial waterbirds can also be found utilizing different estuarine habitats. For example, species such as red-breasted mergansers (*Mergus serrator*), clapper rails (*Rallus longirostris*) and ospreys (*Pandion haliaetus*) can be found in and surrounding inlet habitats such as Rich Inlet. Many waterbirds are piscivorous and forage by surface diving, some are aquatic gleaners, while others are herbivores that feed on submerged aquatic vegetation. These waterbirds can be found in estuaries, marshes, and in the vicinity of Rich Inlet year-round or part of the year. However, they are mainly present during spring and fall migrations, as well as during the winter.

Benefits of Salt Marsh Habitat to Terrapins

The Carolina diamondback terrapin is the only North American turtle found in brackish waters, and are common in salt marsh environments. Juveniles use matted *Spartina* and other marsh grasses as cover. The marshes behind Figure Eight and Hutaff Island provide suitable habitat for diamondback terrapins (LeGrand, pers. comm., 2008).

Benefits of Salt Marsh Habitats to Fishery Resources

Finfish and shellfish using salt/brackish marsh habitats fall into several categories based on location and timing of use (Street *et al*., 2005). EFH species that are expected to occur in estuarine emergent wetlands of North Carolina include the penaeid shrimp, blue crab, coastal sharks, cobia, summer flounder, red drum, and others. Year-round residents of the marsh include small forage species such as killifish (*Fundulus confluentus, F. luciae, F. majalis, Lucania parva*), mummichogs (*Fundulus heteroclitus*), sheepshead minnows (*Cyprinodon variegates*), gobies (*Coryphopterus glaucofraenum, Gobionellus boleosoma, G. hastatus, G. shufeldti, Evorthodus lyricus, Gobiosoma bosci, G. ginsburgi, G. xanthiprora, Microgobius carri, Evermannichthys spongicola*), grass shrimp (*Palaemonetes pugi*), bay anchovies (*Anchoa mitchilli*), and silversides (*Membras martinica, Menidia* spp.). Transient species include those spawning near the marsh, but inhabiting deeper channels (i.e., river herring (*Alosa pseudoharengus, A. aestivalis*), and those spawned in deeper waters using marsh habitat as nursery or foraging areas. Among transient species, some prefer the edge of salt/brackish marsh (i.e., red drum (*Sciaenops ocellatus*), flounder (Family Bothidae, Family Pleuronectidae)) while others are found near the marsh edge on non-vegetated bottom (i.e., spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*)). Some species are not found in the marsh, but derive substantial food resources from marsh plants as detritus (i.e., menhaden (*Brevoortia* spp.)) or from microalgae produced on the marsh surface. Of the fishery species in North Carolina, penaeid shrimp (*Penaeus duorarum, P. setiferus, P. aztecus*) and red drum are considered critically linked to marsh edge habitat (SAFMC, 1998).

Red drum spawning occurs in the fall (August through October) in estuaries and around coastal inlets with optimal temperatures being between 22^0 C and 30^0 C (72^0 to 86^0 F) (NCDMF 2005). In North Carolina, spawning adults were reported to be common in salinities above 25 ppt in Bogue Sound and the Cape Fear River. Spawning adults were present but not frequently encountered in Pamlico Sound and the New River (ASMFC, 2002).

Penaeid shrimp are reported to spawn offshore, moving into estuaries during post-larval stage during the early spring. As the shrimp grow larger in size, they migrate to higher salinity environments. In late summer and fall, they return to the ocean to spawn (NCDMF, 2005). It is during the July through October period that approximately 77% of the North Carolina shrimp harvest (for all waters) is landed, 66% of which is taken from ocean sub-areas <3 mi offshore and south of Cape Hatteras (NCDMF, 2005). In a NCDMF juvenile brown, white and pink shrimp sampling program (1999 – 2003) the majority of shrimp were "collected in close proximity to shallow wetland systems, such as salt marsh.

- Brown Shrimp

Brown shrimp spawn in the deep ocean during February and March. Larval immigration to estuaries peaks from mid-March through mid-April. Brown shrimp prefer peat and muddy bottoms as habitat (NCDMF, 2005).

- Pink Shrimp

Pink shrimp spawn in ocean waters from April to July. Post larvae immigrate to estuaries from May to November. Juvenile pink shrimp are reported to over-winter in North Carolina estuaries. Pink shrimp prefer foraging in shallow waters among marine plants. They are nocturnal feeders but may feed during the day in turbid water (NCDMF, 2005).

- White Shrimp

White shrimp spawn at depths greater than 30 feet in the ocean from March to November. Post larvae immigrate to estuaries two to three weeks after hatching when they become benthic. Juvenile white shrimp prefer muddy bottoms in low to moderate salinity estuarine waters and brackish waters. White shrimp migrate south from estuaries during fall and early winter. "Some of the slower-growing individuals overwinter in the estuaries, but usually do not survive in North Carolina" (NCDMF, 2005).

2. Submerged Aquatic Vegetation (SAV)

In North Carolina, Submerged Aquatic Vegetation (SAV) is defined as "estuarine waters vegetated with one or more species of submerged vegetation such as eelgrass (*Zostera marina*), shoalgrass (*Halodule wrightii*) and widgeon grass (*Ruppia maritime*). These vegetation beds occur in both subtidal and intertidal zones and may occur in isolated patches or cover extensive areas (Street *et al.*, 2005). In North Carolina the dominant seagrass in North Carolina is *Z. marina*. *H. wrightii* is also observed in North Carolina; however it is not as abundant. Seagrass meadows are now much reduced, probably due to elevated nitrogen and increased sedimentation (Mallin *et al*., 2000).

Submerged Aquatic Vegetation

North Carolina is in a "transitional area which represents the southernmost extension for some cold-adapted species and the northernmost extension of warm-adapted species.

Rosov, 2008

Don Field of the Applied Ecology and Restoration Research Laboratory at the National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Fisheries and Habitat Research identified potential occurrences of SAV within the Permit Area via interpretation from April 2006 aerial photography. Similarly, limited presence/absence data collected by Dr. Wilson Freshwater of UNCW in 2003 and 2004 from areas within the Rich Inlet complex was obtained. Each of the 47 potential SAV beds identified by Mr. Field and Dr. Freshwater were groundtruthed on September 15th, 17th, and 22nd, 2008 (Figure 4.3). Of these, three were confirmed to contain SAV resources. Two contained sparse patches of *Z. marina* (eelgrass) while one site contained a dense to sparse bed of *Z. marina* and *R. maritima* (widgeon

grass). The remaining sites were identified as dark sandy bottom, shellfish shells, macroalgae, or other substrate types devoid of seagrass. Utilizing the three SAV beds identified through groundtruthing efforts as confirmed SAV resources, an additional 17 sites with similar color signatures were extrapolated from the 2008 high resolution aerial photographs (Figures 4.3, 4.4a and 4.4b). In total, 7 acres of SAV habitat have been identified within the Permit Area.

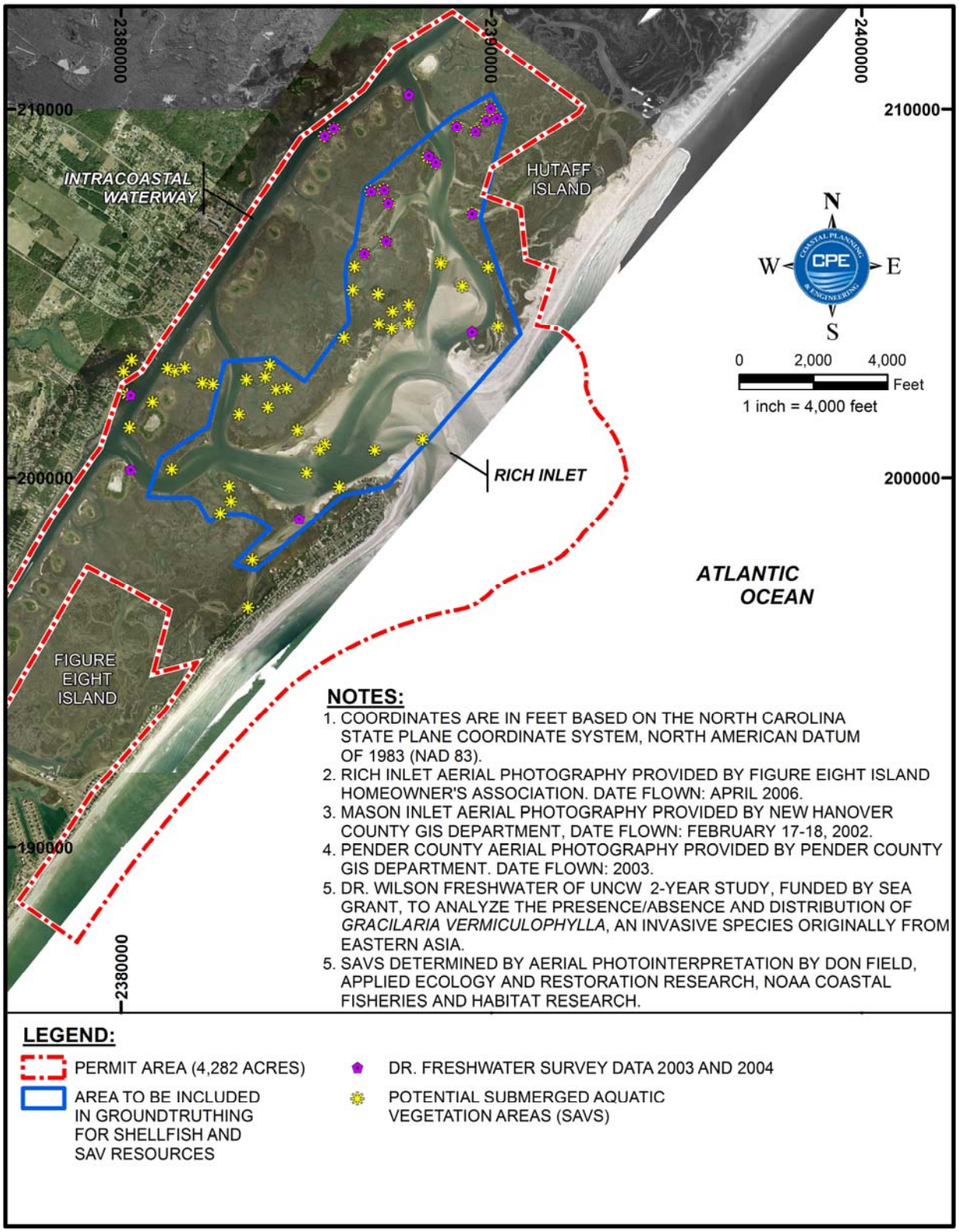


Figure 4.3. Potential Submerged Aquatic Vegetation (SAV) Locations

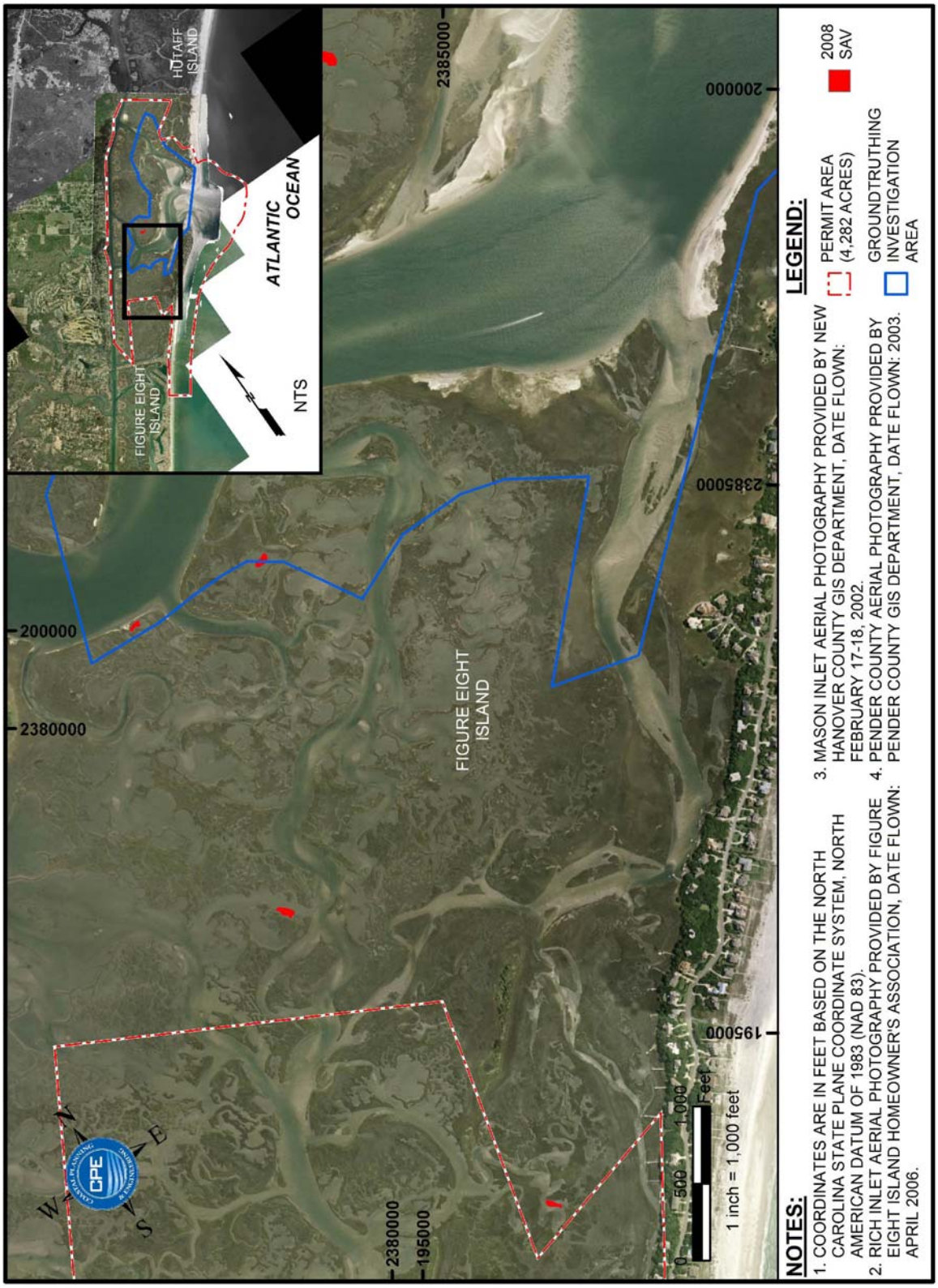


Figure 4.4a. Identified SAV Resources within the Permit Area

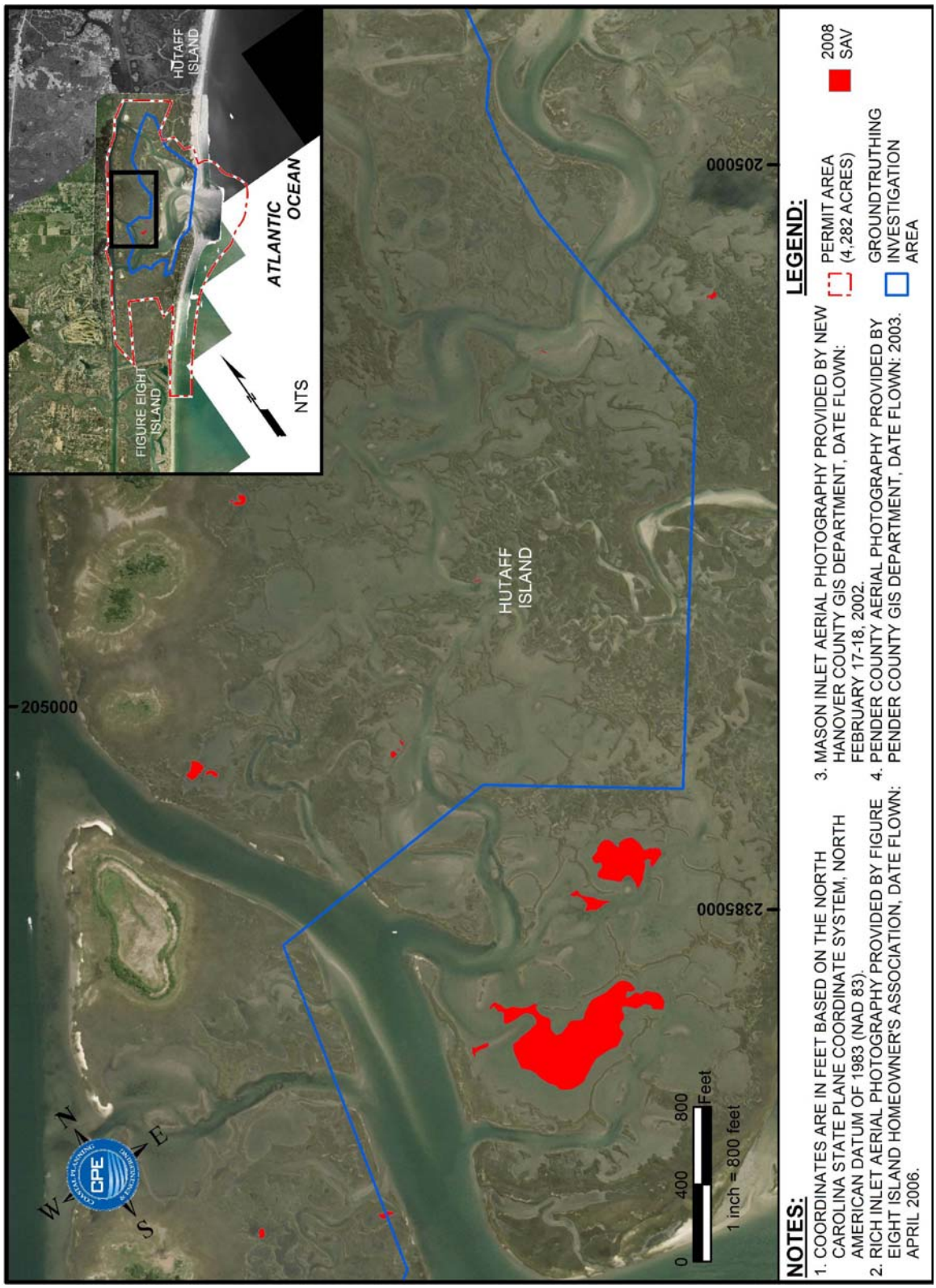


Figure 4.4b. Identified SAV Resources within the Permit Area

Benefits of SAV Areas to Fishery Resources

Submerged Aquatic Vegetation (SAV) is designated EFH for the snapper/grouper complex, red drum and penaeid shrimp by the SAFMC. Blue crabs, which are managed by the NCDMF, also utilize seagrass habitat during various life stages. Blue crab migration and movement are seasonal and depend on parameters such as life stage, sex, temperature and salinity. Research indicates that "juvenile blue crabs have wide distributions, but they are most abundant in middle and upper estuarine waters of low to intermediate salinity…. Optimum sediment for small crabs is detritus, mud, or mud-shell bottom….Subtidal sand and mud bottoms have been documented as overwintering habitat for juvenile blue crabs…Small creeks and rivers in and around salt marshes provide shallow-water habitats for larger juveniles and mature crabs for feeding and refuge during molting" (NCDMF, 2004). The blue crab fishery is North Carolina's most valuable commercial fishery (NCDMF, 2005). Blue crabs mate from May through October in the upper areas of estuaries and lower portions of rivers. Mated females then migrate to higher salinity waters in lower reaches of estuaries or in the ocean where they spawn. In North Carolina, spawning occurs from March through October. Blue crab eggs are reported to require 23 – 33 ppt salinity at temperatures between 19^0 C (66^0 F) and 29^0 C (84^0 F) for hatching (Blue Crab Archives, 2006).

SAV are utilized by larval and juvenile fishes for foraging, spawning, and escape from predation. Commercial and sport fishes in their larval and juvenile stages, such as; gag grouper (*Mycteroperca microlepsis*), gray snapper (*Lutjanus griseus*), bluefish (*Pomatomus saltatrix*), flounder species (*Paralichthys* sp.), fish of the Clupeidae family and others, are found in seagrass beds in the early spring and summer. Bay scallops (*Argopecten irradians concentricus*) are also typically found in SAV habitat. Because of its use for foraging, spawning and shelter, SAV is designated as HAPC. The red drum (*Sciaenops ocellatus*) is one species for which SAV serves as a HAPC.

3. Shellfish

The shellfish industry is a large economic industry for North Carolina coastal areas. Three species of shellfish found in coastal waters include eastern oysters (*Crassostrea virginicus*), hard clams (*Mercenaria mercenaria*), and bay scallops (*Argopecten irradians concentricus*).

Shellfish

Common terms used to describe shell bottom habitats in North Carolina are "oyster beds," "oyster rocks," "oyster reefs," "oyster bars," and "shell hash."

Shellfish are also an important resource in the estuarine environment within the permit area. The structures that shellfish create, such as beds and reefs, are used by many species of fish and invertebrates (Burrel, 1986). The SAFMC defines this habitat as "the natural structures found between (intertidal) and beneath (subtidal) tide lines, that are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats, and from wave-formed shell windrows" (SAFMC, 1998). The SAFMC has designated oyster reefs as EFH for red drum (NMFS, 1999). NCDMF has designated two Oyster Management Areas (OMA) within the Permit Area and one adjacent to the southwestern boundary (Figure 4.5).

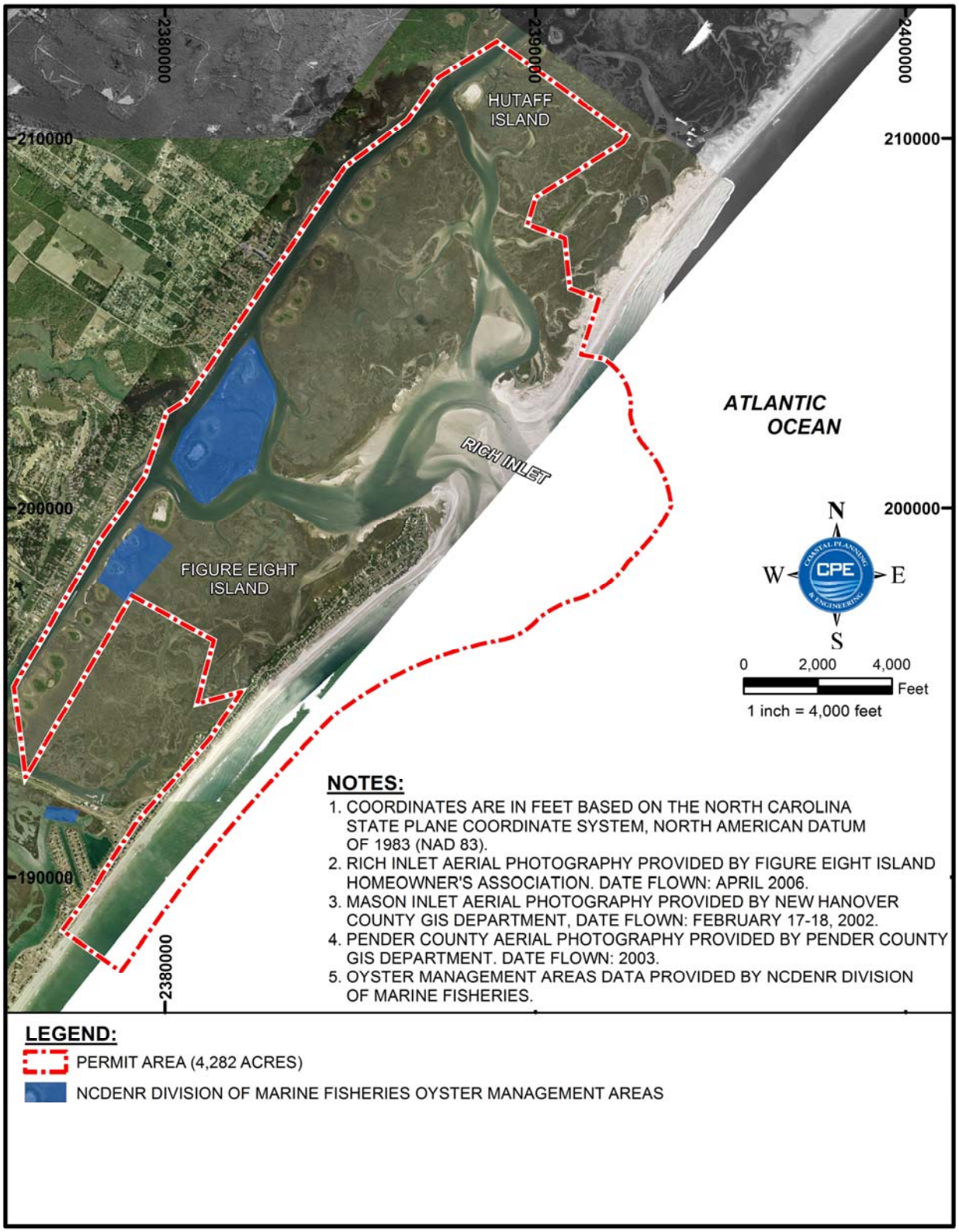


Figure 4.5. Oyster Management Areas within and in proximity to the Permit Area

Table 4.1 below summarizes the spawning seasons for the three shellfish species typically found within the Permit Area.

Table 4.1. Spawning Seasons for Shellfish

SPECIES	SPAWNING SEASONS
Hard Clam *(Mercenaria mercenaria*)	May through November
Eastern Oyster (*Crassostrea virginica*)	May through September
Bay Scallops (*Argopecten irradians*)	August through December

The NCDMF Shellfish Mapping Program was developed using a stratified random sampling design that delineates all bottom habitats (or strata) and samples the density of oysters, clams, and bay scallops in these areas (Street *et al*. 2004). Benthic habitat surveys in Rich Inlet and the estuarine habitats behind Figure Eight Island and Hutaff Island were conducted by the NCDMF in 1991 (Conrad, pers. comm.). Shellfish were found within strata R (intertidal firm, vegetated without shell), strata S (intertidal firm, non-vegetated with shell), strata T (intertidal firm, non-vegetated without shell), and strata W (intertidal hard, non-vegetated with shell) (Conrad, pers. comm.). Figures 4.6 and 4.7, created by the NCDMF Shellfish Mapping Program, illustrates the distribution of the various habitats within proximity of the Permit Area. The number and density of clams (*M. mercenaria*), oysters (*C. virginica*), and scallops (*A. irradians*) present within these strata are listed in Tables 4.2 and 4.3. Stratum W is the habitat containing the highest densities of shellfish in this area. No scallops were observed in these sampling surveys.

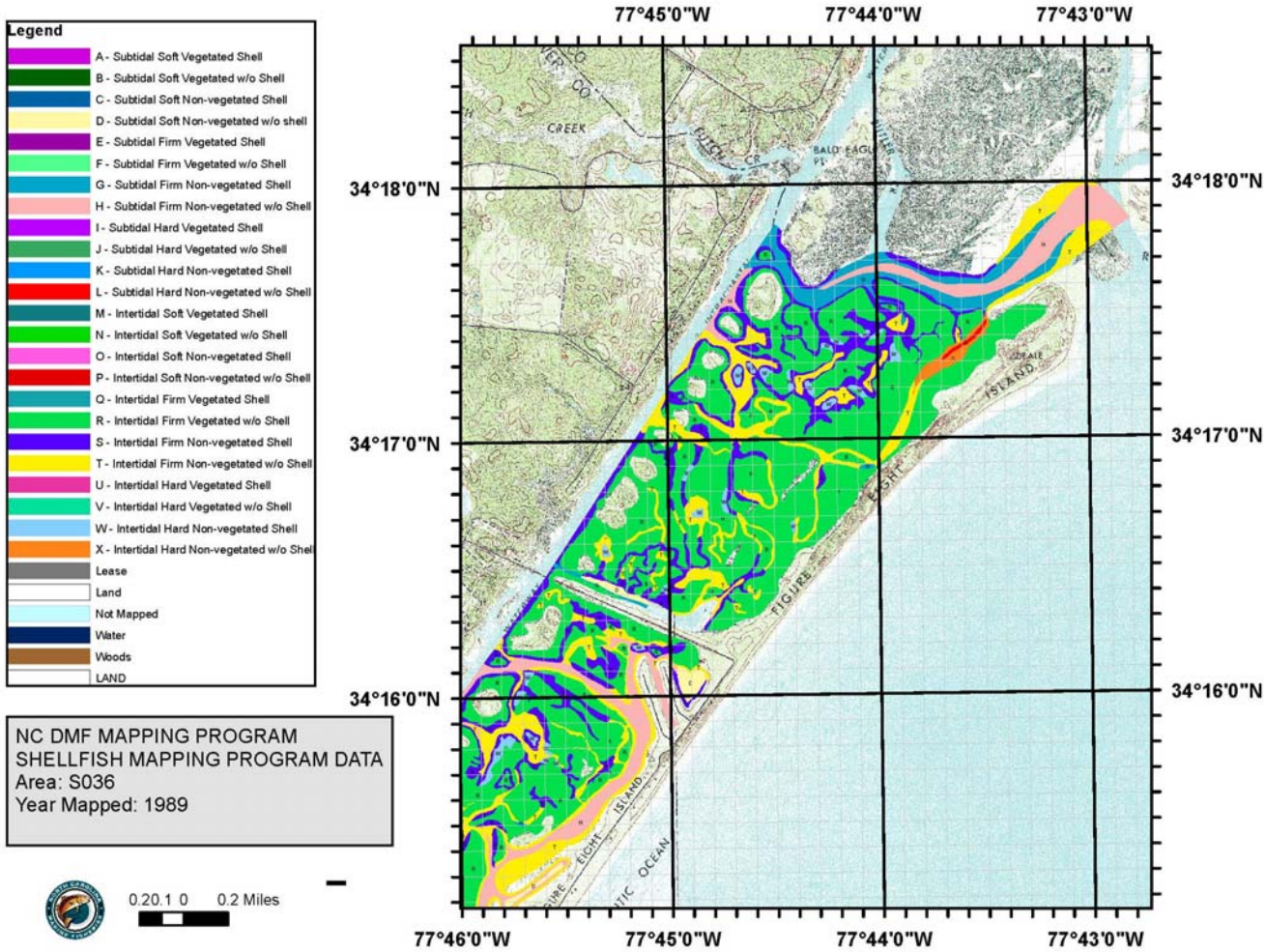


Figure 4.6. NCDMF Shellfish Mapping Program – Area SO36

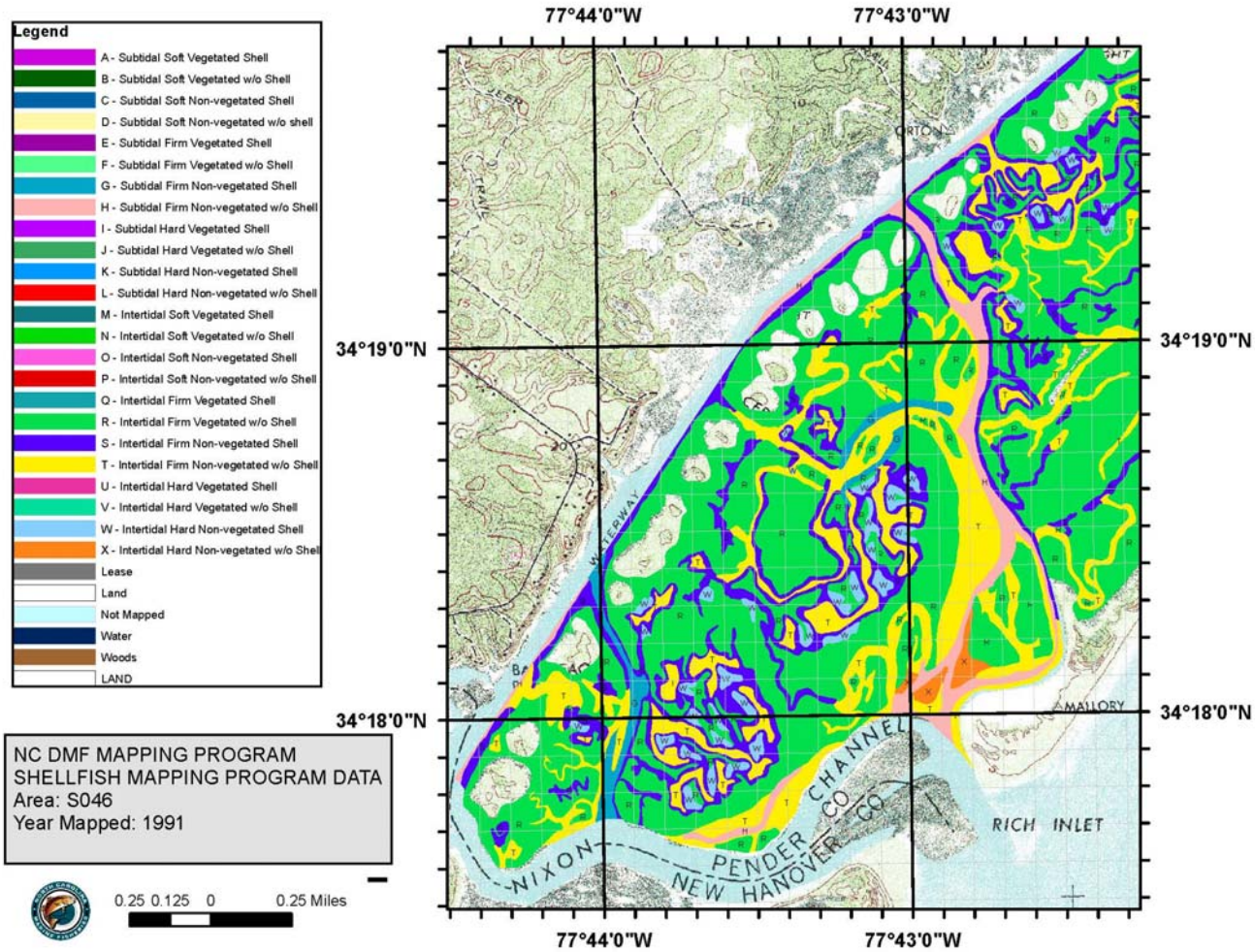


Figure 4.7. NCDMF Shellfish Mapping Program – Area SO46

Table 4.2. Shellfish Density Data for Area SO36. Surveys conducted by NCDMF between 1989 and 1991

Strata	Number of Samples	Area Sampled (Square meters)	Collection Number	Density (Shellfish per square meter)
S036				
		CLAM		
D	15	13.50	0.00	0.00
G	19	17.10	0.00	0.00
H	25	22.50	0.00	0.00
L	15	13.50	0.00	0.00
R	105	105.00	2.00	0.02
S	56	55.20	75.00	1.36
T	44	43.60	13.00	0.30
W	21	20.40	69.00	3.38
X	15	14.50	0.00	0.00
		OYSTER		
D	15	13.50	0.00	0.00
G	19	17.10	0.00	0.00
H	25	22.50	0.00	0.00
L	15	13.50	0.00	0.00
R	105	105.00	1,176.00	11.20
S	56	55.20	4,469.00	80.96
T	44	43.60	1.00	0.02
W	21	20.40	5,354.00	262.45
X	15	14.50	0.00	0.00
		SCALLOP		
D	15	13.50	0.00	0.00
G	19	17.10	0.00	0.00
H	25	22.50	0.00	0.00
L	15	13.50	0.00	0.00
R	105	105.00	0.00	0.00
S	56	55.20	0.00	0.00
T	44	43.60	0.00	0.00
W	21	20.40	0.00	0.00
X	15	14.50	0.00	0.00

Table 4.3. Shellfish Density Data for Area SO46. Surveys conducted by NCDMF between 1989 and 1991

Strata	Number of Samples	Area Sampled (Square meters)	Collection Number	Density (Shellfish per square meter)
S046				
		CLAM		
G	15	13.50	0.00	0.00
H	15	13.50	0.00	0.00
R	15	15.00	0.00	0.00
S	39	39.00	114.00	2.92
T	15	15.00	3.00	0.20
W	15	15.00	45.00	3.00
X	15	15.00	0.00	0.00
		OYSTER		
G	15	13.50	0.00	0.00
H	15	13.50	0.00	0.00
R	15	15.00	79.00	5.27
S	39	39.00	6,506.00	166.82
T	15	15.00	0.00	0.00
W	15	15.00	6,413.00	427.53
X	15	15.00	0.00	0.00
		SCALLOP		
G	15	13.50	0.00	0.00
H	15	13.50	0.00	0.00
R	15	15.00	0.00	0.00
S	39	39.00	0.00	0.00
T	15	15.00	0.00	0.00
W	15	15.00	0.00	0.00
X	15	15.00	0.00	0.00

The NCDMF shellfish habitat maps contain 23 individual polygons representing the W stratum within the limited area within the Permit Area. These areas were groundtruthed to determine the size and extent of shellfish beds within this area. Of the 23 potential shellfish sites groundtruthed, nine were confirmed to contain live shellfish. Each of these confirmed areas contained scattered patches of live shellfish (primarily *C. virginica*) fringing along the edge of a salt marsh and were not considered to be a discrete shellfish bed. Therefore it was not possible to determine distinct boundaries utilizing GPS. The remaining sites were identified as muddy substrate or scattered shellfish shells.

CPE-NC located and delineated one discrete shellfish bed that had not been identified by the NCDMF. Utilizing this site as a confirmed shellfish bed, an additional three sites with similar color signatures were extrapolated from the 2008 high resolution aerial photographs (Figures 4.8 and 4.9). In total, 0.1 acres of shellfish bed habitat have been identified within the Permit Area.

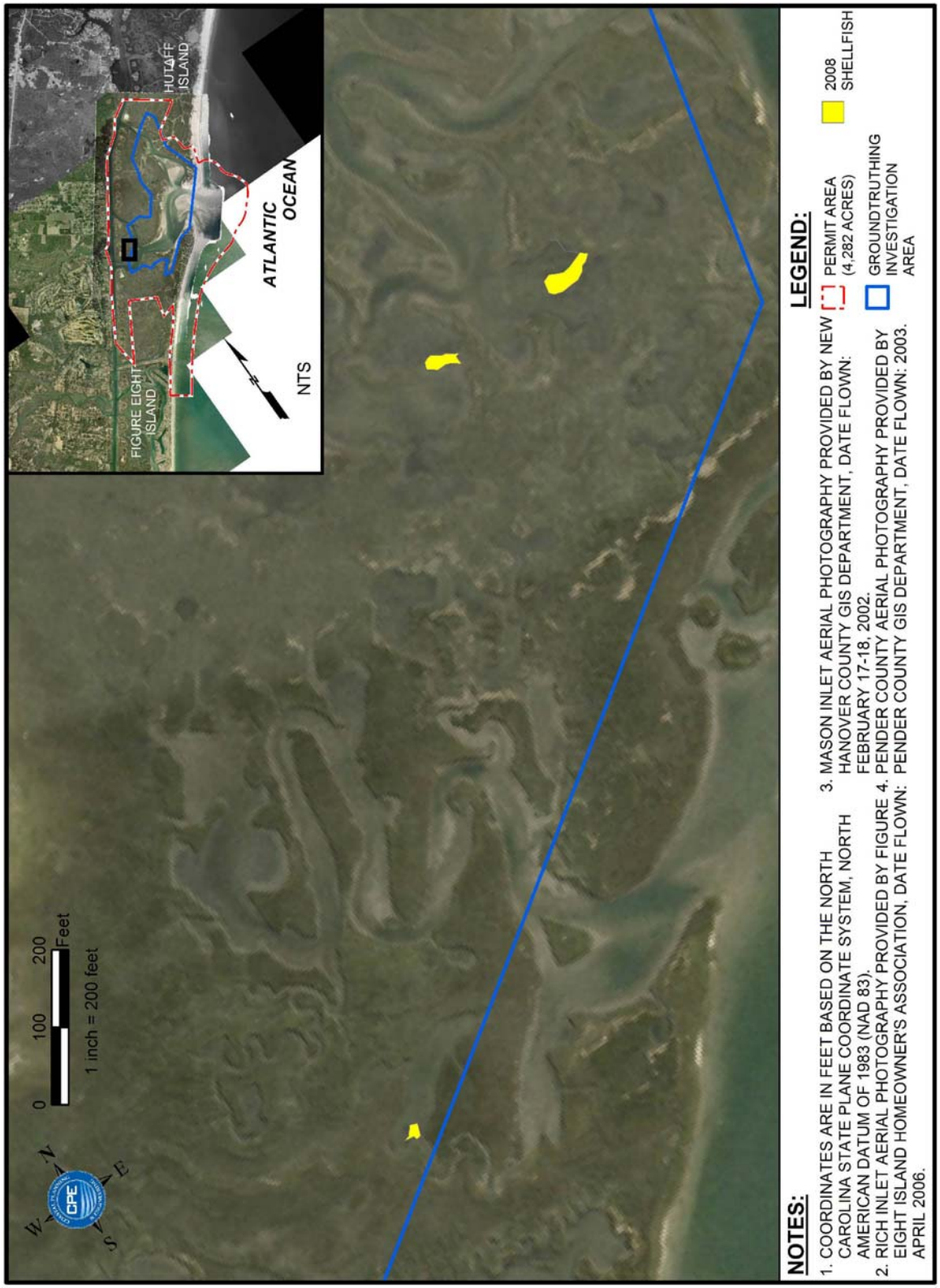


Figure 4.8. Identified Shellfish Resources within the Permit Area

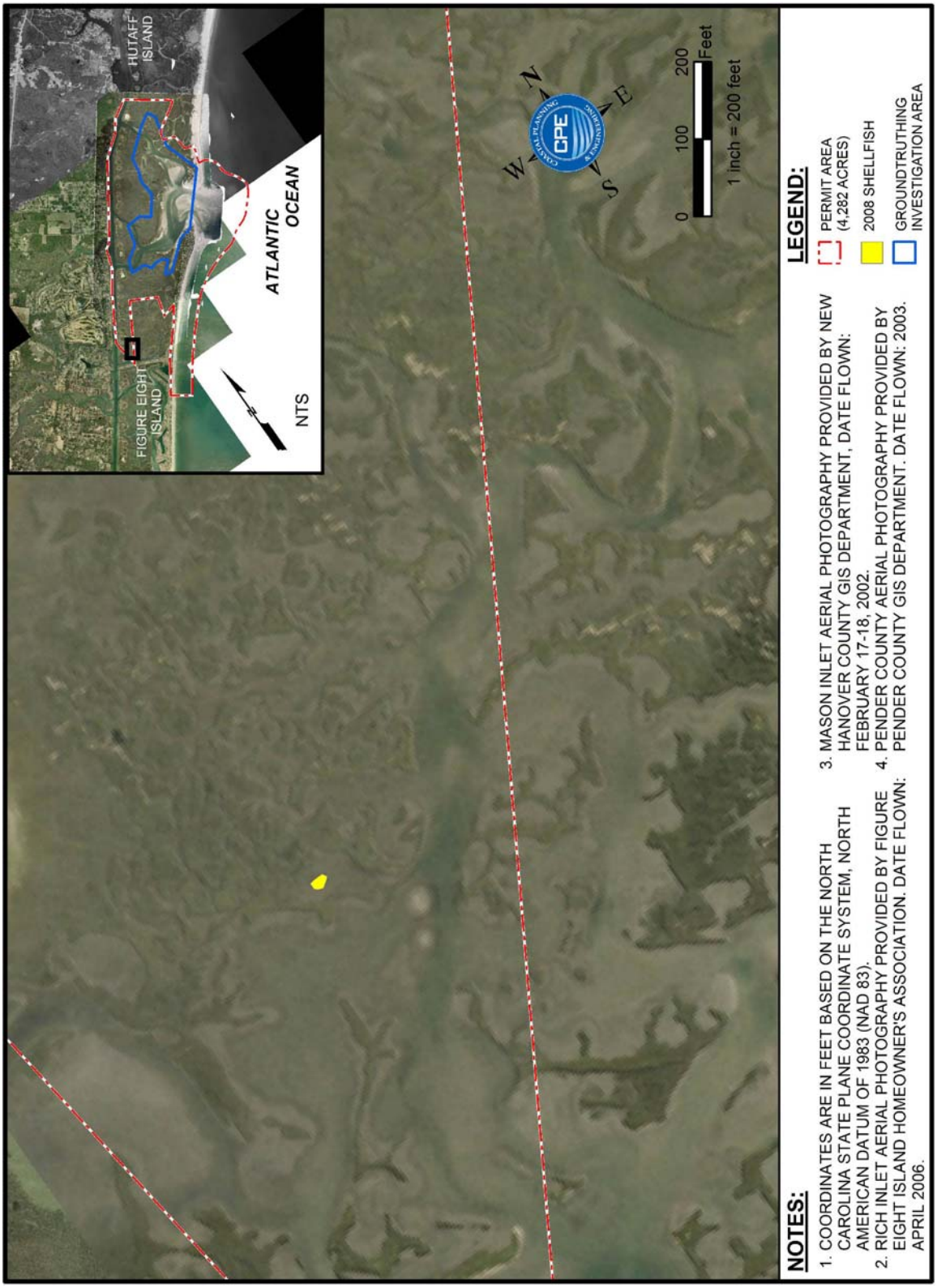
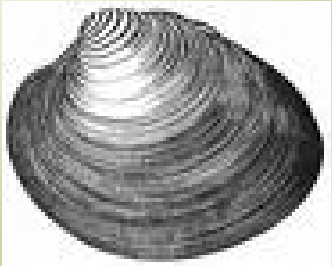


Figure 4.9. Identified Shellfish Resources within the Permit Area

- Hard Clams

According to the NCDMF, the stock status of hard clams (*Mercenaria mercenaria*) is unknown because there is no data available to assess the population size (NCDMF, 2001). Hard clams are an estuarine-dependent mollusk found primarily in sandy and vegetated bottoms. Increased fishing, poor water quality, and habitat loss have impacted this fishery (NCDMF, 2003a). The EFH for the hard clam, as designated by the SAFMC, includes subtidal and intertidal flats, oyster reefs and shell banks, and SAV (NCDMF, 2001). A State Fishery Management Plan was approved for the hard clam in August 2001.

Hard clam



Hard clams are suspension feeders that subsist primarily on phytoplankton. Growth of hard clam larvae is quickest at temperatures found between 22.5 and 36.5ºC (72.5 and 97.9°F) with salinities of 21.5 to 30.0 ppt (Eversole, 1987). They spawn from May through November, when water temperatures reach 20ºC (68°F). Salinities above 25 ppt significantly affect normal embryonic development while temperatures too low will not allow maturation and spawning (Eversole, 1987). Hard clams can be found in nearly all of the sheltered marine waters of North Carolina. Based on research examining clam landings per trip, the NCDMF found that the harvest of clams appeared to be particularly stable (NCDMF, 2001). Results from the 1991 surveys conducted by NCDMF indicated that clams were present in the permit area.

- Eastern Oysters

Eastern oysters (*Crassostrea virginica*) are long-lived (approximately 40 years) and are capable of forming large reefs. According to the NCDMF, the eastern oyster has a stock status designation of concern due to a long-term decline most likely caused by over harvesting, habitat disturbances, and pollution. Oysters require a relatively clean, firm substrate to attach to and can be found in intertidal or subtidal estuarine environments. Spawning in North Carolina occurs from May through September. Vast intertidal reefs formed by oysters are significant biological and physical formations in the estuaries of North Carolina. Fish, crabs, and shrimp utilize oyster beds as refuge and as a source of food. The intertidal oyster beds also provide habitat for various infaunal and epifaunal species.

Eastern oyster

The eastern oyster is a very successful estuarine bivalve and can tolerate a wide variety of salinities, temperatures, currents, and turbidities. The preferred habitat for eastern oysters is from just below MLW to 1 m (3.28 ft) above MLW (Burrel, 1986). The eastern oyster is a prolific bivalve, whose stocks have been depleted, which identified a need for a State Fishery Management Plan (adopted in August of 2001) in parallel with the Hard Clam Fishery Management Plan.

Results from the 1991 surveys conducted by NCDMF indicated that eastern oysters were present in the permit area.

- Bay Scallop

The NCDMF lists the bay scallop (*Argopecten irradians*) as a species of concern based on poor recruitment and low abundances. However, the NCDMF has not yet developed a fisheries management plan for the bay scallop. *A. irradians* is an estuarine-dependent bivalve found in seagrass (mainly eelgrass) beds. Bay scallops are rarely found attached, although they do have the ability to attach by byssal threads, mainly as juveniles, but as they mature, scallops sink to the bottom and continue to grow (Fay *et al*., 1983). Adult scallops prefer calm waters, secluded from high winds, storms, with tides and depths of 0.3 to 10 m (0.98 to 32.8 ft). Environmental factors, such as temperature and rainfall, play a critical role in scallop abundance (NCDMF, 2003b). They spawn between August and December when water temperatures are approximately 15.5°C (60ºF). No scallops were present during the 1991surveys conducted by the NCDMF. However, habitat with the potential to support scallops was identified within the Permit Area.

Bay Scallop

Benefits of Shellfish Habitat Areas to Fishery Resources

Shell bottom provides critical fisheries habitat not only for oysters, but also for recreationally and commercially important finfish, other mollusks, and crustaceans. The SAFMC has designated oyster reefs as EFH for red drum (*Sciaenops ocellatus*). The ecological functions of oyster reefs related to oyster production are well known and accepted. These functions include aggregation of spawning stock, chemical cues for successful spat settlement, and refuge from predators and siltation. Oysters have also been described as "ecosystem engineers" that create reef habitat important to estuarine biodiversity and fishery production. Several studies have found higher biological abundance and diversity on shell bottom than adjacent softbottom, particularly pinfish (*Lagodon rhomboides*), blue crabs (*Callinectes sapidus*), and grass shrimp (*Palaemonetes pugio*) (Street *et al*., 2005).

B. Upland Hammock Habitat

Maritime hammocks, also known as maritime forests, tropical hammocks or coastal hammocks, are characterized as narrow bands of forest that develop almost exclusively on stabilized backdunes of barrier islands, inland of primary dunes and scrub. This habitat type is typically dominated by species of broad-leaved evergreen trees and shrubs, maritime hammocks are climax communities influenced heavily by salt spray. Figure 4.1 depicts the upland hammock habitat and designates the area as "scrub-shrub" and "upland

Upland hammock

These forested systems are typically dominated by live oak (*Quercus virginiana*), loblolly pine (*Pinus taeda*), and red cedar (*Juniperus virginiana*) trees with an understory of shrub thicket which can support such species as swamp bay (*Persea palustris*) and sweetbay (*Magnolia virginiana*).

forest". The dominant wind direction and influence of salt spray is usually evidenced by the sculpted vegetation (Texas Cooperative Research Unit, 2002). 27 acres of upland hammock as well as 67 acres of scrub-shrub habitat have been delineated within the Permit Area, as determined through interpretation of high resolution aerial photography.

Benefits of Upland Hammocks to Colonial Waterbirds

Colonial waterbirds utilize a variety of habitats for foraging, roosting, and nesting, which includes estuaries, oceanfronts, open dunes, inland areas, and intertidal shoal habitats. These birds also use a variety of habitats for nesting. Some colonial waterbirds such as brown pelicans, herons, and egrets utilize vegetated, upland environments. These three colonial waterbird groups prefer trees, shrubs, and grass lands for nesting and, as a result, may utilize the upland hammocks identified within the Permit Area.

C. Inlet Dunes and Dry Beach Habitats

This section identifies and discusses the dune and beach communities within the Rich Inlet complex. These habitats are present around the periphery of the inlet. Inlet dunes and inlet beaches are similar to coastal dunes and coastal beaches, however, as a result of episodic overwash, these habitats are typically not as established as coastal beaches and often lack the vegetation common on the coastal beach and dune systems. Inlet dunes are defined as any hill, mound, or ridge of sand along the inlet coastline created by natural or artificial forces. The inlet dry beach habitat is defined as the portion of the ocean beach in proximity to the inlet that is between mean high water and the toe of the dune. These inlet dunes and beaches are also susceptible to forecasted sea level rise.

Benefits of Inlet Dunes and Dry Beaches to Shorebirds, Colonial Waterbirds, and Other Waterbirds

Most shorebirds are long distance migrants, who migrate through and winter in North Carolina en route to find suitable breeding sites in the Arctic. To complete these flights, shorebirds must obtain a large food reserve. The inlet dunes and beaches in proximity to Rich Inlet provides a migration stop-over areas used by shorebirds to replenish food reserves and accumulate fat needed for the long flights. There are few places that have the necessary combination of resources. In some areas, between 50% and 80% of the entire population of a species may visit a single site (MCCS, 2003). Migratory arctic-bound shorebird species that may be found during the non-breeding season within inlets of North Carolina include the red knot (*Calidris canutus rufa*), dunlin (*Calidris alpine)*, western sandpiper (*Calidris mauri)*, and sanderlings (*Calidris alba*). Many arctic breeding species are experiencing declines, including the red knot, which was recently listed as a candidate for protection under the Endangered Species Act. Surveys conducted between 2002 and 2007 by NCAS revealed 1022 red knot individuals observed between Mason Inlet, south of the Permit Area, to New Topsail Inlet which is of the Permit Area (Mangiameli, pers. comm., 2008).

Shorebirds utilize these inlet dunes and beaches for breeding, wintering and migrating. Many species rely on a few, key stopover sites to complete their annual migratory cycle. The Outer Banks of North Carolina constitute a prime example of a potentially important area for which only limited information on migratory birds is available (Dinsmore, *et al*., 1998).

Colonial waterbirds also utilize this habitat. These species include terns (*Sterna* spp.), black skimmers (*Rynchops niger*), herons, egrets (Family Ardeidae), gulls (*Larus* spp.), ibis (Family Threskiornithidae), and pelicans (*Pelecanus occidentalis*) (Cameron, pers. comm.). Wading birds using the inlet complex include herons and egrets, and ibises (*Threskiomis* spp.). In addition to intertidal shoal habitats, these birds can be found foraging, roosting, and nesting in estuaries, oceanfronts, open dunes located within the inlet complex.

Some species of waterbirds, such as terns and black skimmers, nest on bare sand and shell with little or no vegetation. These species will change nesting areas in response to changing environmental conditions, such as increased vegetation or storm events. In selecting nesting habitat, waterbirds recognize the area and past success, but mainly adhere to group dynamics. This type of grouping creates nesting, resting, and foraging areas with large colonies that can include multiple species of waterbirds.

1. Overwash Habitats

One type of dry inlet beach habitat that is an important feature is overwash areas. Natural processes, such as storms, create overwash features behind primary sand dune areas. A total of 7 acres of overwash habitat has been delineated within the Permit Area. Overwash areas are usually created during strong storm events when tides wash over portions of the beach and move sand back towards the sound, creating new habitat. Overwash areas are characterized by the low sand flats left where storm waves have washed across a barrier island. This includes loose sand, perhaps piled into dunelets and/or divided by sluiceways, and usually scattered weedy shrubs and herbs. After the site has gone for an extended period without storm scouring, the vegetation may develop into a dense mat of vines and grasses. Island overwash is an important natural process in maintaining coastal barrier islands. Large man-made dunes may limit the occurrence of overwash features. When overwash occurs, the net volume of sand is often maintained and the island migrates landward (Donnelly *et al.*, 2006). Barrier islands naturally migrate landward as a result of sea level rise. This is accomplished through overwash events where sediments are pushed to the sound side, which contributes to building marsh on the sound side.

Benefits of Overwash Habitats to Shorebirds, Colonial Waterbirds, and other Waterbirds

Overwash features are not unique to inlets; however, the dynamic and productive microhabitats formed as a result of inlet migration are very important to both breeding and non-breeding waterbirds. Overwash habitats include ephemeral pools and bayside mudflats which are important feeding areas to piping plovers at the start of the nesting season and throughout the year (Fraser, 2005; USFWS, 1996). Overwash habitat is utilized by wildlife, particularly shorebirds, colonial waterbirds and other waterbirds as they provide suitable foraging and nesting habitat for these birds. Overwash events usually occur during storm events or in low areas during spring high tide conditions when seawater flows through the primary dune line, spreading out sand from the beach and dunes. Recently created overwash fans are generally unvegetated and function similar to the dry beach community. Willets, American oystercatchers, piping plovers, Wilson’s plovers, and killdeers usually nest on open areas such as above the high tide line on coastal beaches, on sand flats at the ends of sand spits, and along blowout areas behind dunes and in overwash areas. These open habitats are utilized by breeding and non-breeding colonial waterbirds. In particular, the Wilson's plover and the federally threatened

piping plover are both dependent on hurricanes and storms to provide the overwash needed for nesting habitat (Street *et al*., 2005).

D. Intertidal Flats and Shoals

Intertidal flats and shoals

These habitats areas are considered to be important feeding areas to shorebirds at the start of the nesting season and throughout the year. This includes the federally protected piping plover (Fraser, 2005; USFWS, 1996).

Intertidal flats and shoals are defined as non-vegetated, soft sediment habitats, found between mean high-water and mean low-water spring tide datum (Dyer et al. 2000) and are generally located in estuaries and other low energy marine environments. Mean high water is defined as the average elevation of all high waters recorded at a particular point or station over a considerable period of time. Mean low water is defined as the average elevation of all low water at a particular location also over a considerable period of time. Intertidal flats and shoals are distributed widely along coastlines world-wide, accumulating fine-grain sediments on gently sloping beds, forming the basic structure upon which coastal wetlands build. The tidal flats and shoals of North Carolina are habitat to a variety of migratory shorebirds, colonial waterbirds, marine mammals, reptiles, fish and macro-infauna. For this reason, these habitats are considered to be a valuable natural resource. These habitats have developed in a dynamic inlet system and, therefore tend to be ephemeral in nature, especially with regard to dynamic island formation within the inlet. A total of 206 acres of intertidal flats and shoals are located within the Permit Area, mainly within the inlet complex.

Benefits of Tidal Flats and Shoals to Shorebirds, Colonial Birds and Other Waterbirds
During all months of the year, Rich Inlet provides important foraging, roosting and nesting habitats for shorebirds, colonial birds, and other waterbirds. The intertidal shoals and sand flats provide sheltered and isolated habitat for roosting and foraging. Prey resources for shorebirds include mainly invertebrates and small fish. Most shorebirds are aquatic and terrestrial probers/gleaners that can wade in the surf of intertidal areas. Breeding and non-breeding federally endangered species and species of special concern also utilize intertidal flats and shoals. Therefore, Rich Inlet's habitats and the shorebirds that utilize them are a very important natural resource to the coast of North Carolina.

Benefits of Tidal Flats and Shoals to Benthic Macroinfaunal Community
These tidal flats and shoals in the inlet complex provide habitat for the macroinfaunal community due to their softbottom consistency. Softbottom habitats are comprised of unconsolidated sediment and defined as "unvegetated", lacking visible structural habitat. However, this "soft" substrate supports an abundance of macroalgae and numerous burrowing organisms (macroinfauna) living below the surface (Street *et al*., 2005).

Macroinfaunal species are resident to the upper 1 m (3.28 ft) of the substrate due to the available oxygen content and aeration properties; although some larger species may live deeper in the seabed (USFWS, 2002). Dominant macroinfaunal species typical of the bays and sounds of North Carolina include bivalves, decapods, polychaetes, and amphipods.

Macroinfaunal species are a primary food source for several migratory and resident shorebirds, waterbirds, as well as for many commercially and recreationally important fish. Bird species can be found utilizing the Inlet and surrounding estuarine environments as a stop-over feeding station while traveling to their wintering and nesting grounds. Migratory fish species utilizing the inlet depend upon the macroinfaunal community as a food reserve, en route to upstream seagrass beds and estuarine habitats.

Benefits of Tidal Flats and Shoals to Fishery Resources

As stated above, these habitat areas host an abundance of macro species which are food sources for many fishery resources. The tidal flats and shoals of North Carolina are habitat to a variety of, anadromous, estuarine, and marine fish species (USFWS, 2002), such as black grouper (*Mycteroperca bonaci*), blueline tilefish (*Caulolatilus chrysops*), cobia (*Rachycentron canadum*), lane snapper (*Lutjanus synagris*), mahogany snapper (*Lutjanus mahogoni*), margate (*Haemulon album*), mutton snapper (*Lutjanus analis*), ocean triggerfish (*Canthidermis sufflamen*), queen triggerfish (*Balistes vetula*), red drum (*Sciaenops ocellatus*), red grouper (*Epinephelus morio*), red porgy (*Pagrus pagrus*), red snapper (*Lutjanus campechanus*), schoolmaster (*Lutjanus apodus)*, spadefish (*Chaetodipterus faber*), banded rudderfish (*Seriola zonata*), black snapper (*Lutjanus griseus*), bluestriped grunt (*Haemulon sciurus*), cero (*Scomberomorus maculates*), dog snapper (*Lutjanus jocu*), gag (*Mycteroperca microlepis*), goldface tilefish (*Caulolatilus chrysops*), goliath grouper (*Epinephelus itajara*), gray triggerfish (*Sufflamen bursa*), king mackerel (*Scomberomorous cavalla*), white shrimp (*Penaeus setiferus*), brown shrimp (*Penaeus aztecus*), pink shrimp (*Penaeus duorarum*), Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), southern flounder (*Paralichthys lethostigma*), summer flounder (*Paralichthys dentatus*), and tomtate (*Haemulon aurolineatum*).

E. Oceanfront Dry Beach and Dune Habitats

1. Oceanfront Dune Communities

The primary dune extends landward to the lowest elevation in the depression behind that same mound of sand (commonly referred to as the dune trough). Frontal dunes are defined as the first mound of sand located landward of the ocean beach having sufficient vegetation, height, continuity and configuration to offer protective value (NC DCM, 2008b).

Dunes and their associated plant species are important in providing shorefront protection against coastal storms and supplying sand to the beach system during periods of erosion. A total of 60 acres of dune communities are located within the Permit Area primarily the oceanfront shoreline along Figure Eight Island and Hutaff Island behind the dry beach habitat. This habitat is also found within the back side of the inlet system.

Oceanfront beach and dune habitats

Section 15A NCAC 7H .0305(c) of the North Carolina Administrative Code defines primary dunes as the first mounds of sand located landward of the ocean beaches having an elevation equal to the mean flood level (in a storm having a one percent chance of being equaled or exceeded in any given year) for the area plus six feet.

Benefits of Oceanfront Dune Communities to Plant Species

High temperatures, strong winds, and varying wet and dry conditions typical of a dune environment provide unique conditions for plant species with specific adaptations. These specific adaptations include plant species that grow extensive root systems, allowing for prolific growth in unconsolidated beach sand. Perennial grasses are the primary stabilizers of frontal dune systems along beaches and dunes. North Carolina is located in a vegetation transition zone, between American beach grass (*Ammophila breviligulata*) to the north, and sea oats (*Uniola paniculata*) to the south.

2. Oceanfront Dry Beach Communities

Eroded material from the dune system contributes to the dry beach located between the toe of dune or scarp and mean high water (MHW) line. The dry beach area is susceptible to wind and storm surge, which supports less vegetation than the dune community. However, this habitat type provides recreational areas for humans and nesting grounds for sea turtles and shorebirds. A total of 75 acres of dry beach communities are located along the ocean shoreline on Figure Eight Island and Hutaff Island within the Permit Area.

Benefits of Oceanfront Dry Beach Habitats to Sea Turtles

Five species of sea turtles nest on North Carolina beaches: the green sea turtle, loggerhead sea turtle, leatherback sea turtle, hawksbill sea turtle and Kemp's Ridley sea turtle. Sea turtles prefer to nest on wide sloping beaches or near the base of the dunes. Dry beaches must allow for the following in order for nesting to be successful: beach areas above the mean high water line must be wide enough to allow nesting to occur; access to the dry beach must be devoid of obstructions (i.e. fencing, seawalls); the sand compaction must allow for digging, and; the nesting area to be located away from areas of inundation throughout the nesting season. The composition, color, and grain size can affect the incubation time, gender, and hatching success of turtle hatchlings (Street *et al*., 2005).

Benefits of Oceanfront Dry Beach Habitats to Shorebirds, Colonial Waterbirds, and other Waterbirds

Beach-nesting birds that utilize dry beach habitats for nesting include terns, black skimmers, Wilson's plovers, piping plovers and American oystercatchers. Terns and black skimmers nest on bare sand and shell with little or no vegetation. These species will change nesting areas in response to changing environmental conditions, such as increased vegetation. Waterbirds use group dynamics to select suitable nesting areas. This grouping creates nesting, resting, and foraging areas with large colonies that can include multiple species of waterbirds (Cameron, pers. comm., 2007). This is one reason why it is important that these birds have a number of suitable nesting, foraging, and roosting sites along the coast. For colonial waterbirds such as black skimmers and gulls, they utilize estuarine habitats, oceanfront shorelines, open dunes, inland areas, and dry beach habitats for foraging, roosting, and nesting.

The undeveloped beaches along Hutaff Island have been identified by the NCWRC as one of the most important migratory stop over sites and wintering sites for the federally threatened piping plover. Portions of the Permit Areas are regulated under a Critical Habitat listing as identified in the Endangered Species Act.

F. Wet Beach Communities

The intertidal zone of oceanfront barrier island beaches or wet beach communities are areas that are periodically exposed and submerged by waves, varying with frequency and with lunar tidal cycles. Like intertidal shoals, these areas are comprised mainly of sandy bottoms and shell hash and are influenced by tidal changes and are susceptible to storms. This high energy area is habitat to many benthic organisms and foraging grounds for birds and finfish. A total of 96 acres of wet beach habitat are found primarily along the oceanfront shoreline of Figure Eight Island and Hutaff Island within the Permit Area.

Wet beach with scarp formed on Figure Eight Island (March 18, 2008)

(Jarrett, 2008)

1. Benthic Infaunal Community

On oceanfront beaches, most benthic organisms in the intertidal zone consist of infaunal burrowing forms, particularly polychaete worms (Phylum Annelida), coquina clams (*Donax variabilis and D. paruvula*) and mole crabs (*Emerita talpoida*) (USFWS, 2002). Many benthic organisms are filter feeders, which pump large amounts of water through their bodies. As they pump water, they remove sediments and organic matter, thus filtering the water. Some of the organic matter filtered from the water is not used and instead deposited in the sediment. These nutrients can later be recycled by benthic organisms and dispersed back into the water column, making them available to other organisms. Thus, benthic organisms are critical in maintaining the high production rates of estuaries.

While several species of amphipods and polychaetes populate the intertidal and shallow subtidal beaches of North Carolina, their contribution to the total biomass of benthic infauna is low due to their small body size. Due to their short life spans and frequent reproduction events and despite their relatively low biomass, these species are important to the benthic infaunal community in regard to their contribution to primary and secondary productivity. Therefore, mole crabs and coquina clams dominate the benthic infaunal community due to their biomass (Peterson *et al.*, 2000).

- Mole Crab

Mole crabs (*Emerita talpoida)* live at depths above 5 cm under sand in shallow water in the swash zone or marine intertidal areas (Bowman and Dolan, 1985). *E. talpoida* is a very mobile species and is highly adaptable to the harsh and dynamic swash zone environment. Mole crabs have the color of rippled sand at the water's edge and live mostly buried in the sand, with their antennae reaching into the water forming a "V" shaped obstacle in the water as the wave recedes. These antennae filter plankton and organic debris from the water. Mole crabs also eat the tentacles of Portuguese man o' war (*Physalia physalis*), which are collected by winding the tentacle around the mole crab's leg. Camouflage protects the mole crab from predators, primarily fish and birds. Males are smaller than females, only reaching 20 mm, making the sexes easy to tell apart when fully grown. Females grow to 35 mm in length and carry their bright orange colored eggs under their telson until they are ready to hatch. Recruitment can occur year round, but large numbers of recruits are found in early summer and in early fall. Diaz (1980) found that

most recruitment occurred in September as a result of summer spawning. Amend and Shanks (1999) also found that the reproductive season ended in late September.

Female mole crabs do not rely on tidal cues to time larval release; instead, larvae are released at sunset regardless of the time of the tide. Since larval release occurs within the intertidal zone, the physical wave motions and currents are most likely strong enough to transport larvae away from the shoreline to coastal areas for development (Ziegler and Forward, 2005). Amend and Shanks (1999) reported that larval release is also influenced by wave height during rough seas where larvae are rapidly transported offshore away from adult habitat and predation.

As the swash zone changes with the tide, so does the location of the mole crabs. The mole crabs move up and down the beach with the tides. In the winter, storms carry them offshore possibly into sandbars; however, when the sand is transported back onshore in the spring, the mole crabs travel with it. Bowman and Dolan (1985) found that the overwintering populations migrate onshore in April during a period of rapidly increasing water temperatures. These population fluctuations are an important consideration when using *E. talpoida* as an indicator species for assessing environmental impacts.

- Coquina Clam

Coquina clams (*Donax variabilis)* are small, generally less than 2.5 cm in length, and possess wedge-shaped shells (Ruppert and Fox, 1988). Like most bivalves, coquinas are filter feeders, ingesting phytoplankton, bacteria, and other small suspended particles in the surf zone. The wet beach environment is extremely dynamic, eroding and accreting several times in a period of months. Although many organisms feed in the surf zone, this clam has unique adaptations to this habitat type, making the coquina clam a key habitat indicator species.

Donax variabilis migrates shoreward with the incoming tide and seaward with the outgoing tide (Ellers, 1995). While these clams spend most of their time buried in the sand, they emerge several times per tidal cycle to ride waves. Ellers (1995) named this method of movement "swash-riding" where each clam emerges from the sand and the flow from waves drags it to a new position to maintain optimum position at the sea's edge. Coquina clams actively migrate up and down the beach during spring and summer; however these tide-related migrations cease in winter as *D. variabilis* eventually moves into the subtidal zone in late fall. The fluctuation of the location of populations in relation to the changing tides is an important consideration when assessing this species and one should expect variation if sampling at different tidal levels.

Both males and females are required for reproduction. Spawning occurs subtidally in winter and juveniles recolonize the intertidal beach in late winter (Ruppert and Fox, 1988). The typical lifespan of coquina clams is two years.

The temporal pattern of presence and recruitment of macroinvertebrates of the South Atlantic Bight are depicted in Table 4.4 below.

Table 4.4. Temporal presence and major recruitment periods of surf zone invertebrates of the South Atlantic Bight (Hackney, et al., 1996).

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Coquina Clams (Donax variablis)	P	P	P	P	H	H, R	H,R	H	H	H	P	P
Ghost Crabs (Ocypode quadrata)	P	P	P	P	P	P, R	P, R	P, R	P, R	P	P	P
Beach Hoppers (Orchestiodea)	?	?	P	P	P	P	P	P	P	P	P	P
Sand Hoppers (Talorchestia)	?	?	P	P	P	P	P	P	P	P	P	P
Worms (Polychaetes)	P	P	P, R	H, R	H, R	H, R	H, R	H, R	H, R	H	P	P
Mole Crabs (Emerita taploidea)	P	P	P	P	H	H	H	H, R	H, R	H	P, R	P, R

P = present, H = periods of peak abundance, R = periods of recruitment

Benefits of Wet Beach Habitats to Fishery Resources

Many infaunal species are important food sources for demersal predatory fishes and mobile crustaceans. Some of the species that forage on benthic invertebrates in the swash zone include inshore lizardfish (*Synodus foetens*), pompano (*Alectis crinitus*), pigfish (*Orthopristis chrysoptera*), pinfish (*Diplodus holbrookii*), spot (*Leiostomus xanthurus)*, kingfish (*Menticirrhus littoralis, M. americanus*), red drum (*Sciaenops ocellatus*), Atlantic croaker (*Micropogonias undulates*), northern sea robin (*Prionotus carolinus*), summer flounder (*Paralichthys dentatus*), weakfish (*Cynoscion regalis*) and penaeid shrimp (Street *et al*., 2005). Many of these species use the high energy environment as protection from other predatory species, as well as for feeding grounds.

Benefits of Wet Beach Habitats to Shorebirds, Colonial Waterbirds, and Other Waterbirds

Many infaunal species are important food sources for a variety of bird species, especially the beach-nesting birds. Colonial waterbirds, such as gulls and black skimmers that utilize estuarine habitats, oceanfront shoreline, open dunes, and inland areas also utilize wet beach habitats for foraging, roosting, and nesting. These colonial waterbirds can rapidly populate and alter ranges in response to changes in environmental conditions.

G. Marine Habitats

Cowardin (1979) classifies marine habitats as open ocean waters overlying the continental shelf and its associated high energy coastline where salinities exceed 30 ppt. With this broad classification, many habitats or community types fall within the definition and have previously been, or will be, discussed in other sections of this EIS. This section, however, will focus on soft and hard bottom communities that are considered marine habitats. Marine nearshore softbottom communities are found in the intertidal zone as well as the subtidal zone. Marine intertidal and subtidal zones along the shoreline are highly affected by tides and bottom friction. North Carolina's tidal amplitude along ocean shoreline is greatest where the continental shelf is widest in the southern coastal area; average tidal height is approximately 2 ft (0.6 m) near Cape Hatteras and 4.3 ft (1.3 m) near Cape Fear (Street *et al*., 2005).

1. Softbottom (Unconsolidated) Communities

Softbottom habitat is the unvegetated bottom sediment in all coastal systems, and includes features such as inlets, shoals, channel bottoms, intertidal ocean beaches, and cape shoals. Softbottom plays a key role in primary productivity in shallow estuarine and marine systems. This habitat strongly influences the water column through dynamic cycling processes, storing and releasing nutrients and chemicals over time. Other ecosystem functions of softbottom include the reduction of physically destructive storm effects on oceanfront beaches, and providing sand sources for barrier island and inlet migration.

Softbottoms consist of both mud and sand substrates. Mudflats are sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas. The sediments generally consist of silts and clays with a high organic content" (NMFS, 2006 - Mudflats). Sand bottoms consist of materials with grain sizes more coarse than silt (>0.0625 mm) (Anderson, 2006). Mud and sand bottoms can be found throughout Nixon Channel, Green Channel, Rich Inlet, and nearshore areas of Figure Eight Island. Penaeid shrimp, blue crab, red drum and flounders utilize this habitat type as nursery, foraging and refuge areas.

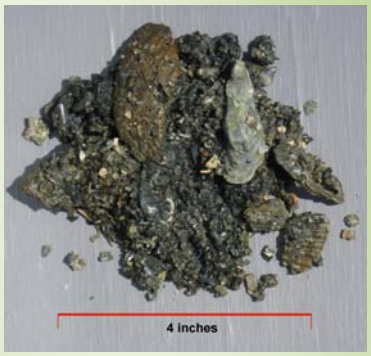
Periodic storms can affect benthic communities along the Atlantic coast to depths of approximately 35 m (115 ft). As a result, softbottom communities tend to be dominated by opportunistic taxa which have adapted to relatively quick recovery from disturbance (Street *et al.*, 2005). Seasonal climatic changes can also influence the diversity and abundance of macroinfaunal species in these areas. Species abundance during the late winter and early spring is typically higher with densities of over 3,500 per 100cm^2 commonly observed (Mallin *et al*., 2000), although individual species vary considerably in their abundance throughout the year. Generally, inadequate data are available to clearly indicate the current condition of softbottom habitat. Fortunately this habitat is relatively resistant to a changing environment. This is the most abundant submerged coastal fish habitat, and estuarine acreage of softbottom has undoubtedly increased over time as shell bottom, SAV, and wetland habitats have declined. This "soft" substrate supports an abundance of macroalgae and numerous burrowing organisms (macroinfauna) living below the surface (Street *et al*., 2005). Intertidal shoal, marine intertidal (wet beach) and subtidal areas in the Permit Area provide a total of 2,580 acres of possible habitat for softbottom communities.

Benefits of Softbottom Communities to Fishery Resources

Mud and sand bottoms can be found throughout Rich Inlet and behind Figure Eight Island and Hutaff Island as well as offshore of the ocean shoreline.

Softbottom habitat is used to some extent by almost all native coastal fish species in North Carolina. Certain species are better adapted to this shallow non-vegetated bottom. Flatfish, rays and skates are well suited for utilization of softbottom. Juvenile and adult fish species that forage on the rich abundance of macroalgae, detritus and small invertebrates are highly dependent on the softbottom. Softbottom habitat is particularly important as a foraging area for all size ranges of bottom feeding fish and invertebrates, such as blue crabs, shrimp, flounders, striped mullet, spot, croaker, and kingfish. Burrowing mollusks (e.g., hard clams, coquina clams), flatfishes (e.g., southern flounder, hogchoker) and baitfish (e.g., striped mullet) are highly associated with shallow softbottom, while larger benthic feeding predators (e.g., weakfish, coastal sharks, sturgeons) typically utilize deeper softbottom areas. Valued fishery species that depend on healthy softbottom habitat include hard clams, shrimp, blue crabs, southern flounder, Atlantic croaker, striped mullet, kingfish, and spot. Of these, the NCDMF stock status of Atlantic and shortnose sturgeons, southern flounder, and coastal sharks was overfished. Striped mullet and Atlantic croaker were listed as Concern. The Atlantic sturgeon, which is classified as Overfished, has been under a fishing moratorium since 1991 but has not shown signs of recovery. Coastal inlets have been federally designated as Habitat Areas of Particular Concern for blue crab, estuarine-dependent snapper and grouper, penaeid shrimp, and red drum.

Samples of material acquired during hardbottom investigations



Course Material

Fine Material

Fluidized Mud

Offshore sand bottom communities along the North Carolina coast are relatively diverse habitats containing over a hundred polychaete taxa (Posey and Ambrose, 1994). Tube dwellers and permanent burrow dwellers are important benthic prey for fish and epibenthic invertebrates.

2. Hardbottom (Consolidated sediment) Communities

The term “hardbottom” refers to areas of rock or consolidated sediments in temperate, subtropical, and tropical regions, generally located in the ocean rather than in the estuarine system. Hardbottom habitats are also called “livebottom” due to the variety and abundance of invertebrates and plants that attach to or bore into these hard substrates. The topography of these habitats can vary from a relatively flat, smooth surface to a scarped ledge with stepped relief. Hardbottom habitats include shallow kelp-covered areas in rocky headlands, rock outcrops, submarine canyon walls, and the deep-water plateau. Along the south Atlantic states, hardbottom ranges from the shoreline and nearshore (within the state’s 3-mi jurisdictional limit) to beyond the continental shelf edge (>200 m deep). It typically occurs in clusters across the shelf in specific areas.

Estimates of the percent cover of hardbottom vary greatly along the south Atlantic coast between Cape Canaveral and Cape Hatteras (NOAA, 2007; Street *et al.*, 2005).

Benthic water temperatures at hardbottom habitats in the ocean off North Carolina range from approximately 52.8° to 80.6° F (11° to 27° C). Salinity is typically around 35 ppt with little fluctuation. The composition of invertebrate, algal, and fish communities varies with temperature, depth and season.

Dr. William Cleary identified two areas of potential hardbottom resources located offshore Figure Eight Island and Hutaff Island (Cleary, 2000) (Figure 4.10). In order to verify the presence of hardbottom communities within the project area, a sidescan sonar survey was conducted off Figure Eight Island on 24 April 2009 (Figure 4.10). Following analysis and interpretation of the sidescan sonar data, a groundtruthing investigation of 11 sites was conducted on 30 June 2009 (See Appendix D). A number of sorted bedform features were identified through sidescan interpretation and verified through groundtruthing. Several areas generically interpreted as “bottom morphology of interest” were found to be sandy areas with abundant sand dollars. Other areas interpreted as “bottom morphology of interest” were found to be areas where fluidized mud had covered the existing bottom substrate. No rock outcrops or hardbottom communities were observed at any of the 11 locations either exposed or buried; therefore, no hardbottoms are likely to be present within the Permit Area.

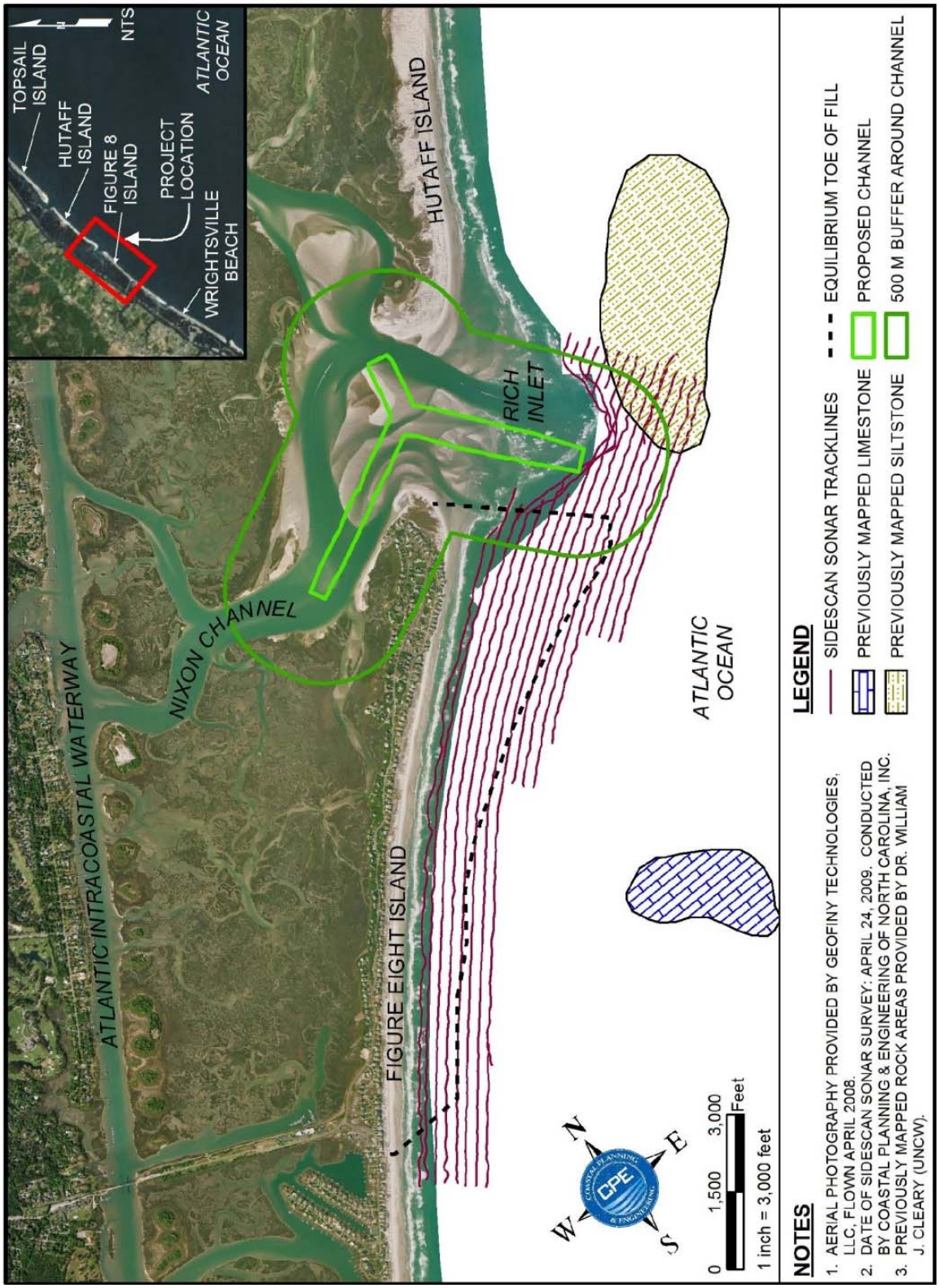


Figure 4.10. Map depicting sidescan sonar survey area. Note the tracklines cover the area within 500 meters of the proposed channel and the shoreface out beyond the point of equilibrium toe of fill.

H. Water Column

Water column is a conceptual column of water from its surface to bottom sediments. The concept of water column is important, since many aquatic processes are explained by the vertical mixing of chemical, physical or biological parameters. The depth of water column varies greatly throughout the Permit Areas. Within the waterbodies of Nixon and Green Channel, the depth ranges from less than 1 foot to approximately 18 feet; and the water column depth from the inlet gorge to the outer bar channel of Rich Inlet ranges from approximately 5 feet to nearly 30 feet. Along the ocean shoreline, the water column ranges from approximately 2 feet deep within the surf zone to approximately 25 feet deep. Conditions that influence the water column are hydrodynamic flow processes and salinity levels. The water column encompasses approximately 2,580 surface acres within the Permit Area.

Water column

Water column habitat is defined in North Carolina's Coastal Habitat Protection Plan (CHPP) as "the water covering a submerged surface and its physical, chemical, and biological characteristics" (Street *et al.,* 2005). It connects all other aquatic habitats, and is the "medium of transport for nutrients and migrating organisms between river systems and the open ocean" (SAFMC, 1998).

1. Hydrodynamics and Salinity

Hydrodynamic flows in nearshore, shallow environments, including the surf zone, are different from coastal and deep-ocean flows mainly because of the shoreline barrier, shallow depths, bathymetric features associated with the continental shelf, and nearshore inputs of freshwater. Moreover, flows in nearshore waters tend to be more complex than in the deep and coastal ocean because many processes operate there, including surface gravity waves, buoyancy driven flows, wind-forcing, surface and internal tides, large-amplitude internal waves and bores, and boundary-layer effects (Pineda et al, 2007). These differences between nearshore and coastal/open ocean hydrodynamics are important for larval transport.

Ocean tides on Figure Eight Island are semi-diurnal (occurring approximately every 12 hours), with a spring-neap variation of 28 days. Tidal ranges inside the AIWW range from 3.2 to 3.6 ft. The tidal range in the throat of the inlet is approximately 3.7 ft. The tidal prism through the throat of Rich Inlet is approximately 560,000 cubic feet.

In the throat of the inlet and Green Channel, the tidally influenced currents are flood-dominated, which means that water flows are greater as the water flows from the ocean through the inlet. In Nixon Channel, the currents appear to be ebb-dominated, meaning that the water flows are greater as the water flows from the inlet toward the ocean. In the throat of the inlet, the peak currents were 3.2 feet/second during flood and 2.7 feet/second during ebb, with a principal axis of 319º/139º. In Green Channel, the peak currents were 3.0 ft/sec during flood and 2.0 ft/sec during ebb, with a principal axis of 341º/161º. In Nixon Channel, the peak currents were 1.7 ft/sec during flood and 1.8 ft/sec during ebb, with a principal axis of 280º/100º. For more information regarding the tides and tidal flow within the Permit Area, refer to the Engineering Analysis (Appendix B).

The principal direction of waves along the beaches of Figure Eight Island and Hutaff Island are from the east-southeast and the southeast. The highest waves occur in February during the northeaster season and in August and September during hurricane season. During the summer, waves tend to approach from the south-southeast, driving the sediment transport towards the northeast. During the winter, waves tend to approach from the east-southeast, driving the sediment transport towards the southwest. For more information regarding the wave climate within the Permit Area, refer to the Engineering Analysis (Appendix B).

Rich Inlet is a sediment sink that gains 100,000 to 200,000 cy of sand material each year. The source of this material alternates between the adjacent beaches on Figure Eight Island and the adjacent beaches on Hutaff Island depending on the orientation of Rich Inlet. The present source is Hutaff Island.

Near the northern end of Figure Eight Island, there is a nodal point, at which eroding sediments spread towards both the northeast and the southwest. This nodal point has shifted towards the northeast since 1999, but currently lies near Inlet Hook Road. Along the middle of Figure Eight Island, sediment transport can occur in either direction. The present sediment transport direction is towards the southwest. On the southern end of Figure Eight Island, the predominant sediment transport is towards the southwest. Sediment transport rates at the south end of Beach Road vary from 50,000 to 250,000 cy per year. Given the present and past erosion patterns within a mile of Rich Inlet, the northeasterly sediment transport on Topsail Island (USACE, 2006), and the southwesterly transport near Mason Inlet, Rich Inlet probably functions as a regional nodal point.

A primary factor affecting the distribution of estuarine-dependent fish and shellfish is salinity. Marine waters of the Permit Area vary on a daily basis in current and salinity conditions due to fresh water inflow, tides, and wind.

The North Carolina Recreational Water Quality Program (RWQ) also tests coastal waters. Their mission is to protect the public health by monitoring the quality of N.C.'s coastal recreational waters and notifying the public when bacteriological standards for safe bodily contact are exceeded. The coastal waters monitored include the ocean beaches, sounds, bays and estuarine rivers. RWQ tests for *Enterococci* bacteria, an indicator organism found in the intestines of warm-blooded animals. While *Enterococci* will not cause illness itself, its presence is correlated with that of organisms that can cause illness. The program tests 241 ocean and sound-side areas, most of them on a weekly basis. Lower-use beaches are tested twice a month.

Three RWQ sampling stations are located within the Permit Area. These stations include Station 50 (located in the AIWW between Mason’s Creek and Pages Creek), 50A (located in Middle Sound at the south end of Figure Eight Island), and 50B (located in Nixon’s Channel). Information taken at the stations includes salinity readings. In 2007, measurements obtained by RQW within stations 50, 50A, and 50B averaged 35.7 ppt, 36.0 ppt, and 35.9 ppt, respectively. These salinity levels support a wide range of fishery resources that are typical in inlet and estuarine complexes similar to Rich Inlet and associated water bodies.

Benefits of Water Column to Fishery Resources

Estuarine and marine water column environments in the Permit Area include the beach areas and surf zones of Figure Eight Island, Hutaff Island, Rich Inlet, Nixon Channel, Green Channel, and Middle Sound. Fish that utilize the water column of North Carolina include: anadromous fish, which can be found in coastal waters but migrate into rivers to spawn in freshwater (e.g. striped bass, Atlantic and shortnose sturgeon, herring); estuarine-dependent species (e.g. flounder, blue crab, panaeid shrimp, red drum); permanent resident species (e.g. black sea bass, Atlantic bumper, lizardfish); and seasonal migrant species (e.g. bluefish, Spanish and king mackerel, cobia, spiny dogfish). The transport of larval fish from the offshore water column to the estuarine nursery areas through inlets plays a vital role in the life cycle of many fish species.

2. Larval Transport

Larval transport is defined as the horizontal translocation of a larva of any species between points (Pineda, et al, 2007). In the southeastern USA, many species of estuarine-dependent fishes spawn offshore and their larvae are transported into estuaries. The dispersal and subsequent retention of larvae back into the estuary is regulated by a number of factors including astronomical and meteorological tides. Some larvae have the capability to actively migrate horizontally and vertically in the water column to utilize the stratification, tidal currents, flows, and other physical properties of the aquatic environment to help regulate their transport from spawning grounds to settlement areas.

Larvae utilize inlets as the conduit between the open ocean and the estuarine environment. Rich Inlet, a relatively large inlet separating Hutaff Island from Figure Eight Island to the southwest, drains an expansive marsh-filled lagoon where two large, relatively deep tidal creeks, Nixon and Green Channels, connect the inlet to the AIWW. The tidal prism for Rich Inlet has been estimated at approximately 560,000 cubic feet (Appendix B). This mass of flowing water acts as a conduit for larvae found within the water column in proximity to the inlet. Settle *et al.* (2005) estimated that the larval fish concentrations in close proximity to Bogue Inlet ranged throughout the water column between 0.5 and 5.0 larvae per cubic meter. Assuming that there is similar larval concentration in proximity to Rich Inlet, Rich Inlet would serve as an important pathway for numerous species of zooplankton into the estuary.

3. What are the characteristics of the threatened, endangered, and State listed species found within the project area?

Federal and State Listed Species

The following section describes the federal and state listed species that occur, or have the potential to occur in the Permit Area, as listed in Table 4.5.

Table 4.5. Federal and State Listed Species Found or Have the Potential to be Found within the Permit Area

Common Name	Scientific Name	Federal Status	State Status
Reptiles			
Green Sea Turtle	*Chelonia mydas*	Threatened	Threatened
Hawksbill Turtle	*Eretmochelys imbricate*	Endangered	Endangered
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Endangered	Endangered
Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Endangered
Loggerhead Sea Turtle	*Caretta caretta*	Threatened	Threatened
Carolina Diamondback Terrapin	*Malaclemys terrapin centrata*	None	Species of Special Concern
Mammals			
West Indian Manatee	*Trichechus manatus*	Endangered	Endangered
North Atlantic Right whale	*Eubaleana glacialis*	Endangered	Endangered
Sei whale	*Balaenoptera borealis*	Endangered	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered	Endangered
Finback whale	*Balaenoptera physalus*	Endangered	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered	Endangered
Fish			
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus*	Endangered	Species of Special Concern
Vascular Plants			
Seabeach amaranth	*Amaranthus pumilus*	Threatened	Threatened
Birds			
Piping Plover	*Charadrius melodus*	Threatened	Threatened
Wilson's Plover	*Charadrius wilsonia*	None	Species of Special Concern
American Oystercatcher	*Haematopus palliatus*	None	Species of Special Concern
Common Tern	*Sterna hirundo*	None	Species of Special Concern
Gull-billed Tern	*Sterna nilotica*	None	Threatened
Black Skimmer	*Rynchops niger*	None	Species of Special Concern
Eastern Painted Bunting	*Passerina ciris ciris*	None	Species of Special Concern

Key: Status — Definition

Endangered - A taxon "in danger of extinction throughout all or a significant portion of its range."

Threatened - A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

Species of Special Concern- Any species of wild animal native or once native to North Carolina that is determined by the Wildlife Resources Commission to require monitoring but that may be taken under regulations adopted under the provisions of Article 25

A. Reptiles

1. Sea Turtles

Sea turtles are large marine reptiles that spend most of their lives in marine or estuarine habitats. Sea turtles can be found in subtropical and temperate oceans as well as in sub-arctic seas around the world (Musick and Limpus, 1997). Several studies have shown that the beaches adjacent to inshore and offshore waters along the Atlantic Coast of the United States are important foraging

and developmental habitats for many threatened and endangered species of sea turtles (Shoop and Kenney, 1992; Ehrhart, 1983; Keinath *et al*., 1987).

Although sea turtles spend most of their lives in the ocean, female turtles must return to land to nest (Miller, 1997). Therefore, oceanfront beaches, such as those found along Figure Eight Island and Hutaff Island, provide an important habitat for sea turtle survival. Female sea turtles show nest site fidelity by returning to the nesting beach where they hatched (Limpus *et. al*., 1984; Limpus, 1985). Nesting females prefer beaches with limited lighting and open-water access, while other factors such as elevation from water inundation, dune vegetation, beach slope and the moisture and compaction of the sand may also influence site selection (Hendrickson, 1982; Mortimer, 1982). Female sea turtles typically emerge from the water at night, select a nest site, and excavate a chamber to deposit her eggs. Females cover the nest and return to sea allowing the eggs to develop for 6 to 13 weeks depending upon the species of sea turtle and the temperature of the nest (Miller, 1985). Hatchlings will emerge at night and migrate from the nest to the ocean where they begin their offshore migration into the open ocean.

Five species of sea turtles utilize the waters of North Carolina for breeding, feeding, and development. These species include: the loggerhead sea turtle (*Caretta caretta*); green sea turtle (*Chelonia mydas*); hawksbill sea turtle (*Eretmochelys imbricata*); Kemp's Ridley sea turtle (*Lepidochelys kempii*); and the leatherback sea turtle (*Dermochelys coriacea*) (Epperly *et al*., 1990; USFWS, 2003a). Sea turtles can be found in offshore as well as inshore waters at all times of the year, although they are more common inshore during the spring, summer and fall months (Epperly *et al*., 1995a). Immigration of sea turtles into North Carolina's sounds and estuaries occurred most frequently in the spring with dispersal throughout the sounds as the waters warmed. Emigration out of inshore occurred during the latter part of fall when the waters began to cool. Although the exact numbers and frequencies of species inhabiting the inshore and offshore waters of North Carolina are not available, it is known that these habitats are used at various times throughout the year by all five sea turtle species discussed (Epperly *et al*., 1990). Species composition of turtles captured by fisherman in the inshore waters of North Carolina consisted of loggerheads (71%), greens (17%), and Kemp's ridley (12%) (Epperly *et al*., 1995b). Public sightings reported all five species in inshore waters with leatherbacks and hawksbills being observed infrequently (Epperly *et al*., 1995a).

Green sea turtle

- *Green Sea Turtle*

Breeding populations of green sea turtles (*Chelonia mydas*) along Florida and the Pacific coast of Mexico have been federally listed as endangered, while all other populations have been listed as threatened under the Endangered Species Act since July 28, 1978. Additionally, a green sea turtle Critical Habitat was designated for the coastal waters surrounding Culebra Island, Puerto Rico (NMFS, 2006). Green sea turtles are mid- to large-sized sea turtles that reach an average weight of 136.2 kg (303 lbs) (Pritchard, 1997). Feeding habitats for adults are specific to seagrasses and marine algae, while hatchlings may be found feeding on various plants and animals. Green sea turtles are generally found near seagrass habitats in shallow aquatic

environments, such as nearshore reefs, bays and inlets. Coral reefs and rocky patches may also be utilized for shelter and feeding when seagrass is not available (Hirth, 1997).

The green sea turtle is globally distributed with an estimated population of 600,000 adults (USFWS, 2003e). While green sea turtle populations generally range throughout warm tropical and temperate waters of more than 140 countries, their nesting and feeding grounds are predominantly located along coastal areas between 30° North and 30° South. The green sea turtle nesting season of southern U.S. populations generally occurs between June and September, but varies depending upon its locality. Hatchling incubation time and sex determination are both temperature dependent (Mrosovsky, 1995). Green sea turtle hatchlings emerge at night and migrate offshore spending several years feeding and growing in oceanic current systems (USFWS, 2003e).

Along the U.S. beaches of the Atlantic, green turtles primarily nest in Florida. Less significant nesting populations have been identified in the U.S. Virgin Islands, Puerto Rico, Georgia, South Carolina, and North Carolina (USFWS, 2003e). NCDENR reports that the green sea turtle has been observed in Brunswick, Carteret, Dare, Hyde, New Hanover, Onslow, and Pender Counties. While green sea turtles have been sighted, primarily from spring through fall, along the entire North Carolina coastline, nesting activities have only been observed in Onslow, Brunswick, and Hyde Counties. According to data supplied by Dr. Webster of UNCW and Mr. Golder of the Audubon Society, no green sea turtle nests have been observed in the study area on either Figure Eight Island or Hutaff Island (Webster, pers. comm, 2011; Golder, pers. comm, 2008).

Hawksbill sea turtle

- *Hawksbill Sea Turtle*

The Hawksbill sea turtle (*Eretmochelys imbricata*) was listed as endangered in 1970. The hawksbill is also internationally protected under Appendix 1 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (NMFS, 2007). A Critical Habitat designation has also been identified for the waters surrounding Mona and Monito Islands of Puerto Rico. These islands provide primary foraging habitat for several life stages for this species (NMFS, 2007; USFWS, 2003c).

Hawksbill turtles are usually found in tropical and subtropical waters of the Atlantic, Pacific and Indian Oceans occurring from 30°N to 30°S latitude (NMFS, 2007). These turtles are widely distributed in the Caribbean and the western Atlantic Ocean. Hawksbill turtles prefer the clear shallow waters of coral reefs, creeks, estuaries and lagoons in tropical areas. Their diet primarily consists of sponges but also includes algae, fish, mollusks, and other benthic species found in the nearshore zone. Adults may reach up to 0.9 m (3 ft) in length and weigh on average about 136 kg (300 pounds) (USFWS, 2003c).

Hawksbill neonate behavior is similar to other sea turtles; they remain pelagic for several years before returning to coral reef habitats. Juveniles move from pelagic to coastal habitats at a much

smaller size than other turtles (20 to 25 cm [to 10 in] carapace length) (Lutcavage and Musick, 1985). Juveniles are not often seen in waters deeper than 19.8 m (65 f) (Witzell, 1983), however they are frequently associated with floating *Sargassum* in the open ocean (Musick and Limpus, 1997).

Within the U.S., hawksbill turtles are most common in the waters surrounding Puerto Rico, U.S. Virgin Islands and Florida (NMFS, 2007). Hawksbills are recorded in the continental U.S. from all the Gulf states and from the eastern seaboard as far north as Massachusetts, but sightings north of Florida are rare (NMFS, 2007). The U.S. Fish and Wildlife Service North Carolina Office reports that the presence of hawksbill sea turtles along the North Carolina coast is rare (USFWS, 2007c); therefore, none are expected to be present in the study area.

The hawksbill has experienced major population decline with only five regional nesting populations remaining in the Seychelles, Mexico, Indonesia, and two in Australia (USFWS, 2003c). Nesting females lay on average 3-5 nests per season which contain 130 eggs per nest (NMFS, 2007). Nesting season varies with locality, but most nesting occurs sometime between April and November (USFWS, 2003c). There are no reported nesting activities of hawksbill sea turtles on the beaches within the study area (Godfrey, pers. comm.).

Kemp's ridley sea turtle

- *Kemp's Ridley Sea Turtle*

The Kemp's ridley sea turtle (*Lepidochelys kempii*) has been listed as endangered under the Endangered Species Act since December 2, 1970 (USFWS, 2003d). The range of Kemp's ridley includes the Gulf coast of Mexico, the Atlantic coast of North America as far north as Newfoundland and Nova Scotia, and the Gulf coast of the U.S., especially Padre Island, Texas (USFWS, 2003d). Kemp's ridley is the smallest of the eight species of sea turtles, averaging 35-45 kg (78-100 lbs) with an average length between 56 and 76 cm (22 and 30 in) (Marquez, 1994; USFWS, 2003d). As juveniles, Kemp's ridley turtles feed primarily on crabs, clams, mussels, and shrimp and are most commonly found in productive coastal and estuarine areas. Recruitment from pelagic habitats occurs at a carapace size between 20 and 25 cm (7.9 and 9.8 in) (Lutcavage and Musick, 1985).

Hatchlings are dispersed within the Gulf and Atlantic by oceanic surface currents. According to the U.S. Fish and Wildlife Service, rare nesting events have been recorded in Florida, South Carolina and North Carolina (USFWS, 2003d). Most sea turtle species are widely distributed; however, the Kemp's ridley is mostly restricted to the Gulf of Mexico (Miller, 1997). They have also been sighted in shallow coastal waters along the east coast of the United States.

As reported by the USACE (2006):

> ..*Kemp's ridley sea turtle is commonly observed migrating within North Carolina inshore waters during the spring and fall, but has been documented to nest only once in North Carolina, on Oak Island in 1992* (Godfrey, pers. comm).

Kemp's ridley turtles are also occasionally found stranded on the beaches of North Carolina (Mihnovets, 2003). These strandings may be attributed to the juvenile sea turtles getting caught in the southern Gulf of Mexico loop current that eventually moves these turtles east and north up the eastern Atlantic coast (Musick and Limpus, 1997). Conservation measures initiated in the late 1970's are thought to be contributing to the Kemp's ridley population recovery; however, the Kemp's ridley sea turtle still remains the rarest sea turtle in the world (Pritchard, 1997). Four Kemp's ridley sea turtles were taken by a hopper dredge working off of Bogue Banks in December 2001, but there were no turtles taken during the relocation of Mason's Inlet in 2000 (Sugg, pers. comm.). Since monitoring began, only one (1) Kemp's ridley nest has been observed within in the project area. This nest was observed during the 2010 nesting season on Figure Eight Island (Godfrey, pers. comm.).

Nesting leatherback sea turtle

- *Leatherback Sea Turtle*

The leatherback sea turtle (*Dermochelys coriacea*) was listed as an endangered species on June 02, 1970 (under a law that preceded the Endangered Species Act of 1973), and then listed as endangered throughout its range in the United States under the Endangered Species Act of 1973 (NMFS, 2007). A Critical Habitat designation is listed for Sandy Point, St. Croix, U.S Virgin Islands and surrounding waters (NMFS, 2007; USFWS, 2003b).

The U.S. range of the leatherback extends from Nova Scotia south to Puerto Rico and the U.S. Virgin Islands. Small nesting populations occur in Florida, St. Croix, and Puerto Rico (USFWS, 2003b). Although nesting in the State of North Carolina is rare, Rabon *et al*. (2003) confirmed seven leatherback turtle nests between Cape Lookout and Cape Hatteras. The nesting frequency included two nests in 1998, four nests in 2000, and one nest in 2002. Leatherback sea turtles nest an average of five to seven times within a nesting season, with an observed maximum of 11 nests. The average inter-nesting interval is about 9-10 days (USFWS, 2003b). While infrequently found in inshore waters, Epperly *et al*. (1995) reported that, on average, 15 leatherback sea turtles per year were sighted in inshore waters (within three miles of shore) of North Carolina between 1989 and 1992. According to Epperly *et al*. (1995) these inshore sightings coincided with the appearance of jellyfish and leatherback sightings diminished by late June. The NCWRC (Everhart, 2007) reported a leatherback false crawl in North Carolina in 2007. No leatherback sea turtle nests have been reported within the project area within recent years (Godfrey, pers. comm.).

Loggerhead sea turtle

- *Loggerhead Sea Turtle*

The loggerhead sea turtle (*Caretta caretta*) has been listed in the Federal Register as threatened throughout its range since July 28, 1978 (USFWS, 2003f). Loggerheads are large reddish-brown turtles weighing between 91-159 kilograms (200-350 lbs) (Pritchard, 1997). Adult loggerheads

nest at night along sandy beaches and may nest from one to seven times within a nesting season (USFWS, 2003f). The average nest depth for loggerhead sea turtles is 61 cm (24 inches). Loggerhead sea turtles are the only marine sea turtles that have been reported to nest predominantly outside of the tropics (Bolten and Witherington, 2003).

Hatchling loggerheads migrate offshore into circular oceanic current systems (gyres) and are often found in drifting masses of *Sargassum* macroalgae until they have grown to be much larger juveniles (Carr, 1967; Fletmeyer, 1978). Loggerhead sea turtles will remain within the gyre for several years before leaving their pelagic habitats to return to their coastal foraging and nesting habitats (Klinger and Musick, 1995; Bolten *et al*., 1993). Recruitment into coastal habitats occurs when their carapace length is between 25 and 70 cm (9.8 and 27.5 in) (Lutcavage and Musick, 1985; Bolten *et al*., 1993).

Five nesting subpopulations in the western North Atlantic have been identified through genetic DNA analysis and include: 1) the Northern subpopulation from North Carolina to Northeast Florida; 2) the South Florida subpopulation north of Cape Canaveral, following the eastern coastline south and around to Sarasota on Florida's west coast; 3) the Dry Tortugas, Florida, subpopulation; 4) the Northwest Florida subpopulation, found along the panhandle of Florida's northwest coast; and 5) the Yucatán subpopulation, which includes the eastern Yucatán Peninsula, Mexico (USFWS, 2003f).

Eighty percent of all loggerhead nesting that occurs in the southeastern U.S. takes place in Florida. Loggerhead sea turtle nesting occurs to a lesser extent on suitable beaches on islands off the Gulf states and along the entire North Carolina coastline, including New Hanover and Pender Counties where the study area is located (USFWS, 2003f). The Fish and Wildlife Service reported that although declines in nesting since the 1970's have been documented, no long-term trend data is available for the Northern subpopulation (USFWS, 2003f). Bolten and Witherington (2003) reported that studies on the Northern subpopulation from 1989 to 1998 illustrated a stable or declining population trend.

Loggerhead nesting data for the study area on Figure Eight Island, North Carolina has been recorded since 2001 with an average of 11.7 nests per year. Table 4.6 includes the number of loggerhead sea turtle nests that were documented between 2001 and 2010 for the study area located on Figure Eight Island and Hutaff Island, North Carolina (Webster, pers. comm., 2011; Godfrey, pers. comm., 2011; Golder, pers. comm., 2008). Figures 4.11 - 4.20 depict the distribution of these nests along the beaches within and in proximity of the Permit Area. Godfrey (pers. comm.) 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.

Table 4.6. Number of Loggerhead Sea Turtle Nests Documented in defined Permit Area, Figure Eight Island, NC, 2001 to 2007 (Godfrey, pers. comm., 2011; Webster, pers. comm., 2011) and Hutaff Island, NC, 2005 to 2007 (Golder, 2008)

Loggerhead Sea Turtle (*Caretta caretta*)		
Year	Figure Eight Island	Hutaff Island
2001	5	5
2002	9	NA
2003	31	NA
2004	9	NA
2005	11	4
2006	6	12
2007	5	0
2008	22	9
2009	5	2
2010	13	11

NA – Historic data for the period of 2002 to 2004, for Hutaff Island is unavailable.

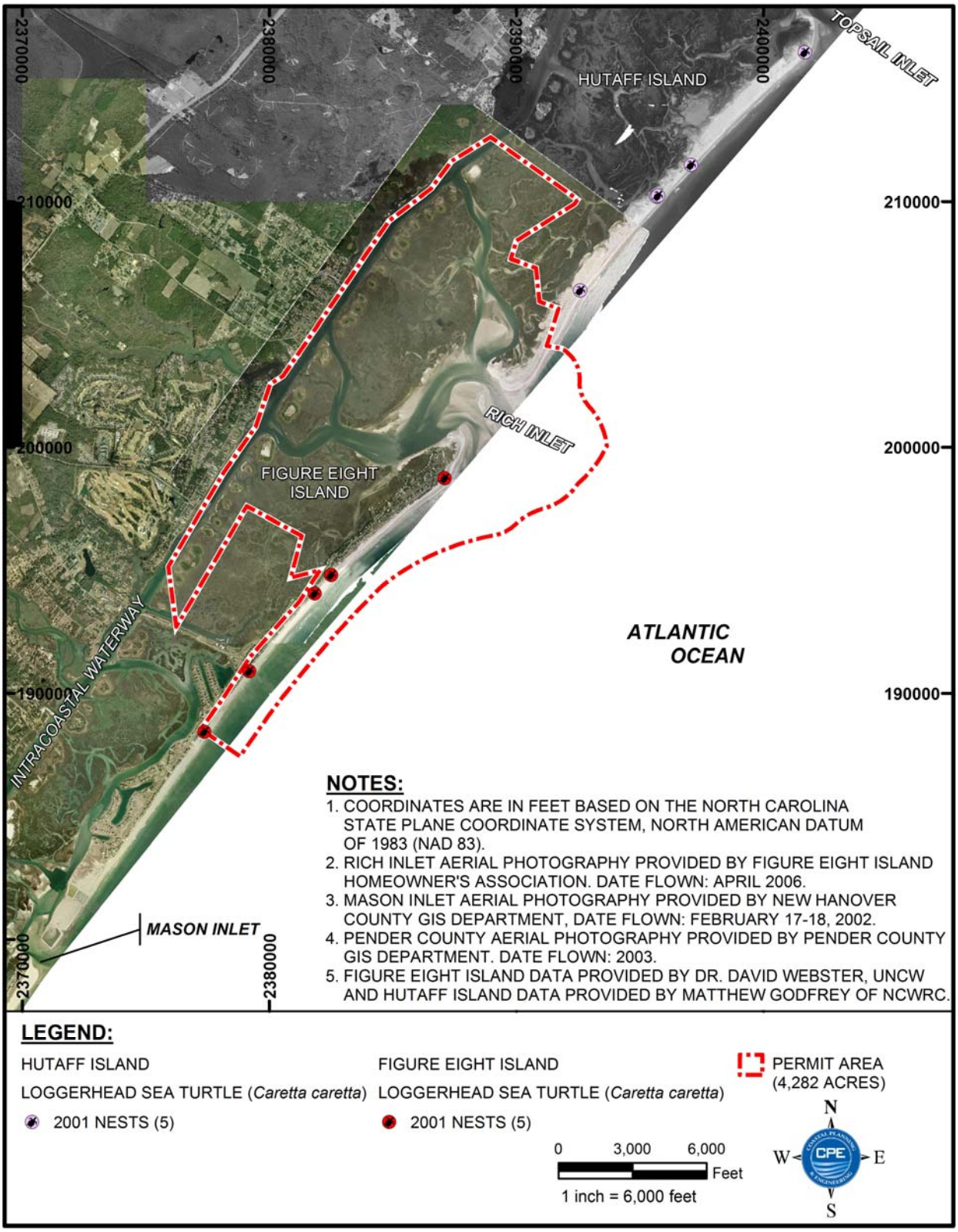


Figure 4.11. 2001 Loggerhead sea turtle nests within the Permit Area

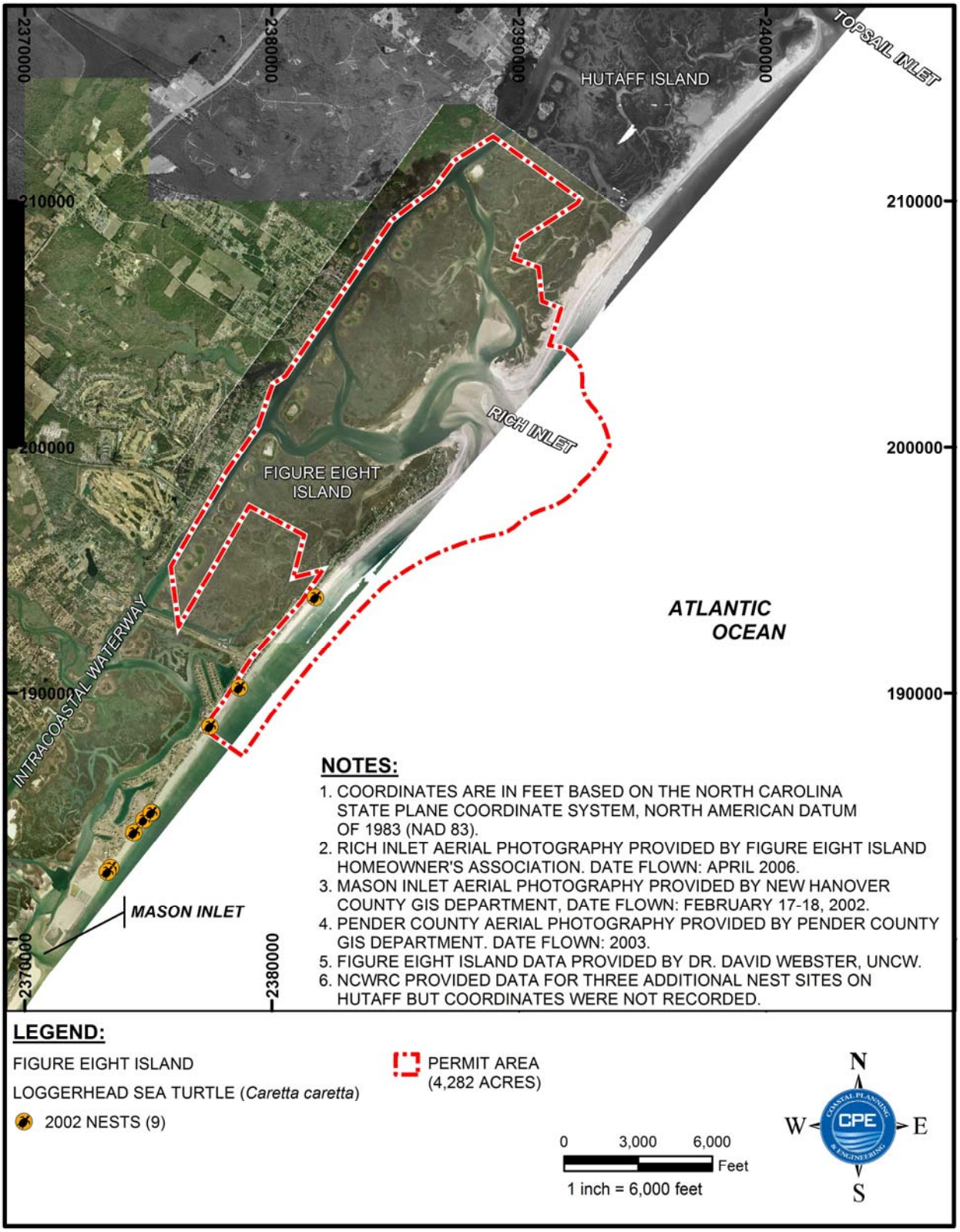


Figure 4.12. 2002 Loggerhead Sea Turtle Nests within the Permit Area. Note that additional nests were observed on Hutaff, however coordinates were not accurately recorded.

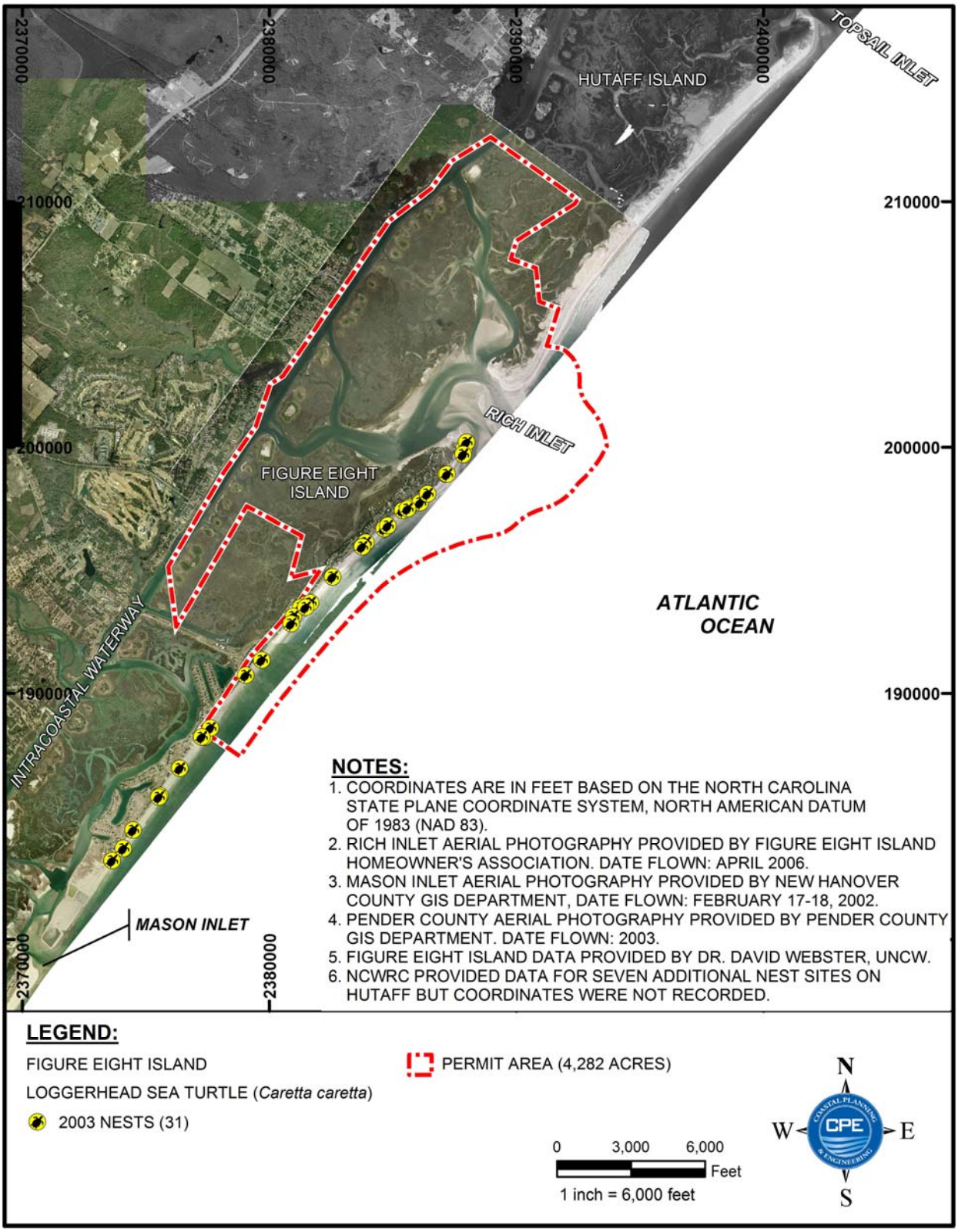


Figure 4.13. 2003 Loggerhead Sea Turtle Nests within the Permit Area. Note that additional nests were observed on Hutaff, however coordinates were not accurately recorded.

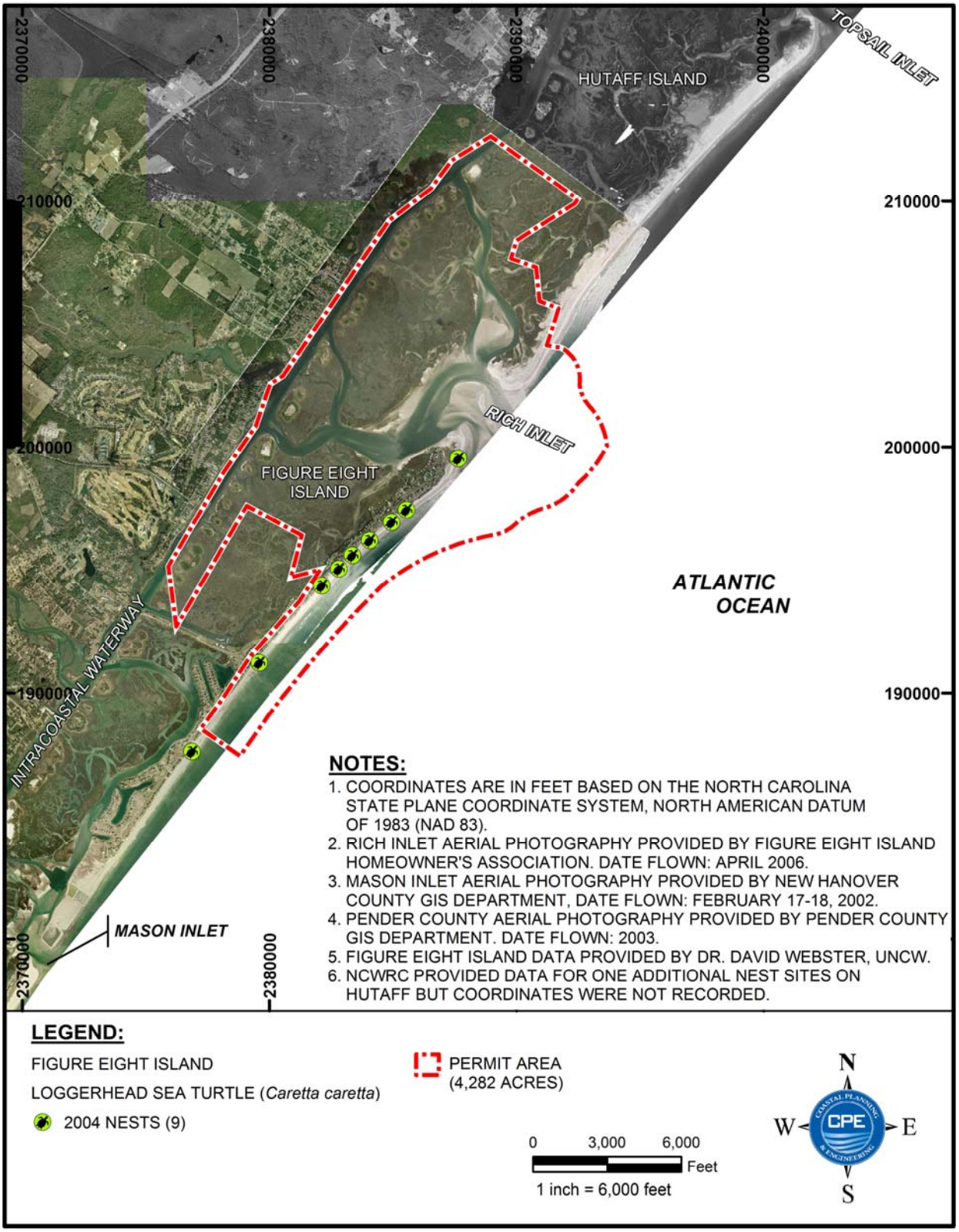


Figure 4.14. 2004 Loggerhead Sea Turtle Nests within the Permit Area. Note that additional nests were observed on Hutaff, however coordinates were not accurately recorded.

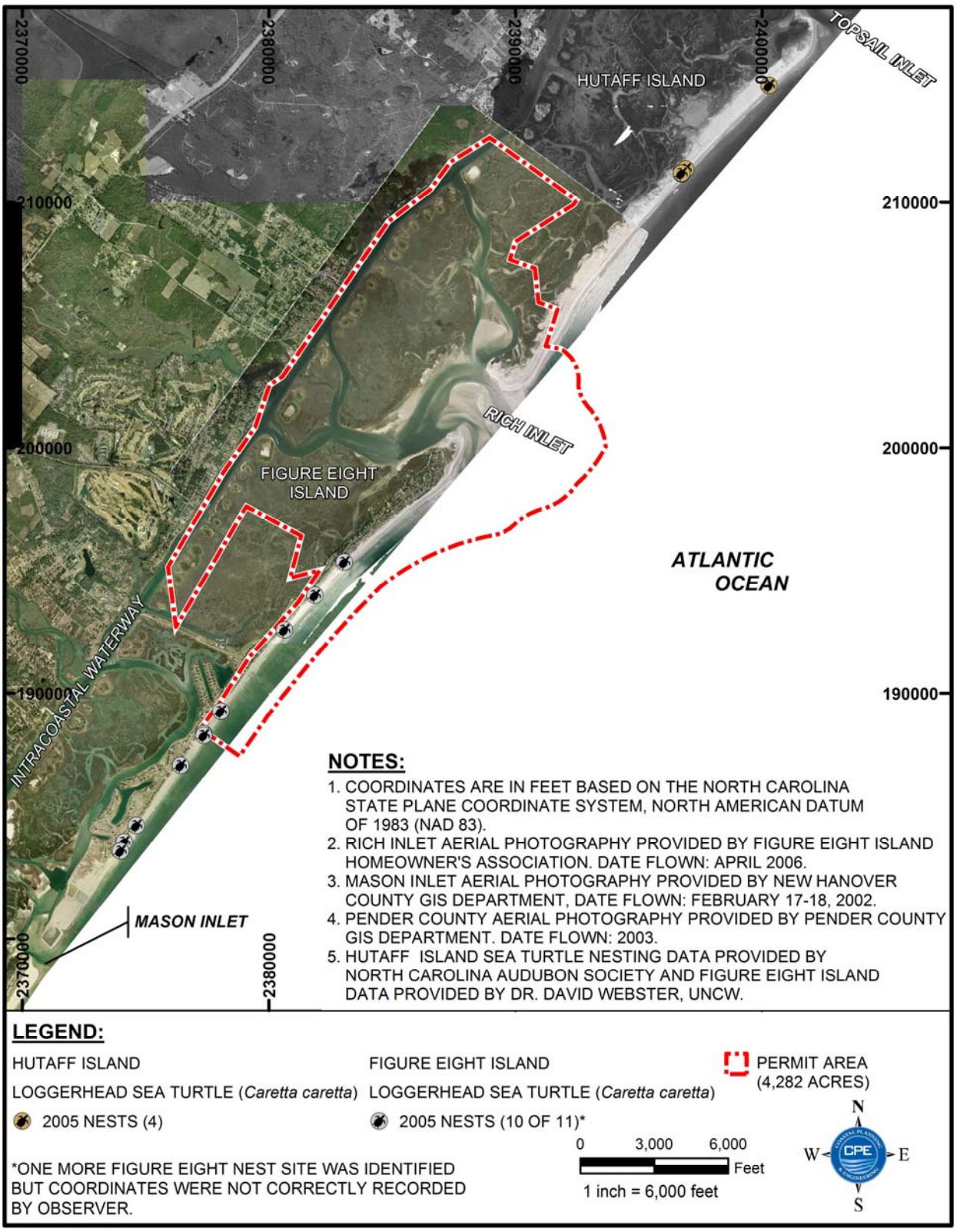


Figure 4.15. 2005 Loggerhead Sea Turtle Nests within the Permit Area

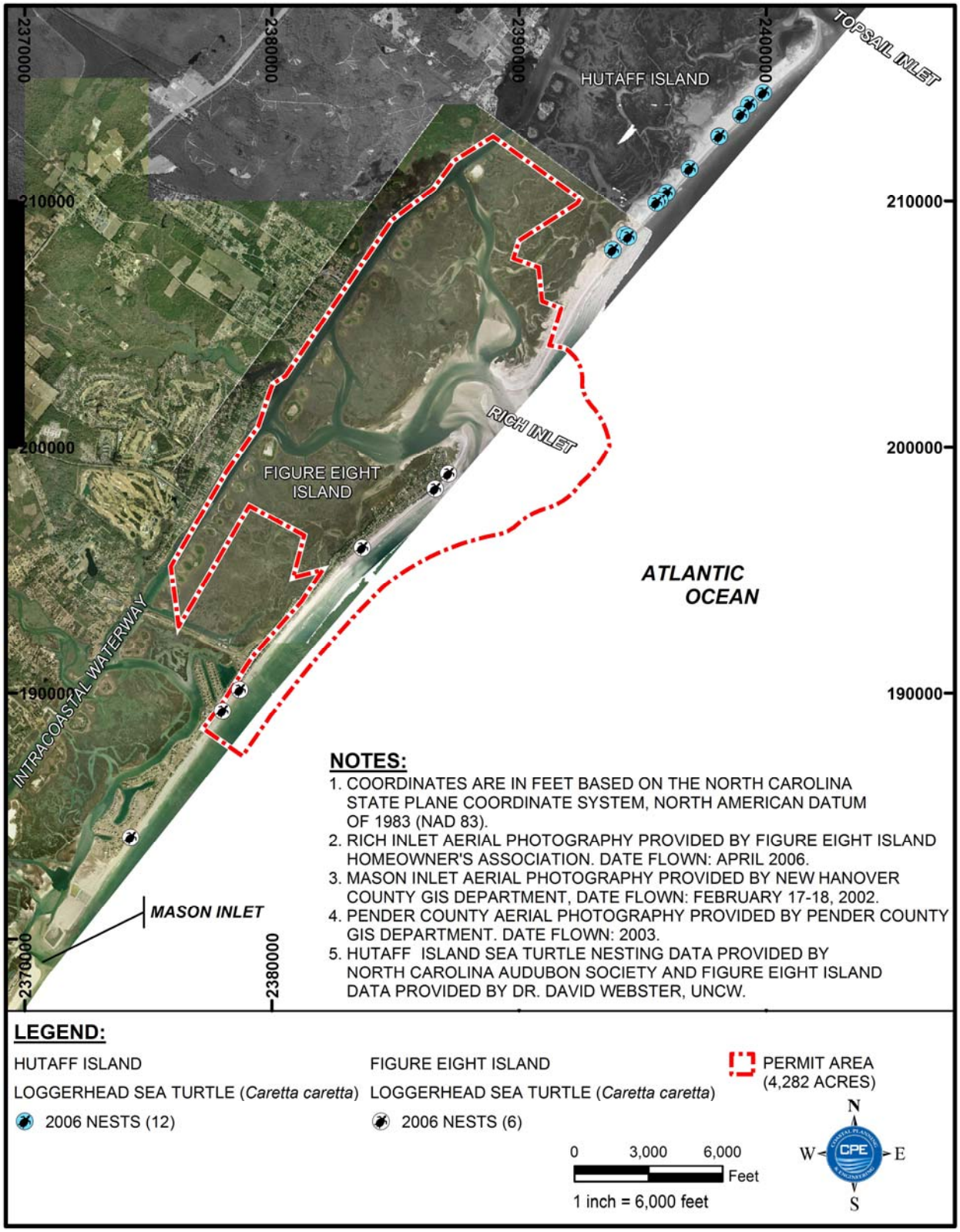


Figure 4.16. 2006 Loggerhead Sea Turtle Nests within the Permit Area

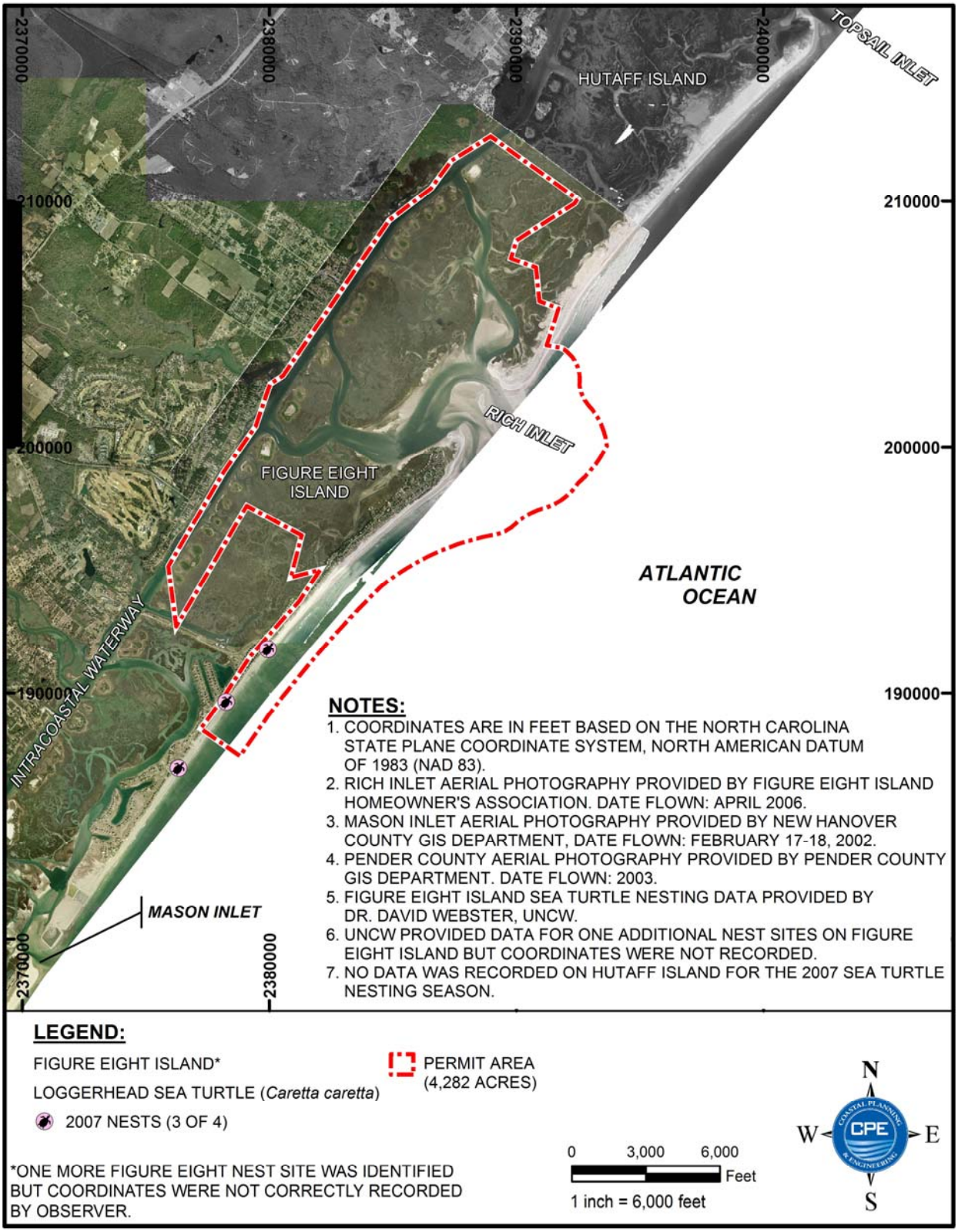


Figure 4.17. 2007 Loggerhead Sea Turtle Nests within the Permit Area. Note that additional nests were observed on Hutaff, however coordinates were not accurately recorded.

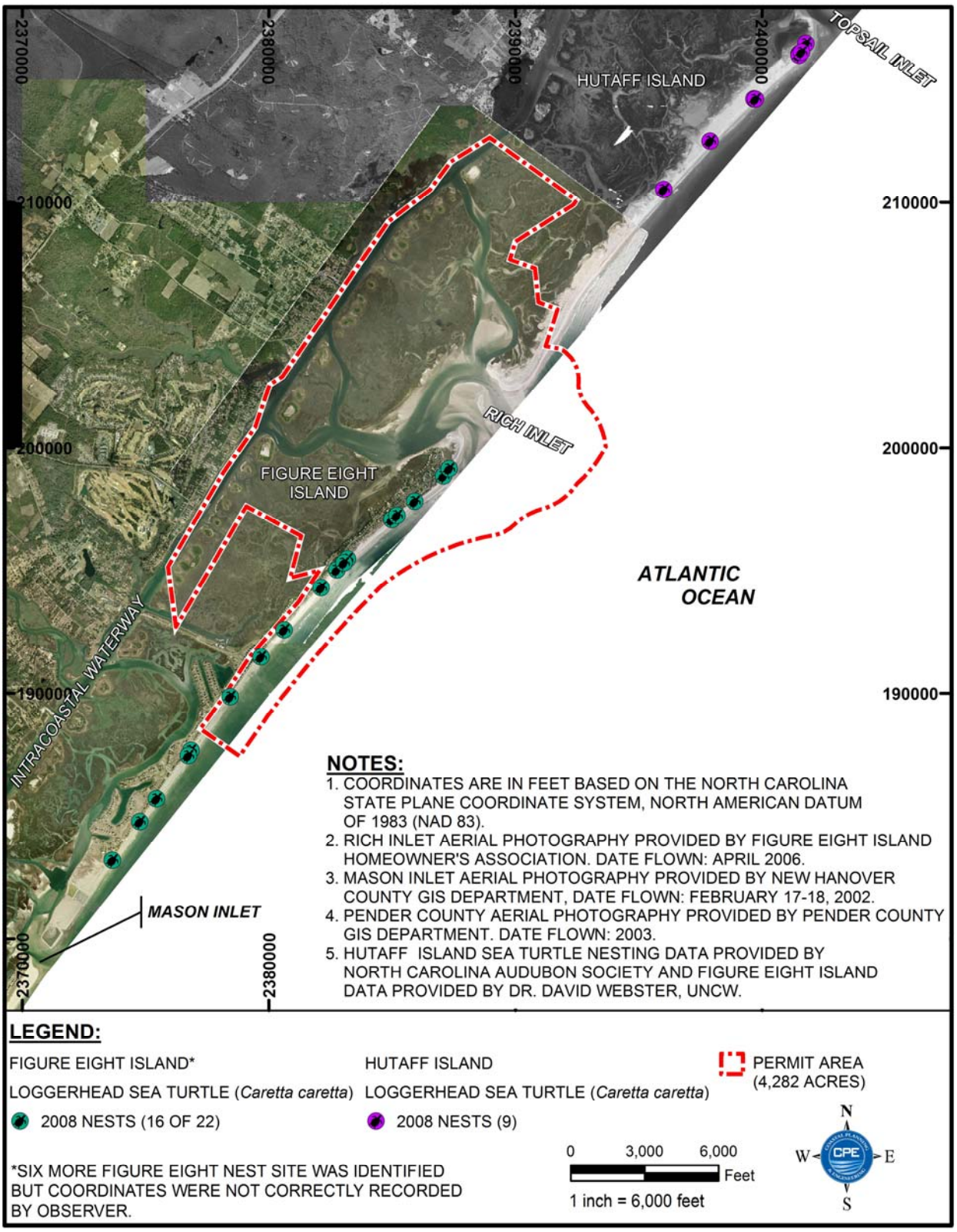


Figure 4.18. 2008 Loggerhead Sea Turtle Nests within the Permit Area

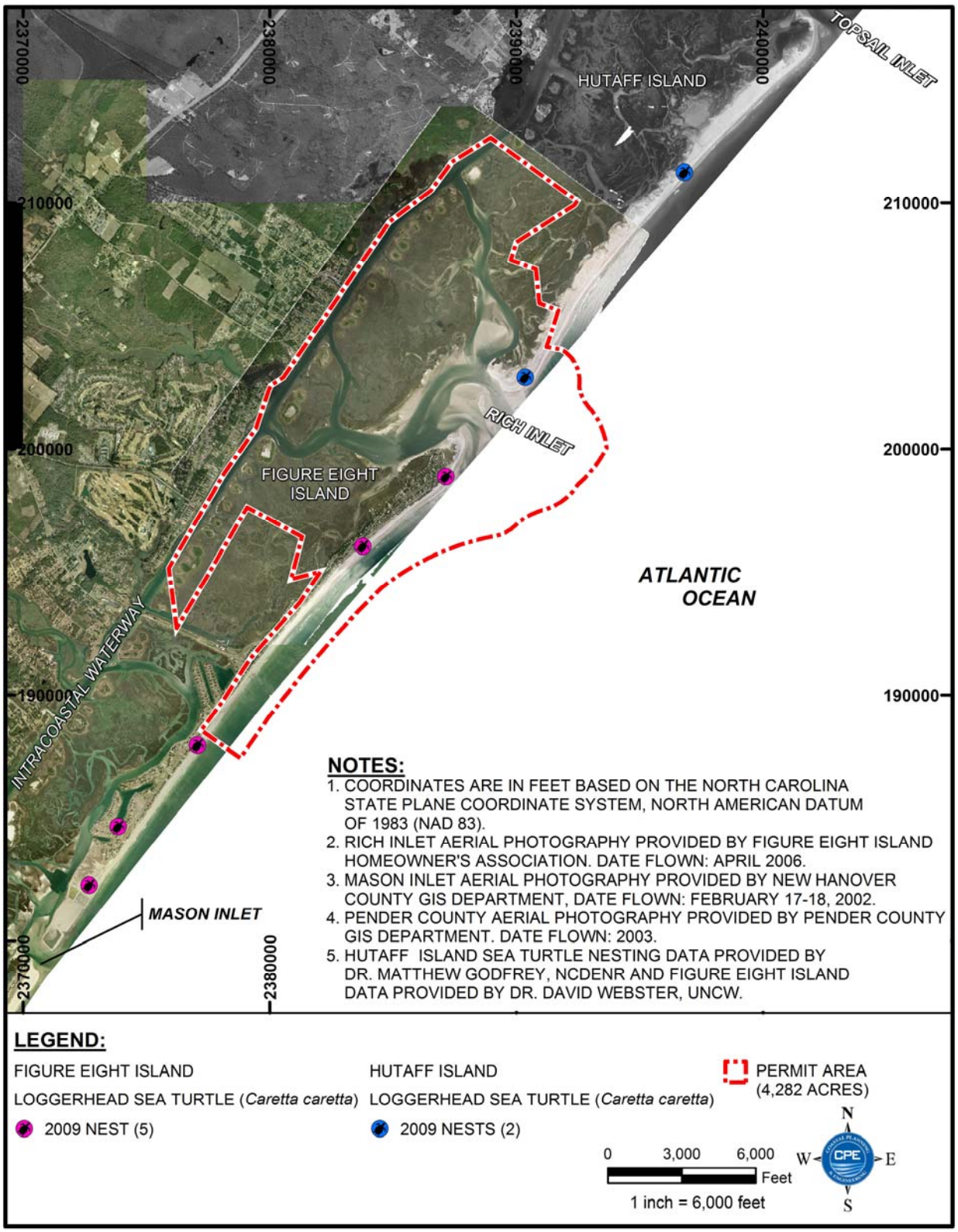


Figure 4.19. 2009 Loggerhead Sea Turtle Nests within the Permit Area

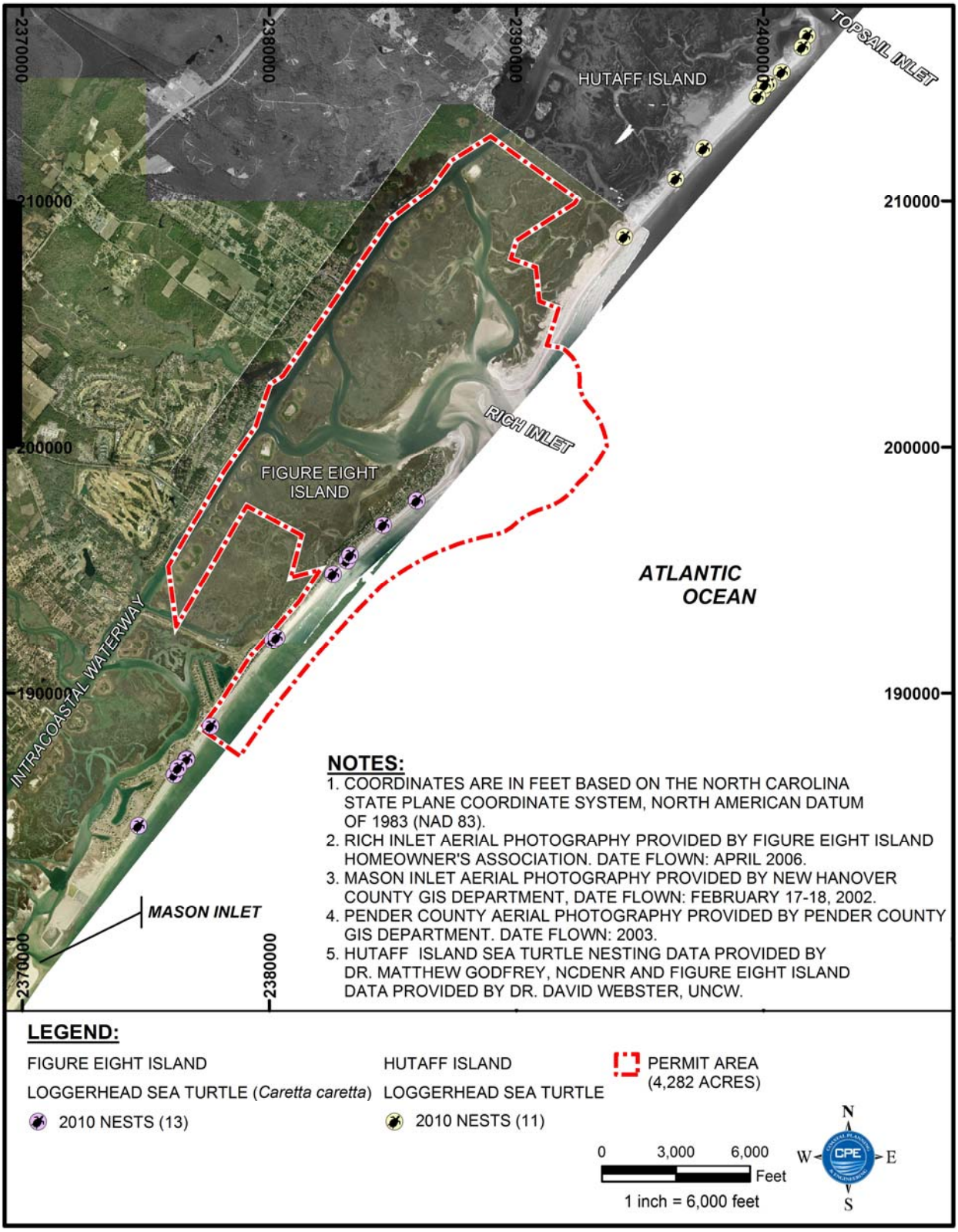


Figure 4.20. 2010 Loggerhead Sea Turtle Nests within the Permit Area

2. Terrapins

Carolina diamondback terrapin

The Carolina diamondback terrapin (*Malaclemys terrapin centrata*) is State and federally listed as a Species of Special Concern. They are commonly found within the inshore waters of North Carolina. This subspecies ranges from Cape Hatteras to northeastern Florida and tolerates a wide range of salinities (Robinson and Dunson, 1975). They are the only North American turtle species native to brackish waters and are commonly found in salt marshes, impoundments, tidal creeks, lagoons and mud flats. These areas serve as central feeding grounds for this species throughout most of the year. Carolina diamondbacks are primarily carnivorous, feeding upon crabs, snails and nereid worms.

During the winter months, Carolina diamondback terrapins hibernate in the muddy burrows along the embankments of tidal creeks. Nesting typically occurs after the mating season in May. Females build nests in sandy substrates above the high tide mark during the months of May and June and eggs are left to incubate for 60 to 120 days depending upon temperature conditions within the nest (Martof *et al*., 1980). Unlike sea turtles, emergence takes place during the day and hatching diamondback terrapins move to the surrounding vegetation rather than out to sea. It has been reported that juvenile terrapins (2.5 to 7 mm [1 to 3 in]) spend their time out of water living beneath surface debris and matted *Spartina grasses*, rarely entering open water. Adult terrapins spend their summer months in full marine conditions and other times of the year are spent in submerged mud and brackish water (Davenport, 1992).

The NC WRC has compiled numerous sightings of the Carolina diamondback terrapin in coastal New Hanover County, particularly in the area of Wrightsville Beach southward. There has been one recorded sighting on Hutaff Island in July of 1981 (LeGrand, pers. comm.). Despite the paucity of data from this area, the marshes on the sound side of Figure Eight Island and Hutaff Island provide habitat for the Carolina diamondback terrapin.

B. Mammals

1. West Indian Manatees

West Indian manatee

The West Indian manatee (*Trichechus manatus*) is listed as a federally protected species under the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972. The average size of an adult manatee is 10 feet, weighing approximately 2,200 lbs and typically referred to as the "sea cow".

West Indian Manatees are rare visitors to the Figure Eight Island area, however, recent manatee sightings have been reported in the Atlantic Intracoastal Waterway approximately 50-60 miles north of Figure Eight Island including observations north of State Highway 101,

July 2000; Beaufort waterfront and near Calico Creek, August 1999; Hammocks Beach State Park, June 1998; Sportsman Pier in Atlantic Beach, August 1994; US Coast Guard Station at Fort Macon, August 1994; Barden Inlet, November 1992; Peletier Creek, October 1990; and the west end of Shackleford Banks, August 1983. All of these observations occurred in Carteret County. Though none of these sightings occurred within the project vicinity, it is likely that manatees transit through the region since sightings occurred north and south of Figure Eight Island. Due to a lack of existing literature on the number of manatees utilizing the coastal waters of North Carolina, it is difficult to determine the number of manatees utilizing the nearshore waters of the Cape Fear region and the study area.

2. Whales

Blue, finback, humpback, North Atlantic right, sei, and sperm whales all occur infrequently in the ocean off the coast of North Carolina. Of these, only the North Atlantic Right (NARW) and the humpback whale routinely come close enough inshore to encounter the Permit Area, therefore the following discussion will only consider these two species in greater detail.

- *Humpback Whales*

Though other whale species sometimes occur off the coast of North Carolina, only the humpback whale and the right whale regularly come close enough inshore to encounter the study area. Both species are federally listed as endangered.

Humpback whale

Humpback whales (*Megaptera novaeangliae*) were listed as federally endangered throughout their range on June 2, 1970 under the Endangered Species Act and are considered "depleted" under the Marine Mammal Protection Act. The North Atlantic population of the humpback whale is estimated at 10,600 individuals (Waring et al., 1999), however the minimum population estimates for the Gulf of Maine stock is 647 individuals (NMFS, 1991a).

Humpbacks are found in protected waters over shallow bars and shelf waters, which are used for breeding and feeding. They migrate towards the poles in the summer and toward the tropics in the winter to breeding and birthing grounds. Humpbacks visit the North Carolina coast during the migratory season, especially between the months of December and April (Conant, 1993). Migrating humpbacks can be found nearshore, but probably migrate well offshore of the study area to their principal wintering range (NMFS, 1991a). On December 6, 2011, a 30 foot humpback whale was sited inshore in proximity to Masonboro Inlet, approximately 7 miles south of the Permit Area.

- *Right Whales*

Right whale and calf

The right whale (*Baleana glacialis*) is considered the world's most endangered large whale, with a total population of only around 300 individuals, and recent models predict this population will be extinct in less than 200 years (NMFS, 2006). The North Atlantic right whale utilizes six (6) major habitats or congregation areas including the coastal waters of the southeastern United States, the Great South Channel, Georges Bank/Gulf of Maine, Cape Cod and Massachusetts Bays, the Bay of Fundy, and the Scotian Shelf. The southeastern United States (Charleston, SC to the east coast of Florida) is considered Critical Habitat for the right whale because of these calving grounds (NMFS, 1991b). A Critical Habitat designation recognizes specific areas "that are essential to the conservation of a listed species, and that may require species management considerations or protection". During late winter and early spring, right whales begin moving north past the North Carolina coast (this includes cow/calf pairs and others wintering south of Cape Hatteras). Southerly migration to wintering areas south of Cape Hatteras begins as early as October (NMFS, 1991b). Right whales have been documented along the North Carolina coast between December and April with the majority of sightings reported between mid to late March. It is unclear as to the frequency with which right whales occur in offshore waters in the southeastern United States (NMFS, 1991b). The Right Whale Program of the New England Aquarium reported that 93% of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Slay, 1993). Typically, when spotted, right whales are observed very close to the shoreline only a few hundred meters offshore (Schmidly, 1981).

C. Fish

1. Shortnose Sturgeon

Shortnose Sturgeon

The shortnose sturgeon, *Acipenser brevirostrum*, was listed as endangered on March 11, 1967 under the Endangered Species Preservation Act of 1966 (a predecessor to the Endangered Species Act of 1973). NMFS later assumed jurisdiction for shortnose sturgeon under a 1974 government reorganization plan (38 FR 41370) (NOAA, 2007). Shortnose sturgeon is the smallest of the three sturgeon species that are found in eastern North America, rarely exceeding a length of 1.1 m (3.5 ft) and a weight of 6.4 kg (14 lbs) (NYSDEC, 2007). Shortnose sturgeon are bottom feeders, typically feeding on crustaceans, insect larvae, worms, mollusks, and some plants (NMFS, 1998). They appear to feed in either freshwater riverine habitats or near the freshwater/saltwater interface. This species is anadromous, primarily utilizing riverine and estuarine habitats, migrating

between freshwater and mesohaline river reaches. Spawning occurs in upper, freshwater areas, typically in January and February, while feeding and overwintering activities may occur in both fresh and saline habitats. Aside from seasonal migrations to estuarine waters, this species rarely occurs in the marine environment (NMFS, 1998; NCWRC, 2007; USFWS, 2007e).

The shortnose sturgeon inhabits lower sections of rivers and coastal waters along the Atlantic coast from the St. John River in New Brunswick, Canada to the St. Johns River, Florida (NOAA, 2007). The NMFS federal recovery plan (1998) for the endangered shortnose sturgeon identifies 19 distinct population segments, each defined as a river/estuarine system in which these fish have been captured within the generation time of the species (30 years). This species is significantly more common in northern portions of its range than it is in the south. Shortnose sturgeon are found in rivers, estuaries, and the sea, but populations are most often confined to natal rivers and estuaries (NMFS, 1998). Those shortnose sturgeon captured in the ocean are usually taken close to shore, in high salinity environments; there are no records of shortnose sturgeon in the NMFS database for the northeast offshore bottom trawl survey (NMFS, 1998).

There are few confirmed historical reports of shortnose sturgeon captures. Because fishermen and scientists often confused shortnose sturgeon with Atlantic sturgeon, there are no reliable estimates of historical population sizes (NMFS, 1998). There are several reports of shortnose sturgeon taken in North Carolina in the early 1800s, but the distribution and status of this species has not been fully documented in North Carolina. No shortnose sturgeon were reported in North Carolina waters between 1881 and 1987. Since then, several shortnose sturgeon have been caught in the Brunswick and Cape Fear rivers by commercial fishermen, a single fish was caught in the Pee Dee River, and it is now believed that a shortnose sturgeon population may also exist in western Albermarle Sound (NCWRC, 2007). With this discovery, the species is once again considered to be a part of the state's fauna; however, because of the lack of suitable freshwater spawning areas in the proposed project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults (NMFS, 1998).

2. Atlantic Sturgeon

In 2009, the Natural Resources Defense Council (NRDC) petitioned NMFS to list the Atlantic sturgeon (*Acipenser oxyrinchus*) under the Endangered Species Act of 1973 (ESA). As a result of the petition, the Carolina Distinct Population Segment (DSP) for Atlantic sturgeon has been designated as endangered under the ESA. Atlantic sturgeon are similar in appearance to shortnose sturgeon (*Acipenser brevirostrum*), but can be distinguished by their larger size, smaller mouth, different snout shape, and scutes (NMFS, 2011). The Atlantic sturgeon is a long-lived, estuarine dependent, anadromous fish. They are benthic feeders and typically forage on invertebrates including crustaceans, worms, and mollusks. Atlantic sturgeon can grow to approximately 14 feet (4.3 m) long and can weigh up to 800 lbs (370 kg) (NMFS, 2011). They are bluish-black or olive brown dorsally (on their back) with paler sides and a white belly. Spawning adults migrate upriver in spring, beginning in February-March in the south, April-May in the mid-Atlantic, and May-June in Canadian waters. In some areas, a small spawning migration may also occur in the fall.

Spawning occurs in flowing water between the salt front and fall line of large rivers (NMFS, 2011). Atlantic sturgeon spawning intervals range from 1 to 5 years for males and 2 to 5 years for females (NMFS, 2011).

Adults range from Hamilton Inlet, Labrador (Scott and Scott, 1988) south to the St. Johns River in Florida (Vladykov and Greeley 1963). Following spawning, males may remain in the river or lower estuary until the fall; females typically exit the rivers within four to six weeks. Juveniles move downstream and inhabit brackish waters for a few months and when they reach a size of about 30 to 36 inches (76-92 cm) they move into nearshore coastal waters (Smith, 1985).

Tagging data indicates that these immature Atlantic sturgeon travel widely once they emigrate from their natal (birth) rivers. Although Atlantic sturgeon are regularly caught in North Carolina, details of their distribution patterns and habitat preferences are unknown (Ross et al., 1988). Atlantic sturgeon have been reported in the Atlantic Ocean off South Carolina in months of low water temperatures (November–April) from nearshore to well offshore in depths up to 40 m (Collins and Smith, 1997). Moser et al. (1998) obtained sturgeon records from federal, private, and state surveys and documented use of nearshore Atlantic Ocean habitats from the North/South Carolina state line to off the mouth of Chesapeake Bay. Stein et al. (2004) found peak Atlantic sturgeon captures along the coast in 10–50 m depths. A study conducted between 1988 and 2006 examined the offshore distribution of Atlantic sturgeon based on incidental captures in winter tagging cruises conducted off the coasts of Virginia and North Carolina, including in and near extensive sand shoals adjacent to Oregon Inlet and Cape Hatteras. A total of 146 juvenile Atlantic sturgeon were captured during this investigation by bottom trawling in depths from 9.1 to 21.3m (Laney et al, 2007). Many of the fish were captured over sandy substrate which coincides with results observed in several other studies (Laney, 2007). In a tagging study conducted my Moser and Ross (1995), 100 juvenile Atlantic sturgeon were captured within the Cape Fear River. Of these, four fish were observed moving from the river into the ocean and were caught in gill nets set from shore at Carolina Beach, Kure Beach, and Ft. Fisher (Moser and Ross, 1995). Therefore, these fish are known to frequent nearshore waters in proximity to the Cape Fear River.

D. Plants

1. Seabeach Amaranth

Seabeach amaranth (*Amaranthus pumilus*) is federally and State-listed as threatened. It grows in low clumps comprised of sprawling, fleshy, reddish branches with dark leaves. The plant is profusely branched and generally grows to 1 m (39 in) in diameter. Historically, this species was found from Massachusetts to South Carolina, but according to USACE surveys between 1992 and 2004 (unpublished data), its distribution is now limited to North and South Carolina with some populations on Long Island, New York (USACE, 2006).

Seabeach amaranth

Seabeach amaranth is an effective sand binder, building dunes where it grows. A single large plant may be capable of creating a dune up to 60 cm high, containing 2 to 3 cu m of sand, although most are smaller (Weakley and Bucher, 1992). The plant is typically found at elevations from 0.2 m to 1.5 m (0.6 ft to 4.9 ft) above mean high tide (Weakly and Bucher, 1992). Seabeach amaranth appears to function in a relatively natural and dynamic manner, allowing it to occupy suitable habitat as it becomes available (USFWS, 1993).
Figure Eight Island has been surveyed by UNCW for seabeach amaranth from 2002 to 2010 (Webster, pers. comm., 2011) while Hutaff Island has been monitored by field representatives of the North Carolina Audubon Society (NCAS) between 2005 and 2010 (Mangiameli pers. comm., 2008; Suiter, pers. comm.). A total of 1,505 plants (ranging from 0 to 768 each year) have been recorded on Figure Eight Island (Table 4.7 and Figure 4.21 – 4.29) (Webster, pers. comm., 2011; Suiter, 2011). A total of 1,130 plants were found on Huaff Island, with observations ranging between 14 and 1,011 between years. Seabeach amaranth data does not exist for Hutaff Island prior to 2005 (Golder, 2007).

Seabeach amaranth experiences a great deal of natural population variability from one year to the next, as is evident by Dr. Webster's and NCAS survey results (Table 4.7). These natural fluctuations can be attributed to a number of factors, such as erosion, storms and seed dispersal.

Table 4.7. Figure Eight Island (Webster, pers. comm., 2011) and NCAS annual Seabeach amaranth data (2005 to 2007) on Hutaff Island, North Carolina (Mangiameli, 2008; Suiter pers. comm., 2011).

Year	Seabeach amaranth (*Amaranthus pumilus*)	
	Figure Eight Island	**Hutaff Island**
2002	72	No Data
2003	3	No Data
2004	656	No Data
2005	768	1011
2006	No Data	47
2007	2	21
2008	0	14
2009	0	19
2010	4	18
Totals	**1505**	**1130**

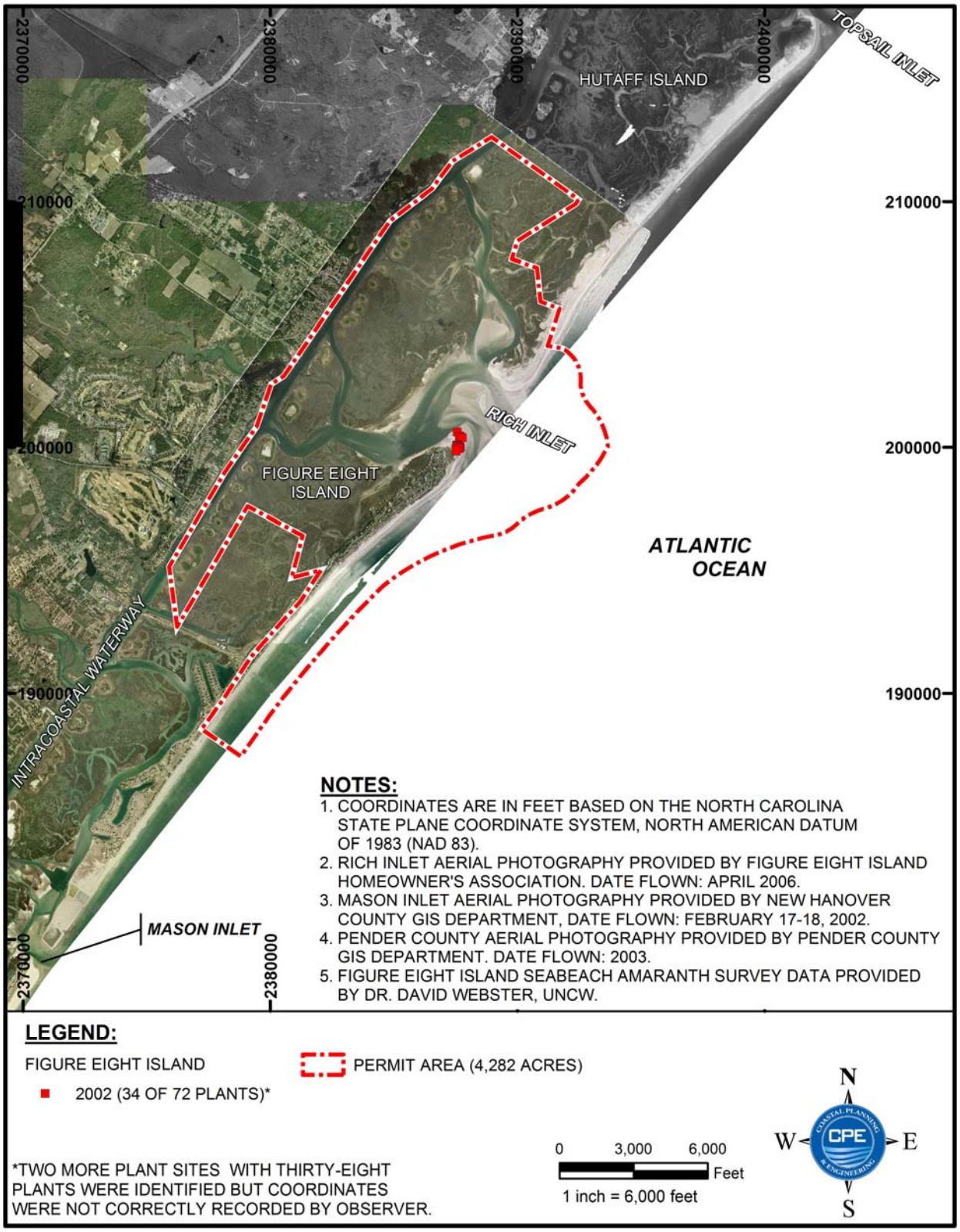


Figure 4.21. 2002 Seabeach amaranth distribution within the Permit Area

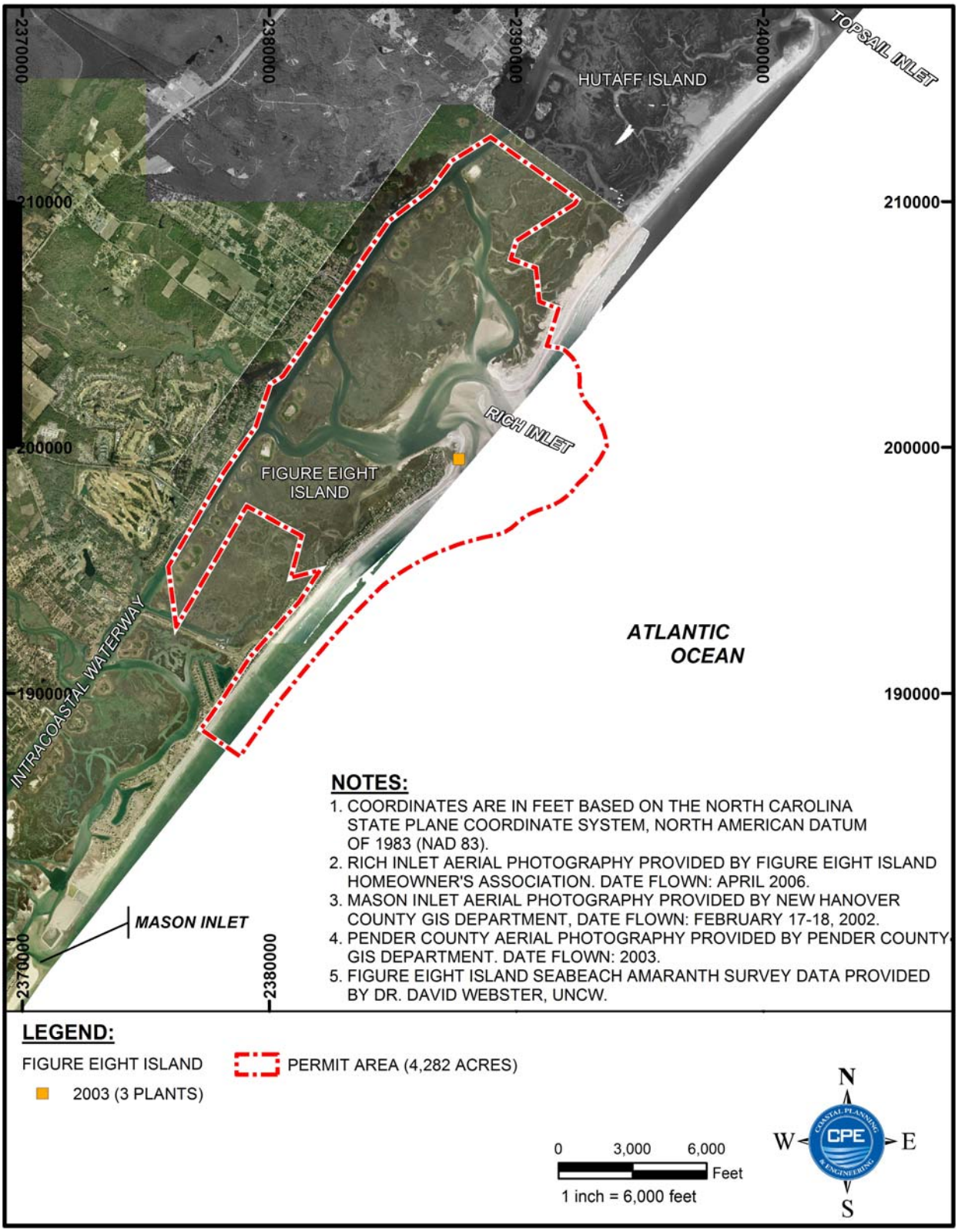


Figure 4.22. 2003 Seabeach amaranth distribution within the Permit Area

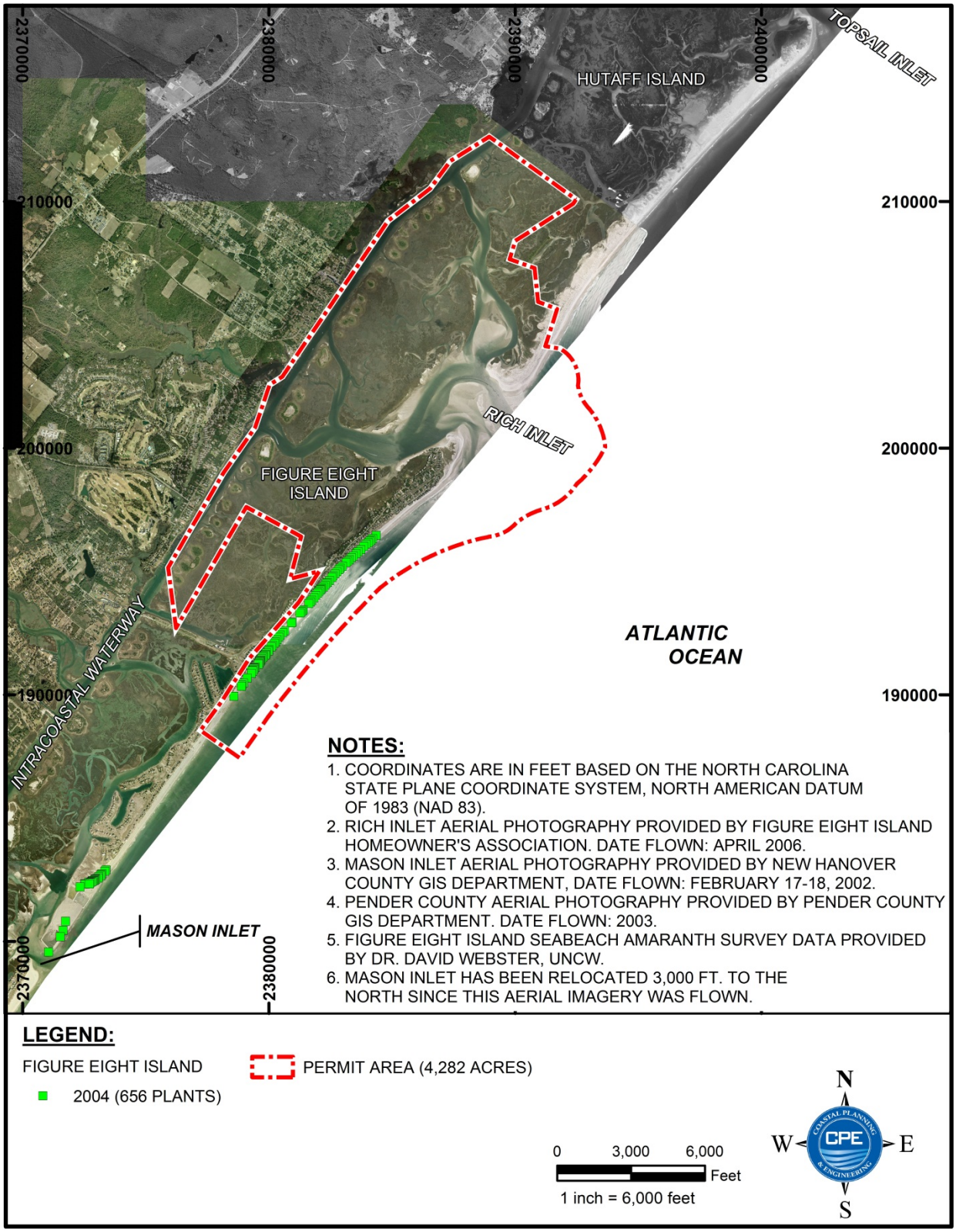


Figure 4.23. 2004 Seabeach amaranth distribution within the Permit Area

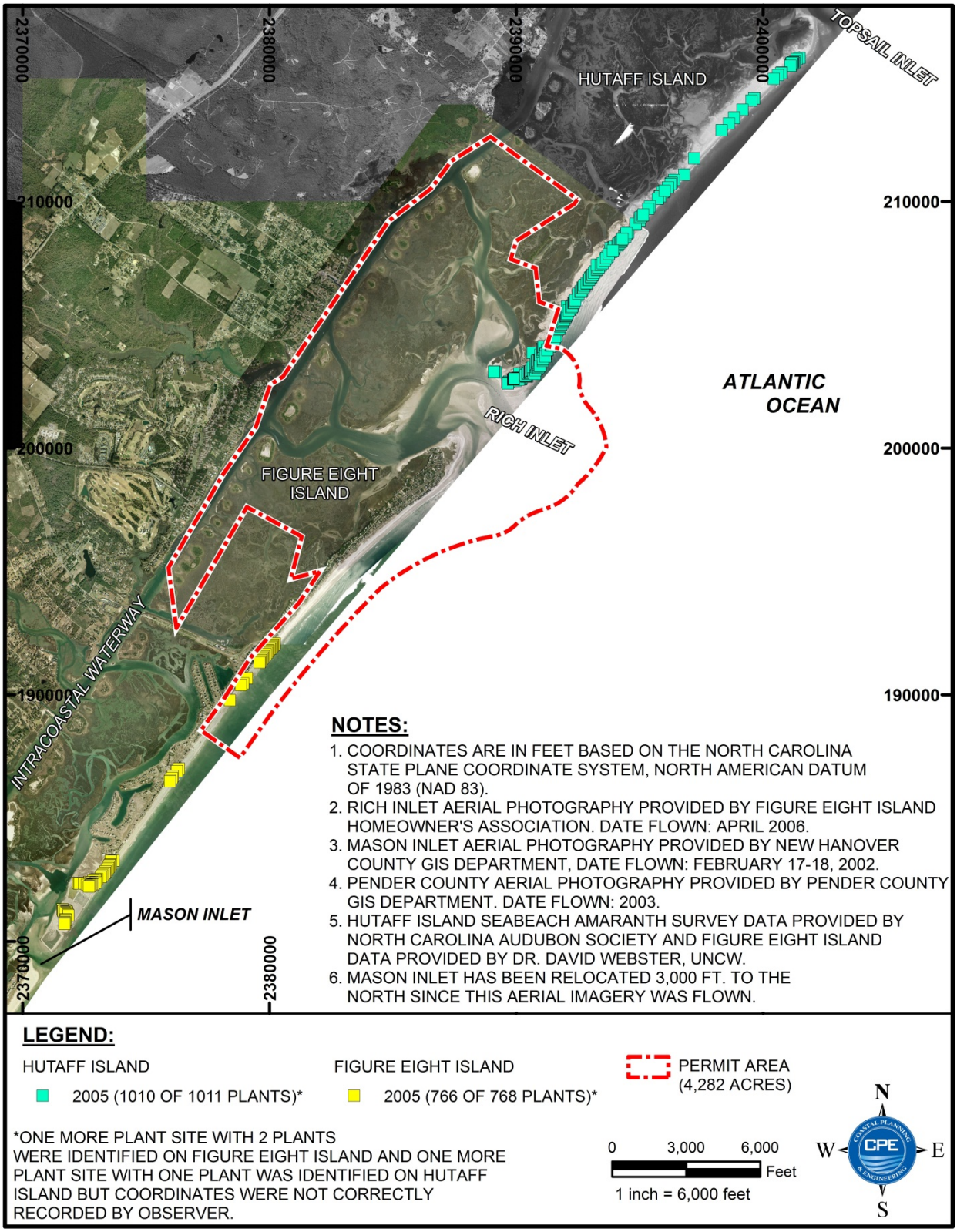


Figure 4.24. 2005 Seabeach amaranth distribution within the Permit Area

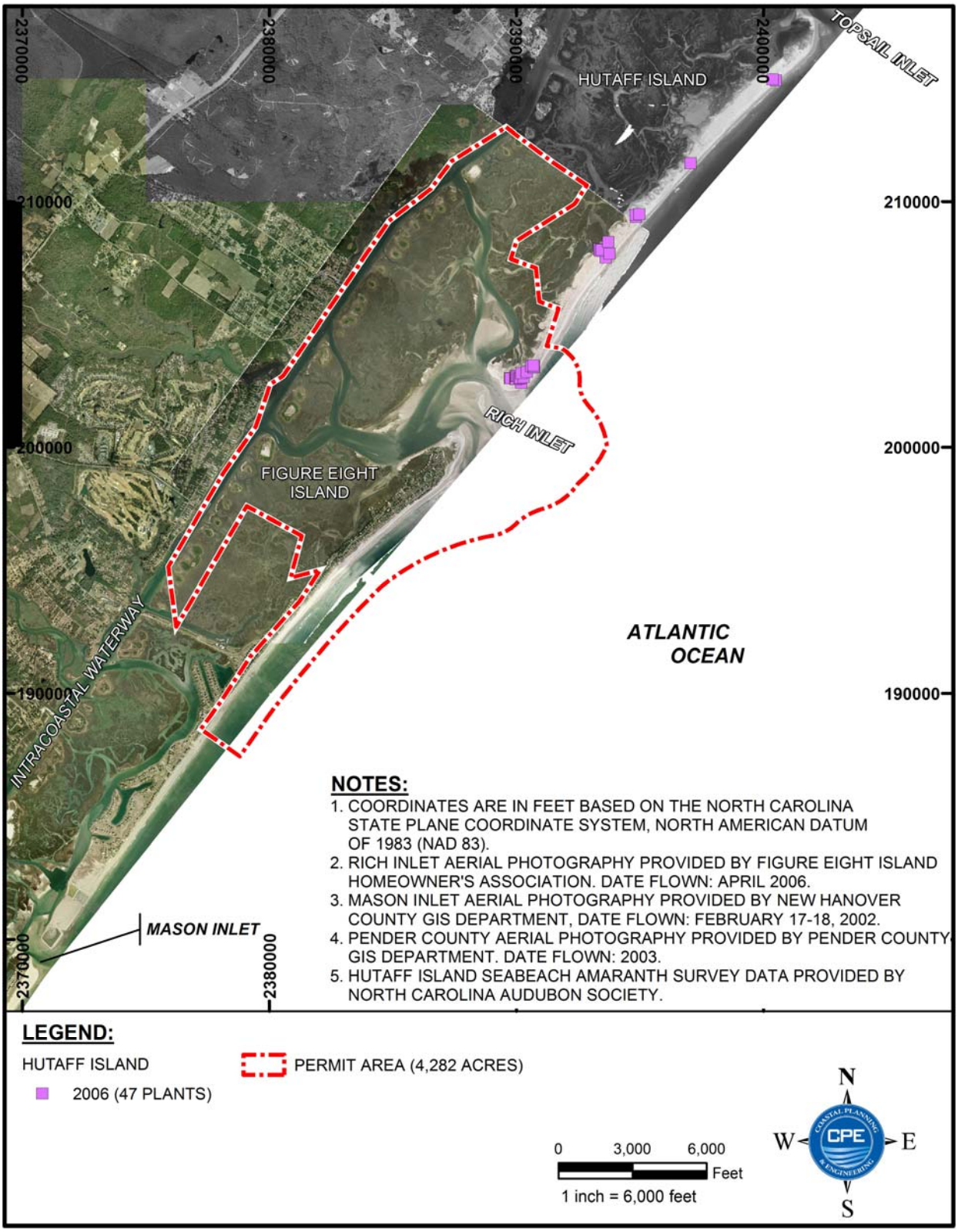


Figure 4.25. 2006 Seabeach amaranth distribution within the Permit Area

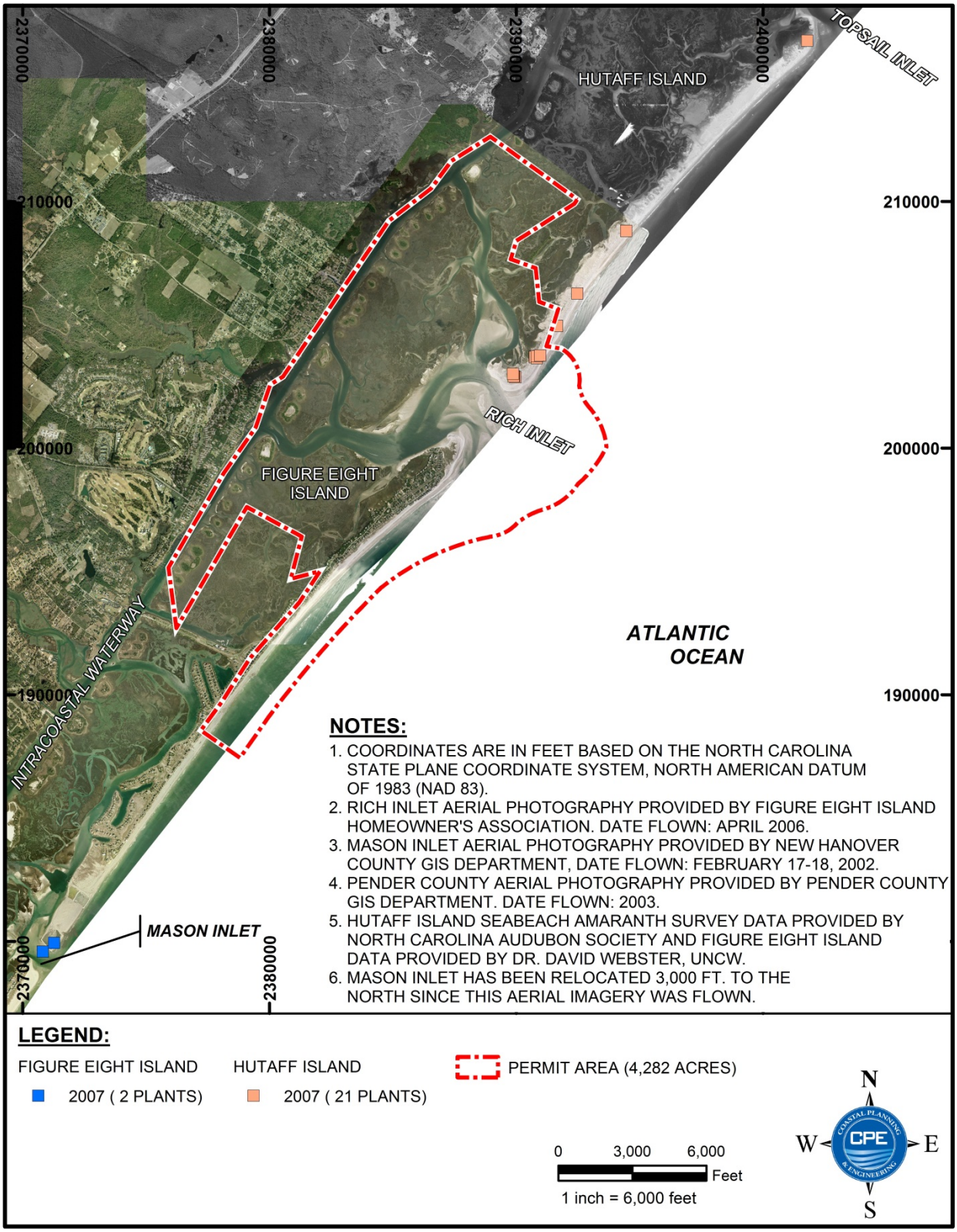


Figure 4.26. 2007 Seabeach amaranth distribution within the Permit Area

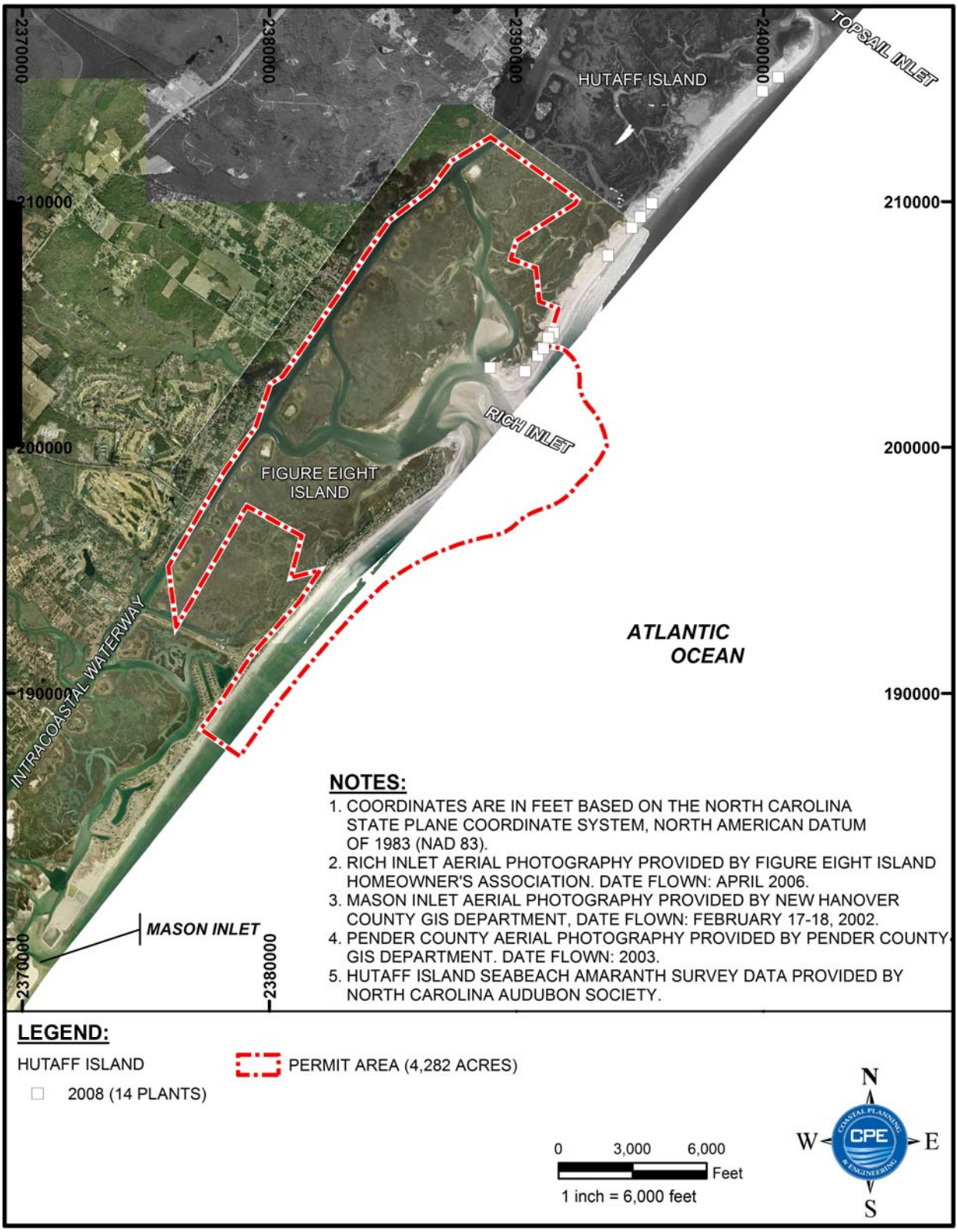


Figure 4.27. 2008 Seabeach amaranth distribution within the Permit Area

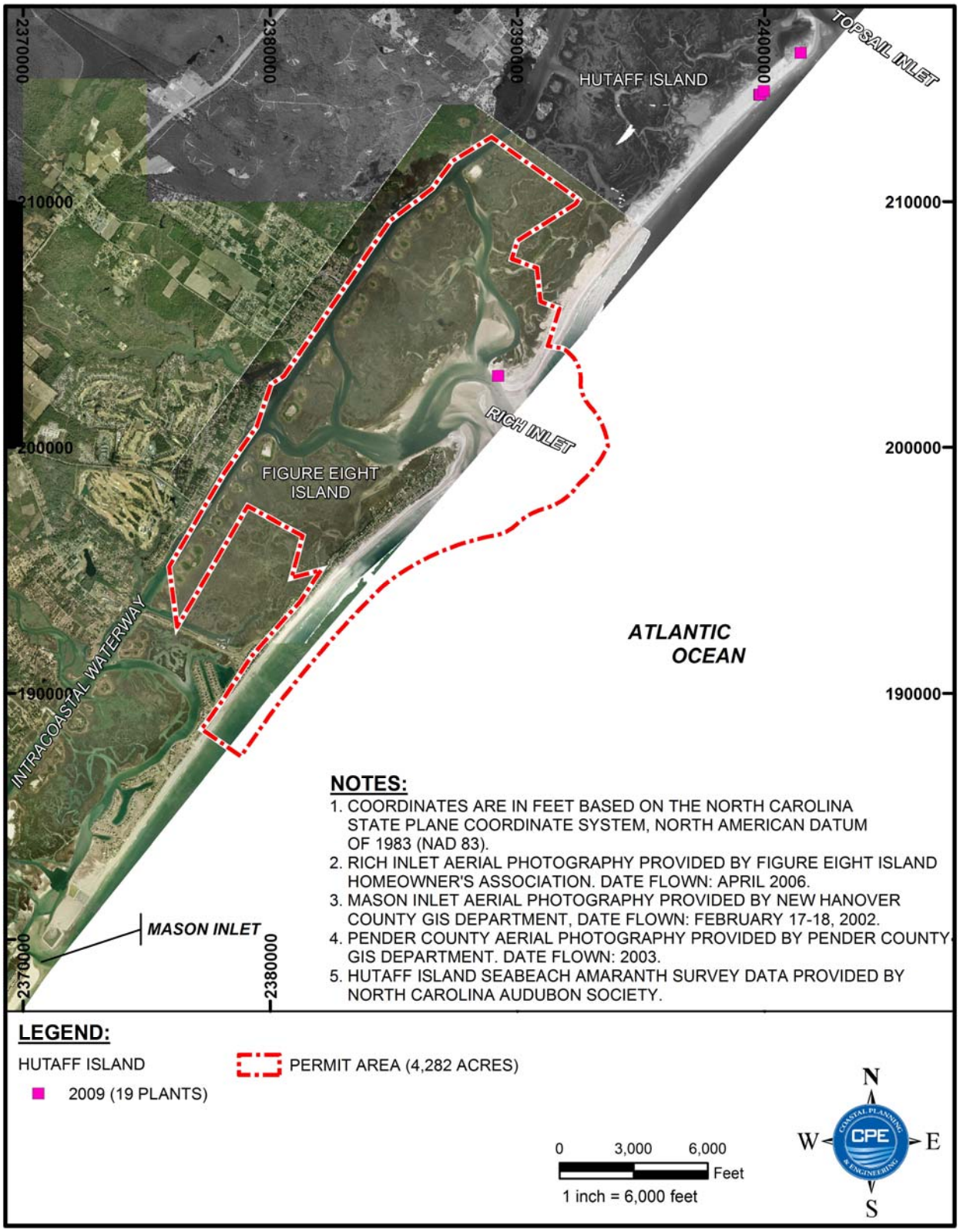


Figure 4.28. 2009 Seabeach amaranth distribution within the Permit Area. Note that more than one plant was observed at several sites.

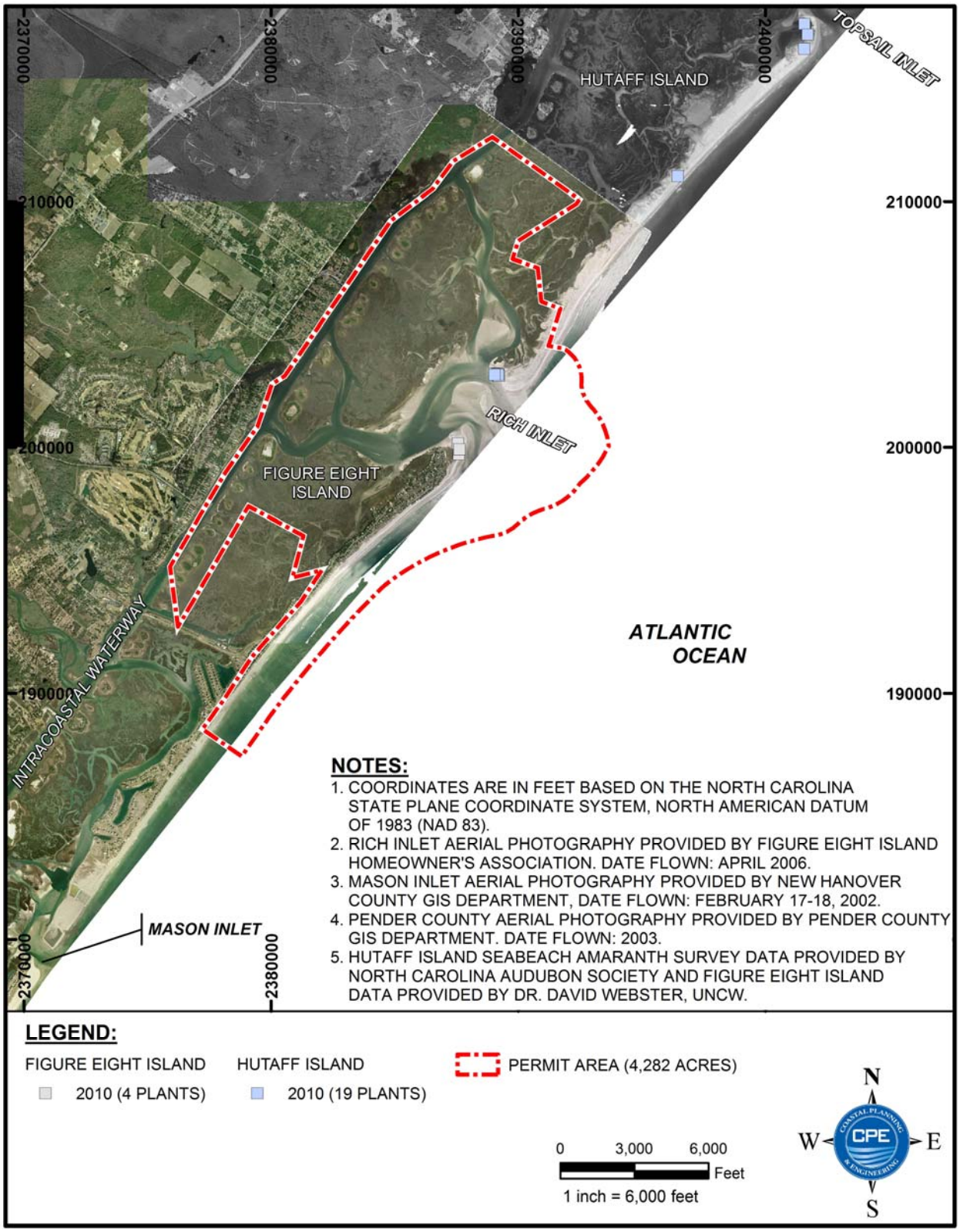


Figure 4.29. 2010 Seabeach amaranth distribution within the Permit Area.

E. Birds

The following section reviews and describes threatened and endangered bird species, both breeding and non-breeding, that have been documented within the Permit Area and/or within the vicinity of the project site. Bird species of special concern and of high conservation priority in North Carolina are also listed and discussed.

The North Carolina Wildlife Resource Commission and North Carolina Audubon have performed breeding surveys for colonial nesting waterbirds within proximity of the Permit Area on a regular basis since 1977. Specifically, surveys have been conducted within the north side of Mason's Inlet and the Southside of Rich Inlet, flanking Figure Eight Island. Surveys have also been conducted on Hutaff Island as well as the Southside of New Topsail Inlet, the northside of Rich Inlet, and Old Topsail Inlet. Surveys for breeding piping plovers have been conducted since 1989 at the same locations. Surveys for non-breeding piping plovers have been conducted in more recent years. These surveys include data from breeding and non-breeding seasons for several listed bird species as well as other shorebirds and waterbirds.

In 2011, researchers with UNCW conducted daily bird surveys on Figure Eight Island in between April 1 and April 14. These surveys occurred along the northern portion of the island between Nixon Channel and Inlet Hook Court, which are within the Permit Area. Surveys were performed at various times of the day and at various tidal stages. A total of 54 bird species were observed during the fifteen (15) surveys, including at least thirty (30) species per survey (Webster, pers. com.). The most commonly observed species were, in order, the Ring-billed gull, Double crested cormorant, Laughing gull, Herring gull, Least tern, and Brown pelican (Webster, pers. com).

1. Piping Plover

The piping plover (*Charadrius melodus*) was federally listed in 1986 under the Endangered Species Act of 1973, as amended with three separate breeding populations in North America: 1) the Atlantic Coast population (threatened), 2) the Northern Great Plains population (threatened), and 3) the Great Lakes population (endangered). Piping plovers are also listed as threatened throughout their wintering range (USFWS, 1996). All three populations migrate to the coastal shorelines of the South Atlantic, Gulf of Mexico and the beaches of the Caribbean Islands to winter (USFWS, 2007c).

Piping plover

The habitat for wintering piping plover is protected under a Critical Habitat listing as identified by the ESA. On July 10, 2002, 137 areas along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas were designated as Critical Habitat for wintering piping plover. Critical Habitat designation for North Carolina wintering piping plover includes Rich Inlet in Unit NC-11, which is described by the USFWS as follows (USFWS, 2001):

> *The entire area is privately owned. This unit extends southwest from 1.0 km (0.65 mi) northeast of MLLW of New Topsail Inlet on Topsail Island to 0.53 km (0.33 mi) southwest of MLLW of Rich Inlet on Figure Eight Island. It includes both Rich Inlet and New Topsail Inlet and the former Old Topsail Inlet. All land, including emergent sandbars, from MLLW on Atlantic Ocean and sound side to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur. In Topsail Sound, the unit stops as the entrance to tidal creeks become narrow and channelized.*

While overwintering piping plovers have Critical Habitat within the Permit Area, this species also nests in the region. Piping plovers nest in dry sand habitats above the high tide line along coastal beaches, spits, flats, barrier islands and other sparsely vegetated dune and beach environments, although they may utilize other shoreline habitats if these are not available. Their nests are comprised of sand and shell material making them well camouflaged, with an average clutch size of three to four eggs (USFWS, 1996).

In 1990 the USFWS (2008) counted fewer than 1,000 piping plover nests in the Atlantic Coast population (including Canada). By 1996, 1,348 breeding pairs were documented. The number of breeding pairs has continued to steadily increase, reaching 1,438 pairs in 2000 and 1,690 pairs in 2002 (USFWS, 2008). The number of piping plover breeding pairs in North Carolina decreased from 55 pairs in 1989 to 24 pairs in 2003. However, estimates indicate a slight increase occurred in breeding pairs to 37 in 2005 and 46 in 2006 (USFWS, 2008).

The North Carolina coastline is important to piping plovers since it provides habitat for wintering, breeding, and migration. Piping plovers have been documented arriving on their breeding grounds in North Carolina beginning as early as mid-March. By mid-July, adults and young may begin to depart for their wintering areas. The piping plover is present year round in North Carolina and utilizes the coastal habitats for foraging, roosting, nesting, wintering and migrating (Cameron pers. comm., 2007).

The UNCW, NCWRC, NCAS and partners have conducted piping plover surveys of the project area during various seasons since 1987. There are three areas that have been monitored, Figure Eight Island, Rich Inlet and Hutaff Island. Only one (1) breeding pair, observed in 1996, has been located on Figure Eight Island. Hutaff Island, however, appears to be an important breeding area based upon the annual observations of breeding pairs. Since 1989, the peak number of breeding pairs observed on Hutaff was five (5) (Cameron pers. comm., 2007).

Data collected within the Rich Inlet area includes observations of the ebb bar in Rich Inlet near the northern end of Figure Eight, bars in Nixon and Green Channels, and the southern tip of Hutaff Island. The exact location of individuals within this complex was not noted in the data set; however it is safe to assume that foraging occurred on the ebb bars during low tide. The greatest number of individuals noted in this area at one time was twenty one (21) during the fall migration in 2006 (Cameron pers. comm., 2007).

Despite the lack of regular monitoring during the non-breeding season, data suggests that the area around Rich Inlet is valuable for migrating and wintering piping plovers. Surveys conducted by North Carolina Wildlife Resources Commission (NCWRC) and their partners have observed approximately 192 individuals which included 31 breeding pairs between 2000 and 2007 surveys (Table 4.8) (Cameron pers. comm., 2007). The Cape Fear Audubon Society has provided raw data from piping plover surveys conducted between 2008 and 2011. A total of 3,039 individuals were observed during the 726 surveys completed during this time resulting in an average of 4.2 individual piping plovers per survey. The annual average number of piping plovers observed per survey ranged between 3.5 and 4.6 (Cape Fear Audubon Society, pers. comm., 2012). Based on the information provided, it is unknown how many individuals were observed foraging, resting, nesting, or flying over. Because the methodologies have not been provided at this time, additional results and analysis cannot be included herein.

In 2011, UNCW observed numerous piping plovers along the northern end of Figure Eight Island during a two week survey. Daily observations ranged from one (1) to nine (9) piping plovers (Webster, pers. comm., 2011) with an average of over five (5) per survey. No breeding pairs of piping plovers were observed on Figure Eight Island during the breeding season, however two nesting pairs were observed on Hutaff Island during breeding season (Schweitzer, pers. comm., 2011).

Table 4.8. Piping Plover Survey Data (1987-2007) for Figure Eight Island (Webster, pers. comm., 2011) & Hutaff Island (Mangiameli, 2007).

Year	Season	Number of birds	Number of breeding pairs
1987	Winter	0	
	Spring Migration	No Data	
	Breeding	No Data	No Data
	Fall Migration	No Data	
1988	Winter	No Data	
	Spring Migration	No Data	
	Breeding	No Data	No Data
	Fall Migration	No Data	
1989	Winter	8	
	Spring Migration	No Data	
	Breeding	0	0
	Fall Migration	1	
1990	Winter	9*	
	Spring Migration	0	
	Breeding	No Data	No Data
	Fall Migration	No Data	
1991	Winter	14*	
	Spring Migration	No Data	
	Breeding	0	0
	Fall Migration	No Data	
1992	Winter	No Data	
	Spring Migration	No Data	
	Breeding	No Data	No Data

Year	Season	Number of birds	Number of breeding pairs
	Fall Migration	No Data	
1993	Winter	No Data	
	Spring Migration	No Data	
	Breeding	No Data	No Data
	Fall Migration	No Data	
1994	Winter	No Data	
	Spring Migration	No Data	
	Breeding	0	0
	Fall Migration	No Data	
1995	Winter	No Data	
	Spring Migration	No Data	
	Breeding	No Data	No Data
	Fall Migration	No Data	
1996	Winter	16	
	Spring Migration	No Data	
	Breeding	6	3
	Fall Migration	No Data	
1997	Winter	19*	
	Spring Migration	No Data	
	Breeding	4	2
	Fall Migration	No Data	
1998	Winter	0	
	Spring Migration	No Data	
	Breeding	4	2
	Fall Migration	No Data	
1999	Winter	No Data	
	Spring Migration	No Data	
	Breeding	4	2
	Fall Migration	6	
2000	Winter	No Data	
	Spring Migration	No Data	
	Breeding	4	2
	Fall Migration	11*	
2001	Winter	18*	
	Spring Migration	9*	
	Breeding	5	2
	Fall Migration	19*	
2002	Winter	5*	
	Spring Migration	6*	
	Breeding	4	2
	Fall Migration	2*	
2003	Winter	4*	
	Spring Migration	3*	
	Breeding	10	5
	Fall Migration	2*	
2004	Winter	No Data	
	Spring Migration	No Data	
	Breeding	6	3

Year	Season	Number of birds	Number of breeding pairs
	Fall Migration	4*	
2005	Winter	No Data	
	Spring Migration	2*	
	Breeding	10	5
	Fall Migration	13*	
2006	Winter	2*	
	Spring Migration	8*	
	Breeding	14	7
	Fall Migration	21*	
2007	Winter	No Data	
	Spring Migration	No Data	
	Breeding	10	5
	Fall Migration	No Data	

* These values represent the greatest number of individuals observed during a single sampling event. This designation has been utilized for those years where sampling events were conducted often and multiple counts of the same individuals in a single season are likely. This method of data reporting may lead to an underestimation of individuals found in these areas in a season. Given the frequency of data collection, it was determined that adding all of the observations in a single season for this data set would result in a gross overestimation of actual individuals would not be an appropriate way to present the data.

2. Wilson's Plover

The Wilson's plover (*Charadrius wilsonia*) is designated by the State of North Carolina as a Species of Special Concern. This is a peripheral species (North Carolina lies at the periphery of its species range) requiring monitoring by the NCNHP. There is no federal status for this species, and it is considered globally secure (G5 rank) (NCNHP, 2006). However, Wilson's plovers are listed as species of high conservation concern in the US Shorebird Conservation Plan (Brown et al., 2001). Wilson's plover breed in eastern and southern coastal areas of the United States and overwinter along the Florida Atlantic coast and Gulf coasts to northern South America. Complete surveys were conducted in 2004 and 2007 along Hutaff Island and the inlet areas flanking Figure Eight Island. Additional surveys were conducted from 1989 and 2001 (Table 4.9). The number of Wilson's plovers recorded during this period ranged from 10 to 54 individuals and 5 to 27 breeding pairs (Cameron, pers. comm. 2007). In 2007, North Carolina Audubon observed 27 breeding pairs of Wilson's plovers on Hutaff Island (Mangiameli, pers. comm., 2008). An average of nearly two (2) Wilson's plovers were observed during each of the daily surveys conducted along the northern portion of Figure Eight Island in April, 2011 (Webster, pers. comm., 2011).

Table 4.9. Wilson's Plover Survey Data Observed 2000-2007 (NCWRC Shorebird Database, 2007)

Location	Year	Season	Number of Birds	Number of Breeding Pairs
Figure Eight Island	1989*	Breeding	48	24
Hutaff Island	1989*	Breeding	51	23
Figure Eight Island	2001*	Breeding	28	14
Hutaff Island	2001*	Breeding	22	11
Figure Eight Island	2004	Breeding	10	5
Hutaff Island	2004	Breeding	52	26
Figure Eight Island	2007	Breeding	2	1
Hutaff Island	2007	Breeding	54	27

*Incomplete survey

3. American Oystercatcher

American oystercatchers *(Haematopus palliatus)* are listed State listed as a Species of Special Concern. However, the American oystercatcher is considered stable globally (G5), and is not federally listed under the ESA. Along the western Atlantic coast, the eastern race of the American oystercatcher breeds from Massachusetts to Florida, with the highest concentrations from Virginia to Georgia (Humphrey, 1990). As indicated in Table 4.10, this species has been observed in or near the Permit Area during the April to June breeding period (Cameron, pers. comm., 2007). An average of two (2) American oystercatchers were observed during each of the daily surveys conducted along the northern portion of Figure Eight Island in April, 2011 (Webster, pers. com., 2011).

American oystercatcher

Table 4.10. American Oystercatcher Survey Data Observed 2000-2007 (NCWRC Shorebird Database, 2007)

Location	Year	Season	Number of Birds	Number of Breeding Pairs
Figure Eight Island	2001	Breeding	8	4
Hutaff Island	2001*	Breeding	10	5
Figure Eight Island	2004	Breeding	10	5
Hutaff Island	2004	Breeding	26	13
Figure Eight Island	2007	Breeding	4	2
Hutaff Island	2007	Breeding	24	12

*Incomplete survey

4. Common Tern

The common tern (*Sterna hirundo*) is designated by the State of North Carolina as Species of Special Concern (species which are determined by the NCWRC to require monitoring). There is no federal status for this species, although the common tern is considered globally secure (G5 rank). Common terns seem to be undergoing a decline in the southeast and are therefore listed as a species of regional concern (Hunter et al., 2001).

Complete surveys were conducted along Hutaff Island and the inlet areas flanking Figure Eight Island by the NCWRC and NC Audubon in 1977, 1983, 1988, 1993, 1995, 1997, 1999, 2001, 2004, and 2007. A total of 495 nests were observed through this period (Table 4.11). Common terns have experienced dramatic population declines in North Carolina and are currently down from their long-term average by 66% (Cameron et al. 2004). Common terns move frequently in response to changes in their highly ephemeral nesting habitat. The area along Hutaff Island and Figure Eight Island provides potentially important nesting habitat for common terns.

An average of nearly twenty (20) common terns were observed during daily surveys conducted along the northern portion of Figure Eight Island in April, 2011 (Webster, pers. com., 2011).

Table 4.11. Number of Common Tern Nests Observed 1977-2007 (NCWRC Shorebird Database, 2007)

Site Name	Survey Date	Number of Nests
Figure Eight Island	1977	7
Hutaff Island	1977	9
Figure Eight Island	1983	0
Hutaff Island	1983	96
Figure Eight Island	1988	11
Hutaff Island	1988	34
Figure Eight Island	1989	13*
Hutaff Island	1989	35*
Figure Eight Island	1990	51*
Figure Eight Island	1993	16
Hutaff Island	1993	0
Figure Eight Island	1995	5
Hutaff Island	1995	25
Figure Eight Island	1997	1
Hutaff Island	1997	52
Figure Eight Island	1999	0
Hutaff Island	1999	67
Figure Eight Island	2001	20
Hutaff Island	2001	38
Figure Eight Island	2004	0
Hutaff Island	2004	15
Figure Eight Island	2007	0
Hutaff Island	2007	0

*Incomplete survey

5. Gull-Billed Tern

The gull-billed tern (*Sterna nilotica*) is designated by the State of North Carolina as threatened. There is no federal status for this species, and it is considered globally secure (G5 rank). However, these terns are listed as species of high conservation concern (Kushlan et al., 2002). Surveys were conducted along Hutaff Island and the inlet areas flanking Figure Eight Island by the NCWRC and NC Audubon in 1977, 1983, 1988, 1993, 1995, 1997, 1999, 2001, 2004, and 2007. Although only nine (9) nests were observed in proximity to Figure Eight Island and two (2) along Hutaff following 10 years of complete surveys spanning 30 years, Sue Cameron of the NCWRC noted that the habitat type within the Permit Area makes these areas potentially important nesting sites (Table 4.12). No gull-billed terns were observed during each of the daily surveys conducted along the northern portion of Figure Eight Island in April 2011 (Webster, pers. com., 2011).

Table 4.12. Number of Gull-Billed Tern Nests Observed 1977-2007 (NCWRC Shorebird Database, 2007)

Site Name	Survey Date	Number of Nests
Figure Eight Island	1977	0
Hutaff Island	1977	0
Figure Eight Island	1983	0
Hutaff Island	1983	0
Figure Eight Island	1988	0
Hutaff Island	1988	0
Hutaff Island	1989	1*
Figure Eight Island	1990	9*
Figure Eight Island	1993	0
Hutaff Island	1993	0
Figure Eight Island	1995	0
Hutaff Island	1995	0
Figure Eight Island	1997	0
Hutaff Island	1997	0
Figure Eight Island	1999	0
Hutaff Island	1999	1
Figure Eight Island	2001	0
Hutaff Island	2001	0
Figure Eight Island	2004	0
Hutaff Island	2004	0
Figure Eight Island	2007	0
Hutaff Island	2007	0

*Incomplete survey

6. Black Skimmer

The black skimmer (*Rynchops niger*) is designated by the State of North Carolina as a Species of Special Concern (species which are determined by the NCWRC to require monitoring). There is no federal status for these species, although the black skimmer is considered globally secure (G5 rank) (Kushlan et al., 2002).

Complete surveys were conducted along Hutaff Island and the inlet areas flanking Figure Eight Island by the NCWRC and NC Audubon in 1977, 1983, 1988, 1993, 1995, 1997, 1999, 2001, 2004, and 2007. A total of 562 nests were observed during this time (Table 4.13).

Of the fifteen (15) daily surveys conducted by UNCW along the northern portion of Figure Eight Island in April 2011, black skimmers were observed on only two dates. These included observations of fifty (50) and twelve (12) individuals (Webster, pers. com., 2011).

Table 4.13. Number of Black Skimmer Nests Observed 1977-2007 (NCWRC Shorebird Database, 2007)

Site Name	Survey Date	Number of Nests
Figure Eight Island	1977	0
Hutaff Island	1977	52
Figure Eight Island	1983	0
Hutaff Island	1983	38
Figure Eight Island	1988	20
Hutaff Island	1988	16
Figure Eight Island	1989	1*
Hutaff Island	1989	41*
Figure Eight Island	1990	48*
Hutaff Island	1991	25*
Figure Eight Island	1993	14
Hutaff Island	1993	0
Figure Eight Island	1995	0
Hutaff Island	1995	42
Figure Eight Island	1997	0
Hutaff Island	1997	24
Figure Eight Island	1999	0
Hutaff Island	1999	27
Figure Eight Island	2000	20
Figure Eight Island	2001	40
Hutaff Island	2001	67
Figure Eight Island	2004	0
Hutaff Island	2004	87
Figure Eight Island	2007	0
Hutaff Island	2007	0

*Incomplete survey

7. Eastern Painted Bunting

The Eastern painted bunting (*Passerina ciris ciris)* is State-listed as a Species of Special Concern. The eastern population of painted bunting breeds in a restricted range within the Atlantic Coastal Plain, from North and South Carolina to Georgia and Florida. In North Carolina, eastern painted bunting breeding habitats are found in a narrow range along marine coasts and waterways (Audubon North Carolina, 2007b). NCWRC Biologist Dave Allen described their habitat as "…early succession habitat such as shrubby areas with occasional shrubs, edge habitat and even marsh edges or marsh interior if some shrubs or trees are nearby. This includes some residential area" (Allen, pers. comm., 2007).

Eastern painted bunting

A volunteer monitoring program has been established for the painted bunting in partnership between UNCW, SCNDR, USFWS, and the North Carolina Museum of Natural Sciences. This goal of this program, called the Painted Bunting Observation Team (PBOT), is to observe, record, and catalogue sightings of painted buntings. PBOT has reported twelve (12) sightings from four (4) locations on Figure Eight Island in 2011. Several hundred additional observations were made along the landward area of New Hanover and Pender County in proximity to the AIWW, (Painted Bunting Observer Team, 2011).

4. What are the public interest factors within the project area?

Public Safety

A total of 215 boating accidents were recorded in North Carolina by the NCWRC in 2005 (including personal watercraft), 14 of them fatal. The U.S. Coast Guard (USCG) Boating Statistics for 2005 ranked the waters of North Carolina as number 11 out of the 56 bodies of water owned by the U.S., for the total number of boats operating in North Carolina waters. In 2005 a total of 362,784 boats were registered in North Carolina. This number increased to 370,291 in 2006 (USGC, 2006). Between 2002 and 2006, the number for boating accidents has steadily risen from 138 to 175. Within the same time period, there was an increase of boat accident related mortalities; from 11 in 2002 to 24 in 2006. In 2005, NCWRC reported 10 boating accidents in New Hanover County resulting in eight injuries and two fatalities. Ten accidents were also reported in Pender County with nine injuries and one fatality. In 2007 a boating accident injured three occupants of a vessel which crashed into the Figure Eight Island bridge as it traveled in the AIWW. On May 26, 2008 a small recreational vessel capsized in proximity to Rich Inlet leading to one drowning fatality. The waters in North Carolina, including those found within the Permit Area are policed by the North Carolina Marine Patrol administered through the North Carolina Division of Marine Fisheries. Their jurisdiction includes all coastal waters, extends to 3 miles offshore, and ranges to 200 miles offshore for some federally regulated species. Officers monitor 2.5 million acres of water and over 4,000 miles of coastline. Currently, the Marine Patrol has 59 officers that work in three law enforcement districts along the North Carolina coast. In addition to checking commercial and recreational fishermen, officers patrol waterways, piers, and beaches in coastal areas. Officers

use a variety of different size boats, aircraft, helicopters, and patrol vehicles to accomplish these tasks.

Figure Eight Island is a privately owned island and access from the mainland by way of Bridge Road is restricted to residents and their guests limiting public entrance. Public access to Figure Eight Island and Hutaff Island, which has no mainland access, is by boat only. Therefore public access to the beach is somewhat restricted limiting recreational opportunities and potential compromises to public safety on the island.

Aesthetic Resources

Figure Eight Island covers approximately 526.1 ha (1300 ac) and is approximately 8.0 km (5.0 mi) long and approximately 0.6 km (0.4 mi) wide. Figure Eight Island is a private, gated residential barrier island situated amongst the Atlantic Ocean, the AIWW, and vast expanses of salt marsh and wetlands. The island is bordered to the south by Mason Inlet and Wrightsville Beach and to the north by Rich Inlet and Hutaff Island, an undeveloped, privately-owned island. The Permit Area includes a wide diversity of estuarine and nearshore habitat types supporting diverse ecosystems typically associated with a developed and undeveloped barrier island system in southeastern North Carolina, and provides uninterrupted to slightly interrupted natural vistas to both residents and non-residents. Because of its private nature, Figure Eight Island is a suitable place for wildlife conservation.

Recreational Resources

The terrestrial and aquatic environment within the Permit Area offers a number of recreational opportunities. Bird watching, surfing, fishing, sunbathing, boating, and swimming are offered to both tourists and local residents. Due to the restricted access to both Figure Eight Island and Hutaff Island, many of these recreational opportunities are limited to residents of Figure Eight Island and boaters. During peak summer periods, Nixon Channel, Green Channel, Rich Inlet, along with the adjacent shoreline beaches are heavily utilized by boaters for watersports and sunbathing.

Navigation

Rich Inlet serves as the access point for numerous recreational and fishing vessels year round. During the year, especially during peak tourist season, the Inlet can experience intense recreation navigation usage. Despite this frequent usage, Rich Inlet and surrounding waters are not maintained by federally authorized dredging activities. Masonboro Inlet is the closest maintained inlet which is located approximately 9.5 miles to the south. Although smaller recreational vessels can typically navigate through Rich Inlet into the ocean, larger vessels will generally access the ocean through Masonboro Inlet. Nixon Channel serves as the primary connecting waterway between the inlet and the AIWW. Outside the area that is periodically dredged, the inlet channel depth ranges from approximately 5 to 10 feet. Green Channel experiences high rates of shoaling and infilling and therefore is not utilized as frequently as Nixon Channel. The depth of Green Channel ranges from approximately 4 to 6 feet NAVD making it difficult to navigate for larger vessels.

Socio-Economic Resources

New Hanover County has a diverse economic base relying on tourism, trade, pharmaceuticals/healthcare, manufacturing, and government. As the population continues to grow, the area becomes more attractive to national retailers and companies. Figure Eight Island, located in New Hanover County, is primarily a residential community with limited commercial and retail facilities. Figure Eight Island contains 463 homes with 93 undeveloped lots. In 2004, the market value of these homes ranged from nearly $1,000,000 to over $7,500,000. Between March 2003 and March 2004, 14 homes sold on the island ranging in price between $825,000 and $2,000,000 with an average listing price of $1,418,266. The average selling price of these homes was $1,244,583. Since this time, the housing market has decreased within the region; however the average selling price of homes on Figure Eight Island has increased. During 2011, 13 homes were sold on the island for an average price of $1,757,514. Commercial activity on the island consists of home construction contractors and associated sub-contractors, landscapers, home cleaning services, and general residential and commercial services.

Land Use

The Coastal Area Management Act (CAMA) requires Counties, Cities and Towns within the 20 coastal counties to periodically prepare Land Use Plans to protect and manage the health of the coastal environment and economy. The North Carolina Division of Coastal Management requires that these counties keep the Land Use plans up to date. The most recent plan for Wilmington and New Hanover County was updated in 2006. The primary focus of the plan has been protection and appropriate development of coastal areas of environmental concern on a countywide perspective.

Figure Eight Island is located on the northeast end New Hanover County, in southeastern North Carolina, approximately eight miles north of Wilmington. It is a private, gated residential barrier island with 463 homes and 93 undeveloped lots. The island is bordered to the south by Mason Inlet and Wrightsville Beach; and to the north by Rich Inlet and Hutaff Island, an undeveloped, privately-owned island.

As a small residential community, the Figure Eight Island has limited land use compatibility problems when compared with larger urban municipal areas. The amount of commercial activity in Town is extremely limited. There are no large manufacturing, industrial or mining type operations in Town.

Infrastructure

World War II had a tremendous impact on the migration of immigrants to the United States in the mid to late 1900's. North Carolina began to notice the effects of this migration as evidenced by the steady increase in infrastructure and development in the 1970's (NCDCM, 2006b). This increase in population and development was most noticeable along the North Carolina coastline. The New Hanover County 2006 Land Use Plan found a high rate of increase in population

growth within the county between 1940 and 2000 (NCDCM, 2006b). Figure Eight Island contains 463 homes providing primary and vacation residences for its owners.

A swing bridge, installed in 1980, provides access to the island via Bridge Road. Beach Road spans the entire length of the island providing access to homes, along with several side roads, to the north and the south. Residential homes utilize individual septic tanks to manage waste water; however there is a Type V onsite wastewater system that serves the yacht club, offices, pool and restaurant facility. This system is maintained and operated by a private management entity and is inspected by the New Hanover County Health Department on an annual basis (Timpy, 2011).

Storm water management on Figure Eight Island falls under the New Hanover County stormwater ordinance and the Sediment and Erosion Control Local Program. However, the majority of the impervious on the island predates the County ordinance that went into effect in September of 2000. Therefore, the permitting for stormwater management is currently managed through NCDENR only.

Solid Waste

New Hanover County has no solid waste collection system, requiring County residents and businesses, including those on Figure Eight Island, to contract directly with private vendors for waste collection. The New Hanover County Department of Environmental Management oversees an integrated solid waste disposal system. Through waste-to-energy, recycling and lined landfilling techniques, the resulting system minimizes the use of land resources for burying waste, and minimizes the potential risks for contaminating the area's groundwater. The County's present solid waste management system is a direct result of long-term planning put in motion in 1981. The resulting system accomplishes the primary goals set in 1981, which were to minimize our reliance on landfilling as a means of managing solid wastes, and to minimize the potential impacts of managing solid wastes on the area's coastal environment. With proactive planning and maintenance, the community has a solid waste system that can provide environmentally sound disposal well into the future.

Since 1990, the use of recycling has increased as a solid waste management tool. In 1990, the City of Wilmington instituted a curbside recycling program, with the Town of Wrightsville Beach, Town of Carolina Beach and the County starting drop-off collection programs. The Town of Carolina Beach began collecting recyclables at the curb in 1992, with the Town of Kure Beach beginning its drop-off program the same year. The Town of Kure Beach began curbside recycling in 1997. A cardboard recovery operation was put in place in 1997 that nearly doubled the amount of material recycled through the County's operations. In 2004 the County’s landfill received 207,000 tons of waste. In the same time period over 10,000 tons of materials came to the facility to be recycled. Figure Eight Island residences utilize drop-off collection facilities to manage recyclable goods.

Drinking Water

The New Hanover County Water and Sewer District operates a public water system in the Unincorporated County. All of the County systems depend on groundwater for potable water and are withdrawn from the Pee Dee aquifer, the Castle Hayne aquifer and the surficial aquifer. The existing County well system consists of 27 small, developer built systems that have been acquired by the County over the last decade. Three of the 27 wells have been abandoned, while 24 wells are active. In 2004, the County had an average day water demand of 2.35 mgd. This average day demand does not include Porters Neck and Figure Eight Island.

Drinking water on Figure Eight Island is provided from public water supply wells administered by Figure Eight Utilities. This supply is also maintained and operated by a third party who submits sample results to the Public Water Supply Section of the Division of Water Resources (Timpy, 2011).

The lack of a countywide treatment system has prompted the majority of the County's customers to install water-softening equipment due to hardness, sulfur, and iron content. The County's existing 24 active well systems produce water at a rate of between 35 and 410 gallons per minute (gpm). The 12-hr yield of the existing well system is approximately 5.9 mgd. The majority of the wells are tapped into the Pee Dee aquifer. The County water system reaches from Wrightsboro across Northchase, along Murrayville Road to Market Street and up to Porters Neck Road. The County also operates the public water systems for Kings Grant and Prince George Estates.

Select North Carolina Primary Surface Water Classifications

HQW: Rated excellent based on biological and physical/chemical characteristics.

SA: Tidal salt waters that are used for commercial shellfishing or marketing purposes and are also protected for all Class SC and Class SB uses.

SB: Tidal salt waters protected for all SC uses in addition to primary recreation such as swimming.

SC: All tidal salt waters protected for secondary recreation such as fishing, boating, and other activities involving minimal skin contact.

Noise Pollution

Since Figure Eight Island is a private primarily residential area, ambient levels of human-induced noise in the area are relatively low. Natural noise levels, such as wind and pounding surf, does vary and is sporadic. During storm events, decibel levels can increase.

Water Quality

Many of the waterways within and in proximity to the Permit Area are designated as either High Quality Waters (HQW) or Outstanding Resource Waters (ORW) by the North Carolina Division of Water Quality (NCDWQ). NCDWQ defines HQW as:

> *waters which are rated excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, primary nursery areas*

> *designated by the Marine Fisheries Commission, and other functional nursery areas designated by the Marine Fisheries Commission*

ORW waterways are described by the NCDWQ as:

> *a subset of High Quality Waters. This supplemental classification is intended to protect unique and special waters having excellent water quality and being of exceptional state or national ecological or recreational significance. To qualify, waters must be rated Excellent by DWQ and have one of the following outstanding resource values:*
>
> - *Outstanding fish habitat and fisheries,*
> - *Unusually high level of waterbased recreation or potential for such kind of recreation,*
> - *Some special designation such as North Carolina Natural and Scenic River or National Wildlife Refuge,*
> - *Important component of state or national park or forest, or*
> - *Special ecological or scientific significance (rare or endangered species habitat, research or educational areas).*

Middle Sound, located north of the Hutaff Island complex, is designated as ORW along with Green Channel, Nixon Channel, Cedar Snag Creek, and Butler Creek. Portions of the AIWW (between the eastern mouth of Old Topsail Creek to the western mouth of Howe Creek) are designated as ORW as well. Futch Creek, located to the west of the Permit Area, is designated as HQW.

The North Carolina Department of Environmental and Natural Resources, Division of Environmental Health, Shellfish Sanitation Section is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting for human consumption. Recommendations are made to the Division of Marine Fisheries to close those waters that have the potential for causing illness and opening those that are assured of having clean, healthy shellfish. All shellfish growing areas are surveyed every three years to document all existing or potential pollution sources to assess the bacteriological quality of the water and to determine the hydrographic and meteorological factors that could affect water quality. Water samples are collected at least six times a year from each growing area and tested for fecal coliform bacteria, which are an indicator that human or animal wastes are present in the water. A number of waterways in close proximity to Figure Eight Island have been closed for shellfishing due to poor water quality. These include the waters surrounding Figure Eight Harbor, Figure Eight Island Marina, Mason's Landing Yacht Club, Scott's Hill Marina, and portions of Futch Creek (NCDENR Shellfish Sanitation, 2008) (Figures 4.30 and 4.31).

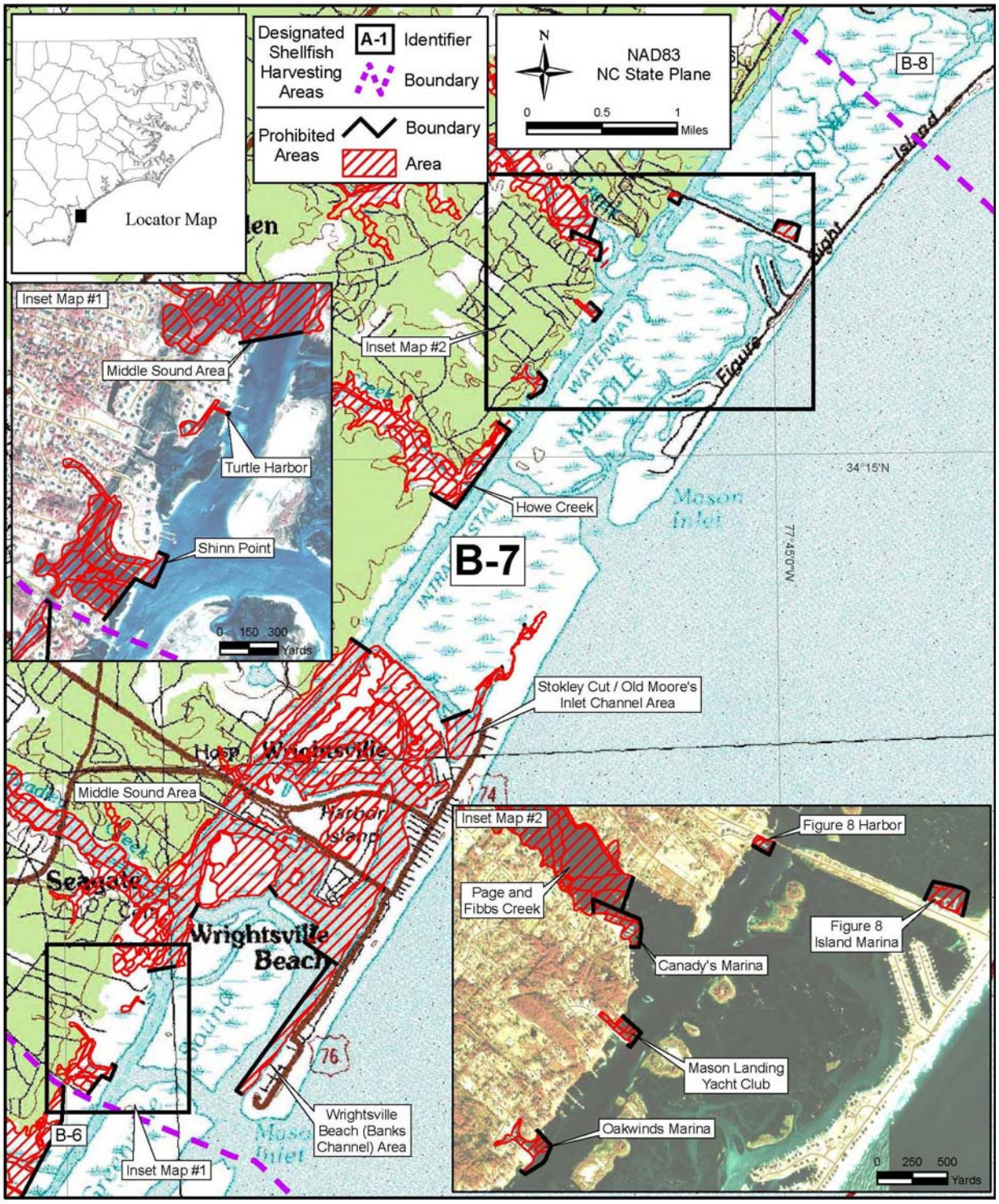


Figure 4.30 - NCDENR Shellfish Sanitation Map of Shellfish Closures in Proximity the Figure Eight Island Permit Area

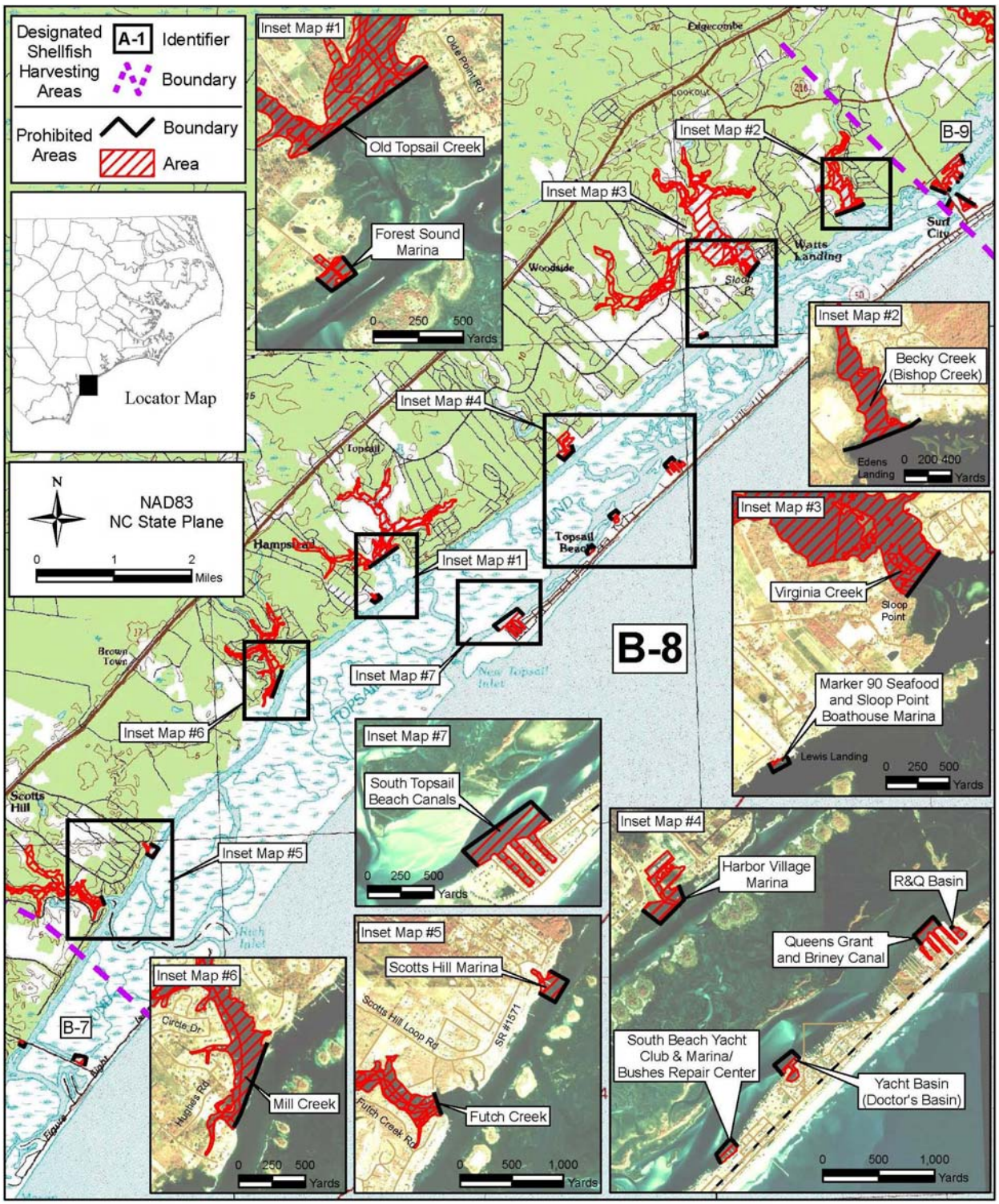


Figure 4.31 - NCDENR Shellfish Sanitation Map of Shellfish Closures in Proximity the Figure Eight Island Permit Area

CPE-NC performed preliminary water quality monitoring at 13 sites within the Permit Area on March 30 and 31 of 2007 (Figure 4.32). Physical parameters collected included depth, temperature, specific conductivity, dissolved oxygen, pH, and turbidity. All dissolved oxygen observations were above the State Standard of 5.0 mg/l with an average value of 8.2 mg/l.

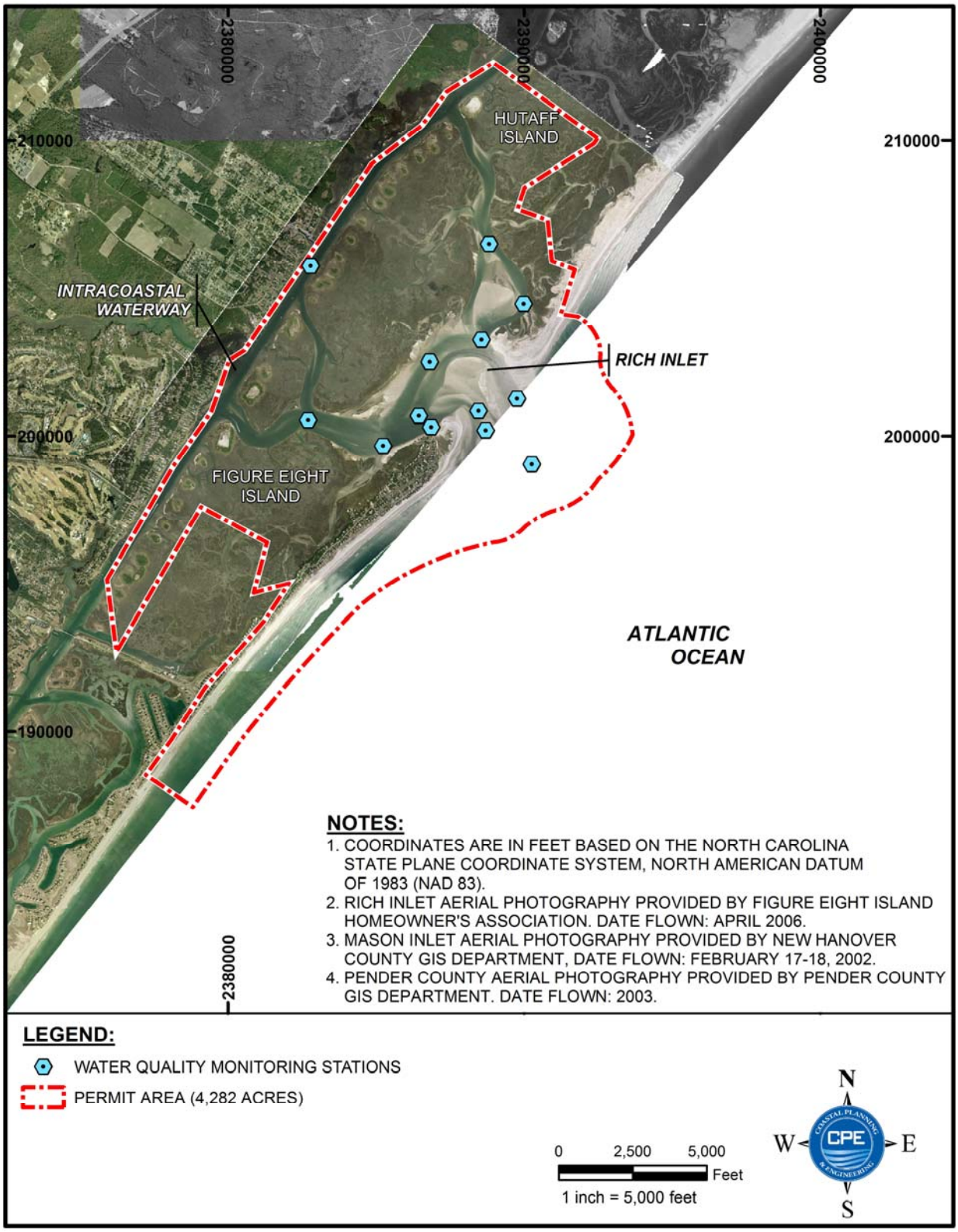


Figure 4.32. CPE-NC Water Quality Monitoring Sites

Until 2007, three RWQ sampling stations were located within the Permit Area. These stations included Station 50 (located in the AIWW between Mason's Creek and Pages Creek), 50A (located in Middle Sound at the south end of Figure Eight Island), and 50B (located in Nixon's Channel). These stations, designated as Tier 2, used for recreational purposes, were sampled on average three times per week. Tier 2-single sample maximum for *Enterococci* bacteria is 276 Colony Forming Units (CFU) per 100 ml water or a running monthly average (geometric mean) of 35 CFU per 100 ml water. In 2007, zero (0) samples from these stations contained *Enterococci* levels beyond the federal standard.

Water quality monitoring has been conducted monthly within Futch Creek and Pages Creek by the University of North Carolina at Wilmington (UNCW) (between 1996 and 2006) and CPE-NC (in 2007 to present). Results have determined that these waterways often contain levels of *Enterococci* and fecal coliform bacteria above the state standards, particularly following a significant rain event. Subsequently, Futch Creek and Pages Creek have been listed on the 303(d) list for impaired waters. These tidal creeks flush into the AIWW in proximity to the Permit Area.

1. Turbidity and Total Suspended Solids (TSS)

Turbidity, expressed in Nephelometric Turbidity Units (NTU), quantitatively measures the light scattering properties of the water. However, the properties of the material suspended in the water column that create turbid conditions are not reflected when measuring turbidity. The two reported major sources of turbidity in coastal areas are very fine organic particulate matter, and sand sized sediments that are re- suspended around the seabed by local waves and currents (Dompe and Haynes, 1993). In Class SA waters, North Carolina state guidelines limit turbidity to values under 25 NTU above ambient levels outside turbidity mixing zones (NCDWQ, 2003).

Total Suspended Solids (TSS) are basically solids that are present anywhere in the water column. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. Currently, there are no standards associated with TSS in North Carolina. Turbidity measurements were recorded by CPE-NC during preliminary water quality monitoring from 13 sites within the Permit Area in March of 2007. The average turbidity was 0.6 NTU, well below the State standard of 25 NTU.

2. Nutrients

Nutrients in the waters within the Permit Area are influenced from the inland tidal creeks, AIW, and the marsh environment. Non-point source pollution including stormwater runoff provides a conduit for nutrients entering these waterbodies which can influence their levels. Nutrient data in the form of nitrate/nitrite and orthophosphate has been collected within Futch Creek and Pages Creek on a monthly basis since November 2007 by CPE-NC. Although a standard has not been developed for nutrients in North Carolina, the levels observed following eight months of sampling have been within typical ranges observed at other tidal creeks in New Hanover County which is approximately 0.01-0.03 mg/l for nitrate/nitrite and orthophosphate. Therefore these waters are not considered to be eutrophic.

Non-Relevant Resources

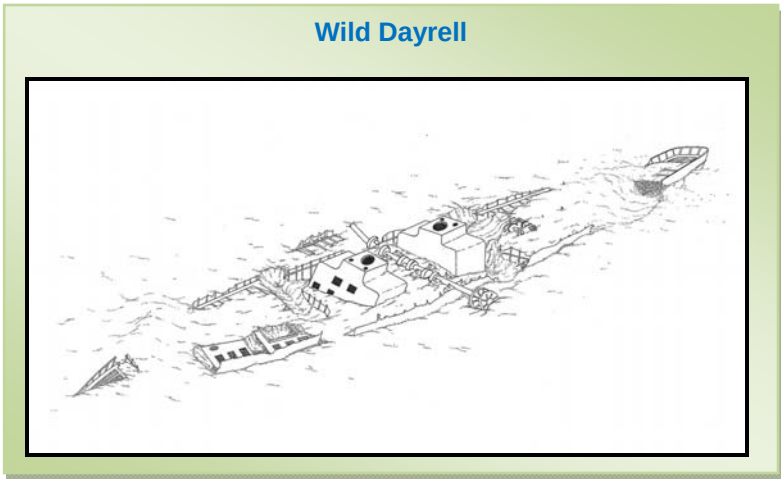
1. Hazardous, Toxic, and Radioactive Waste
There are no known hazardous, toxic, or radioactive wastes in the Permit Area that would be affected by a proposed project.

2. Energy Requirements and Energy Conservation
A proposed project within the Permit Area would not be expected to utilize an unusual amount of energy beyond typical construction needs.

3. Air Pollution
It is not expected that any activities associated with the proposed project alternatives would significantly contribute to air pollution within the Permit Area.

5. How would cultural resources be affected by the project?

Historical Properties and Cultural Resources



1. Rich Inlet Cultural Resources
CPE contracted Tidewater Atlantic Research, Inc. (TAR), of Washington, North Carolina to carry out a remote sensing survey to determine the exact position of the Civil War blockade-runner *Wild Dayrell* located in proximity to Rich Inlet. The remote sensing survey conducted by TAR was successful in identifying the remains of the *Wild Dayrell* and generating an accurate geographical position for the wreck site.

Refer to Appendix C- Submerged Cultural Resources Remote Sensing Survey for more information regarding the wreck of the *Wild Dayrell*.

An additional cultural resources survey in proximity to the proposed terminal groin will be conducted under a methodology approved by NCDCR as stated in an email dated 15 September 2009. This survey has not been conducted at this time, however, it has been suggested that a magnetometer survey of the upland and submerged area in proximity to Rich Inlet. This survey is expected to be conducted prior to the construction of this proposed project.

CHAPTER 5: *CONSEQUENCES*

1. What are the alternatives eliminated from further consideration?

Options within Alternative 3: Options 1, 2A, 2B, 3, 4A, 4B, and without the closure dike.

A screening process was carried out for Alternative 3 to determine which option provided the optimal position and alignment of Rich Inlet to alleviate the erosion occurring on the northern portion of Figure Eight Island. Furthermore, these options were evaluated to determine which would provide minimal alterations to the environmental conditions including the hydrodynamics through Nixon Channel and Green Channel. The rationale for elimination for these options is summarized below. A detailed description of modeling results and specifications for each option are provided in Appendix B.

Alternative 3, Option 1 (Figure 3.3) was eliminated from further consideration because landward extension of the main channel was found to divert flow from the Green Channel connector and increase flow velocities adjacent to the salt mash facing the inlet which could lead to increased erosion of the salt marsh shoreline. The diversion of flow from the Green Channel connector could also lead to eventual closure of this connector. Based on these results, Option 1 was eliminated from detailed consideration.

Alternative 3, Options 2A included relatively longer cuts into Nixon and Green Channels in comparison to Option 2B (Figure 3.4). Modeling results suggested that the longer cut into Nixon Channel was a necessary component to significantly reduce the flow and subsequent erosion along the estuarine shoreline of Nixon Channel. Therefore, the shorter cut into Nixon Channel as described in Option 2B was eliminated. The model results did not show any appreciable difference for the flow into Green Channel with either the long or short connector. Accordingly, the shorter connector into Green Channel as included within Option 2B would be preferred over the longer cut as described within Option 2A.

Alternative 3, Option 3 did not include any connection from the main bar channel toward Green Channel (Figure 3.5). According to model results, Option 3 produced the greatest departure from existing flow conditions inside Rich Inlet and was therefore eliminated from further conditions.

Alternative 3, Options 4A and 4B did not include a connector into Green Channel, and instead included an extension of the main channel through Rich Inlet through the middle ground shoal (Figure 3.6). Option 4A included a long cut into Nixon Channel while Option 4B included a relatively shorter cut. The Delft3D model results for these two screening options verified the need to extend the Nixon Channel cut 1,158.2 m (3,800 ft) as described in Option 4A in order to move flows away from the Nixon Channel shoreline. However, the landward extension of the main channel produced an indirect connection into Green Channel as well as increased the potential for erosion of the salt marsh shoreline. Therefore both Options 4A and 4B have been eliminated from further evaluation.

Constructing the inlet optimal modifications without the closure dike would create two entrance channels at Year 0. Between Years 1 and 2, the tidal flat between the two entrance channels would disappear and by Year 3, a single entrance channel would be present. Between Years 3 and 5, the entrance channel would begin returning to present dimensions due to shoaling and side slope adjustments. The single entrance channel at Year 5 would be narrower than the entrance channel at Year 3, with more gradual slopes on either side of the inlet. The offshore limit of the entrance channel would migrate approximately 152.4 m (500 ft) to the southwest, with approximately 304.8 m (1,000 ft) between the -3.0 m (-10 ft) contours on either side. The back channel between Nixon Channel and Green Channel would fill in, welding some of the tidal flats in the mouth of the inlet to the salt marsh area. In the absence of the closure dike, the reformation of the ebb shoal on the south side of Rich Inlet would not be as advanced at the end of Year 5 as for the with dike scenario and the north side of the ebb tide delta would not diminish in size to the same degree as for the with dike case. Based on these model results, modifying the inlet ocean bar channel of Rich Inlet without constructing a closure dike across the existing entrance channel was eliminated from detailed consideration.

Options within Alternative 4: Mason Inlet, Banks Channel, and Upland Borrow Pits, and AIWW Dredged Material Disposal Site

Mason Inlet

Material removed from Mason Inlet as part of the 30-year program to keep the inlet in its new location is used to manage the shoreline along the southern half of Figure Eight Island. Based on the Mason Inlet permit conditions, the Mason Inlet maintenance material could also be used to mitigate project related negative shoreline impacts on Shell Island. However, much of this material is committed to use in maintaining the southern half of Figure Eight Island and therefore would not be available as a source of nourishment to the area north of Bridge Road.

Banks Channel (maintenance dredging)

In 1969, during the early development of Figure Eight Island, Banks Channel was dredged to a depth of -5.5 m (-18 ft) and a width of 91.4 m (300 ft) with most of the 1.3 million cubic yards removed used to elevate the southern half of the island (Cleary & Jackson, 2004). Maintenance of the navigation channel in Banks Channel since 1985 has removed approximately 2.16 million cubic yards of shoal material with the majority of the material placed on the Figure Eight Island shoreline south of Bridge Road. The equivalent annual rate of disposal of the Banks Channel material is around 108,100 cubic yards per year or about 9.8 cubic yards/lineal foot of beach/year. Similar to the material from within Mason Inlet, this material has been committed to maintaining the southern half of Figure Eight Island.

Upland Borrow Pits

Upland borrow pits located between 30 and 50 miles from Figure Eight Island include:

- Riverside Sand Company, Wallace, NC,
- Hutcheson Landscaping, Burgaw, NC, and
- Morton Minerals Jackson Pit, Jacksonville, NC.

The volume of beach fill material needed to construct the beach fill described under Alternative 3 would be 1,152,300 cubic yards with an additional 5.5 million cubic yards needed to maintain the beach fill over the 30-year analysis period. Of these three borrow pits, only the Riverside Sand Company appears to have sufficient capacity to satisfy this requirement. In addition, the utilization of upland borrow pits have been determined as not practicable due to the high cost of truck haul and potential damage to the island's bridge and roads. It is estimated that the initial beach fill would require 71,700 truckloads of material with a cost of approximately $52.4M.

AIWW Dredged Material Disposal Site

The southern disposal site, known as Cameron Island, is owned by the Figure Eight HOA and has been incorporated into the Mason Inlet Relocation Project management plan as a temporary stockpile area for shoal material removed from the confluence of Mason Creek with the AIWW. The Figure Eight HOA uses material from Cameron Island to supplement nourishment along the southern portion of the island. In 1999, approximately 750,000 cubic yards of material was removed from Cameron Island and deposited on the Figure Eight Island shoreline south of Bridge Road. The USACE uses Cameron Island as a disposal area during maintenance of the AIWW Mason Inlet crossing. Therefore, this site will not be available for utilization with the Figure Eight Island Shore Management Project.

Options within Alternative 5A, Dredging Options 1 and 3 and the construction of a 1200-foot terminal groin

The length of a terminal groin in this document refers to the distance the structure would extend beyond the existing mean high water line. All of the terminal groin lengths evaluated would include a 900-foot shore anchorage section extending back to near the Nixon Channel shoreline.

Although Dredging Option 1, which includes 660-740 foot wide cut, provides the most amount of fill material, it offers only a marginal improvement in performance over Dredging Option 2. Because of the relatively large footprint of this option and the potential environmental consequences associated with it, this option has been eliminated from further evaluation.

On the other hand, Dredging Option 3, which includes a 395-416 foot wide cut, is the smallest of the dredging options in terms of both cost and impact. However, it has two disadvantages. First, the bottom width of the channel is relatively narrow, making the channel less conducive to navigation, especially towards the end of the 5-year maintenance cycle. Second, due to its narrow width, the new channel connector would close within one to two years. This is briefly discussed in the Delft3D modeling study in Appendix B.

Additionally, the performance of a 1200-foot long terminal groin was evaluated utilizing Delft3D model runs. The 1200-foot long terminal groin did not result in appreciable benefits, whether the accretion fillet was artificially filled or not. Similarly, the 1200-foot groin was modeled at an angle of 10, 20 and 30 degrees toward Figure Eight Island. These results did not depict beneficial results compared to the 700 foot groin (Appendix B).

The impacts of the remaining alternatives (Alternatives 1, 2, 3, 4, 5A, and 5B) on public interest factors, physical impact on the inlet and adjacent beaches, economics, and the environment are described in the following sections.

Options within Alternative 5B: Mason Inlet, Banks Channel, Upland Borrow Pits, and AIWW Dredged Material Disposal Site #4

This alternative considered the utilization of the same borrow sources containing beach compatible material other than that found within Rich Inlet for use as beach fill along Figure Eight Island as mentioned above for Alternative 4. For the same reasons discussed above, these sources have been eliminated from further consideration.

2. How were the environmental impacts analyzed?

This chapter includes both a qualitative and quantitative comparative assessment of the direct, and indirect, and cumulative impacts associated with the alternatives under consideration for the Figure Eight Island Shoreline Management Plan. Impacts will relate to the resources and interest factors described in Chapter 4.

The Council on Environmental Quality regulations (40 CFR §§ 1508.7 and 1508.8) defines direct effects as those caused by the action and occur at the same time and place. Indirect effects are defined as those caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. Cumulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Effects and impacts as used in these regulations are synonymous. Effects includes ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative. Effects may also include those resulting from actions which may have both beneficial and detrimental effects, even if on balance the agency believes that the effect will be beneficial.

Anticipated impacts to habitats were determined by Coastal Planning & Engineering, Inc. (CPE) through the analysis of numerical modeling results, historical and recent erosion rates, recent biological characterization investigations, and results from past research and studies. Delft3D, the primary modeling package used for this project, simulated flows forced by a combination of waves, tides, winds, and density gradients, along with sediment transport and bathymetric change using advanced transport formulations that account for bedload and suspended load transport.

With regard to the model results, 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 with certainty, as this would require an ability to predict future weather and oceanic conditions. Rather, the Delft3D model results for Alternative 2, the no action alternative, under a prescribed set of forcing conditions forms 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. Such a relative comparison is achieved by imposing the same set of forcing conditions in the model for each alternative and identifying relative differences in the response of the modeled system to changes observed for Alternative 2. In other words, the model results are only an indication of how the inlet system and adjacent beaches would respond to a given set of forcing conditions (waves, tides, winds, etc.) and physical modification to the system associated with Alternatives 2, 3, 4, and 5A. Model results from these alternatives could be used to determine changes in Alternatives 1 and 5B.

Waves in Delft3D were simulated using SWAN (Simulating Waves Nearshore), an advanced wave transformation model that incorporates most wave transformation processes, including breaking, shoaling, refraction, reflection, diffraction, and bottom friction. Water levels, currents, and bathymetric changes are simulated using Delft3DFLOW. Delft3D simulated the relevant coastal processes over short-term (days-storms) and long- term (seasons-years) time scales. These models were employed to determine impacts for Alternatives 2, 3, 4, and 5A. Because the physical conditions pertaining to Alternatives 1 and 2 are similar, the impacts determined for Alternative 1 were inferred utilizing model results derived for Alternative 2. Similarly, impacts for Alternative 5B were inferred utilizing the model results from Alternative 5A.

A shoreline change numerical model, GENESIS, was used to provide a “second opinion” regarding shoreline changes indicated by the Delft3D model, particularly with regard to shoreline changes associated with the terminal groin alternatives.

For additional information on the model, including calibration and results please refer to Appendix B.

In order to determine changes to habitat acreages within the Permit Area, several methods were employed. Direct impacts were determined via two methodologies. First, the footprints of project-related activities (i.e. proposed areas to be dredged, beach fill locations, the construction toe of fill, etc.) were entered into ArcGIS and overlaid upon the baseline habitat map delineated from 2008 aerial photography. The area of specific habitat types which fell within this footprint were determined to be directly impacted and the acreages were extrapolated. In addition, direct impacts were also defined as the indicated changes to the shoreline at Year 0 from the Delft3D modeling results. The modeled mean lower low water (MLLW) lines were initially determined from a 2006 shoreline survey and entered into Delft3D. The indicated shoreline locations for each modeled alternative (2, 3, 4, and 5A) were then overlaid onto the baseline habitat map. The habitats where then clipped along the MLLW lines. Any portions of the habitats that were located seaward of the MLLW were also considered to be impacted by the modeled changed position of the MLLW. This methodology was also employed to determine indirect impacts by utilizing the Year 5 shoreline obtained from the Delft3D model. Note that while several upland habitat types are present within the permit area, this Delft3D analysis of indirect impact only evaluates habitats which are present on the oceanfront of the islands and the shorelines along the mouth of the inlet within the permit area. These results should be interpreted with caution as they are not intended to be a precise prediction of habitat change considering they are in part based on modeling simulations and are therefore only intended to provide insight on potential changes. Table 5.1, shown below, is an attempt to depict the range of impacts that could be incurred for each alternative in terms of the geographic scope of habitats present within the project area. While it is understood that the footprints of project-related actions along with shoreline change over time will result in habitat impacts, it is difficult to calculate the overall net impacts (positive or negative) due to the conversion of habitat types. Therefore, Table 5.1 illustrates the estimated amount of habitats impacted however it does not account for changes in habitat due to conversion from one habitat type to another.

Table 5.1- Area (in acres) of various habitats that is expected to be affected by project alternatives over a 5-year period

	Impact Type	Alt. 1 (No-Action)	Alt. 2 (Abandon/ Retreat)	Alt. 3 (Rich Inlet Management w/ Beach Fill)	Alt. 4 (Beach Nourishment without Inlet Management)	Alt. 5A (Terminal Groin w/ Beach Fill from Nixon Channel and Connector Channel)	Alt. 5B (Terminal Groin w/ Beach Fill from Nixon Channel and Upland Dredge Disposal Sites)
Inlet Dunes and Dry Beaches	**Direct**	0	0	5-10	5-10	5-10	5-10
	Indirect	0-5	0-5	0	0-5	0-5	0-5
Oceanfront Dunes	**Direct**	0	0	0	0	0-5	0
	Indirect	0	0	0	0	0	0
Oceanfront Dry Beach	**Direct**	*	0	150-200	100-150	100-150	25-50
	Indirect	0-5	0-5	0-5	0-5	0.0	0.0
Intertidal Flats and Unvegeatated Sand	**Direct**	0	0	15-20	0	25-30	0
	Indirect	0-5	0-5	0	0-5	0-5	0-5
Wet Beach	**Direct**	0	0	60-70	60-70	50-60	30-40
	Indirect	15-20	15-20	20-25	20-25	5-10	5
Low Marsh	**Direct**	0	0	0	0	0-5	0-5
	Indirect	0	0	0	0	0	0
Softbottom	**Direct**	40-50	0	120-130	**	80-90	40-50
	Indirect	0	0	0	0	0	0

* - Historically, the extent of fill placed on the dry beach has varied and therefore the area of impacts cannot be generalized

**- The acreages of impacts cannot be determined at this time due to the unknown size and extent of potential offshore borrow sources

3. What impact would each alternative have on the shorelines of Figure Eight Island and Hutaff Island over a 5-year period?

This section will describe the general changes along the oceanfront and inlet shoreline as inferred by the 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. A complete description of the model results is provided in Appendix B. A brief summary of the model results for both conditions follows.

- Alternative 1

The Delft3D model was not specifically run under Alternative 1 conditions. Rather, the results derived from Alternative 2 were utilized to as a proxy for Alternative 1. Shoreline change rates along Figure Eight Island north of Bridge Road for the period 1974 to 2007 range from +1.1 feet/year just north of Bridge Road to -16.8 feet/year in the northern area fronting the sandbags. These shoreline change rates have been adjusted to account for the numerous beach nourishment activities along the north end of the island. As needed, it is expected that Figure Eight Island would continue to pursue beach nourishment along this stretch to help prevent erosion. Along Hutaff Island, the southern 2,000 feet has behaved somewhat erratically due to the changing position and orientation of the bar channel of Rich Inlet, but the general trend between 1974 and 2007 has been accretion.

Under Alternative 1, the shorelines on both islands would be expected to continue to behave as they have in the past.

- Alternative 2

Volumetric changes along the beaches of Figure Eight Island and the southern end of Hutaff Island were determined from the results of the Delft3D model. Volume change computations extended from the dune seaward to the depth of closure which is -24 feet NAVD. Volumetric changes were computed for the five beach segments on Figure Eight Island, described in Table 5.2 and shown on Figure 5.1, and the southern 3,000 feet of Hutaff Island. The modeled beach volume changes for Alternative 2 were used as a frame of reference to determine differences in the relative impacts of the other alternatives on both Figure Eight Island and Hutaff Island.

Table 5.2 Figure Eight Island Beach Segments

F90+00 to 30+00	(Bridge Road to 262 Beach Road North)
30+00 to 60+00	(262 Beach Road North to 322 Beach Road North)
60+00 to 80+00	(322 Beach Road North to 8 Comber Court)
80+00 to 100+00	(8 Comber Court to Rich Inlet Shoulder)
100+00 to 105+00	(Figure Eight Island Sand Spit)

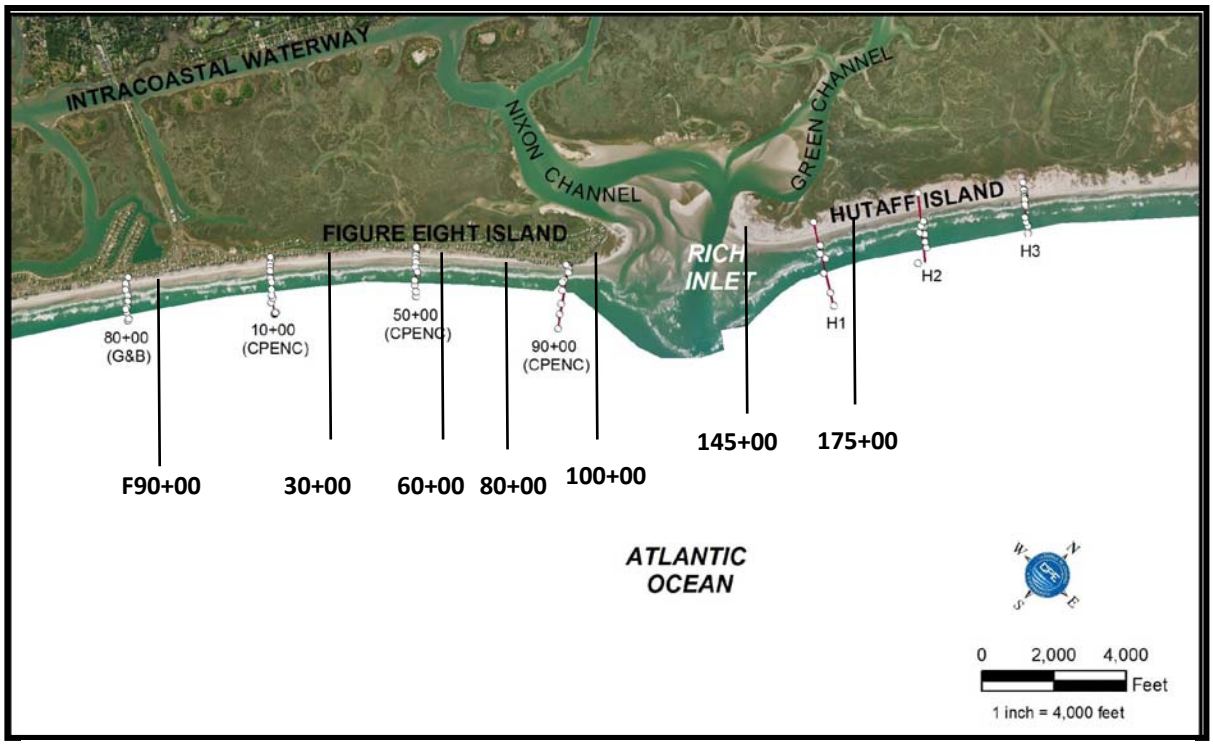


Figure 5.1. Island segments used for model volume change computations.

The shoreline change rates along Figure Eight Island for Alternative 1 are applicable to Alternative 2 since the impacts associated with the previous beach fills were removed. Also, since no modification would be made to Rich Inlet, past shoreline changes along Hutaff Island described for Alternative 1 are applicable to Alternative 2.

Under Alternative 2, future shoreline changes would be expected to mimic past changes.

Based on the environmental conditions used for the Delft3D model simulations, the model indicated the spit area projecting off the north end of Figure Eight Island into Rich Inlet would be eroded and converted to a submerged sand flat at the end of the 5-year simulation.

Modeled shoreline volume changes over a 5-year simulation period for Alternative 2 along the 12,500 feet of Figure Eight Island situated between Bridge Road and Rich Inlet resulted in a loss of 92,200 cubic yards/year. Specifically, losses include 4,900 cubic yards/year between stations F90+00 and 30+00, 16,800 between 30+00 and 60+00, 11,800 between 60+00 and 80+00, 32,900 between 80+00 and 100+00, and 25,900 between 100+00 and 105+00 (Table 5.2). Along the southern 3,000 feet of Hutaff Island, the model results indicated this section of the island would accrete at a rate of 70,600 cubic yards/year."

Shoreline changes along Figure Eight Island and Hutaff Island were also determined from an analysis of aerial photos taken between 1938 and 2007 performed by Dr. William Cleary. These shoreline changes are reported in Sub Appendix A of Appendix B and summarized in Chapter 6.

For the area immediately south of Rich Inlet, shoreline change rates have varied from -12.6 feet/year to -92.8 feet/year during the 1996 to 2007 time period, the time period in which the ocean bar channel of Rich Inlet shifted its orientation toward Hutaff Island. For the area in the vicinity of the existing sandbag revetments, shoreline change rates between 1996-2007 ranged from -9.2 feet/year to -79.3 feet/year. For the area south of the sandbags to Bridge Road, the shoreline changes between 1998 and 2007 displayed a wide range of behavior including periods of both erosion and accretion. The maximum rate of accretion in this area between 1996 and 2007 was +91.9 feet/year while erosion rates were as high as -47.7 feet/year.

Along Hutaff Island, shoreline change rates in the 2,000-foot shoreline segment just north of Rich Inlet during the 1996-2007 time period ranged from accretion of +29.4 feet/year to erosion of -14.9 feet/year. Farther north, shoreline change rates for the period ranged from an accretion rate of +0.9 feet/year to erosion of -37.7 feet/year. However, near the location of Old Topsail Inlet, which closed sometime around 1996, the shoreline was generally erosional between 1996 and 2007 with rates ranging from -5.4 feet/year to -37 feet/year.

The highly variable nature of shoreline changes along both Figure Eight Island and Hutaff Island were factored into the development of shoreline change thresholds presented in Chapter 6 with the shoreline change thresholds representing possible future shoreline changes along both island in the absence of any modifications to Rich Inlet.

The modeled morphological changes within the project area that would occur over the 5-year simulation period for Alternative 2 are shown in Figures 5.2 to 5.7.

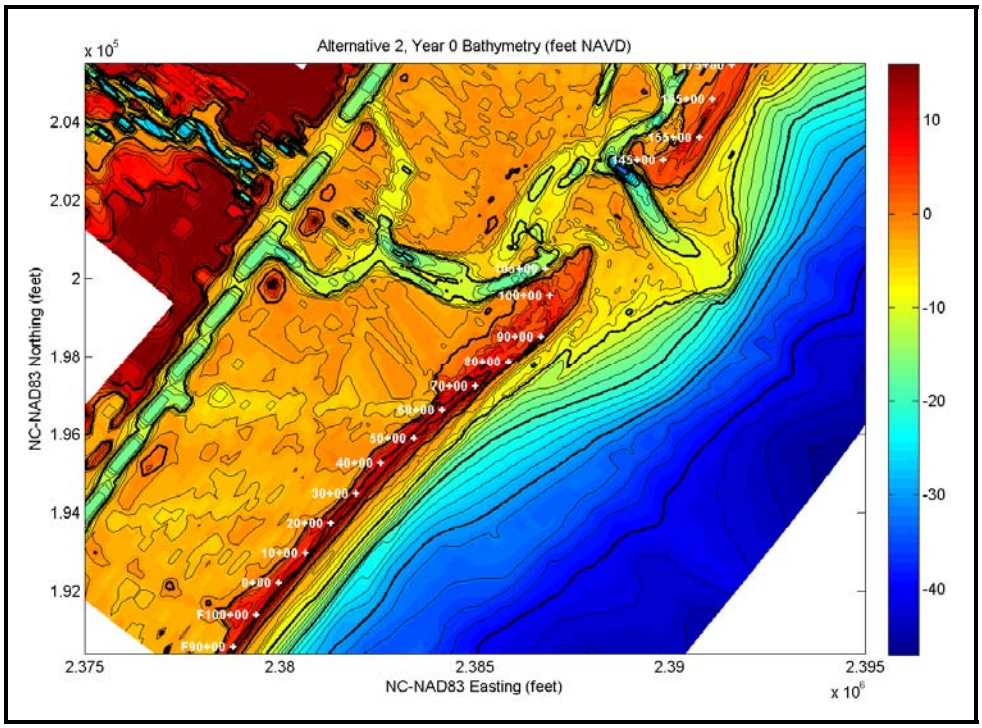


Figure 5.2. Alternative 2 – Year 0.

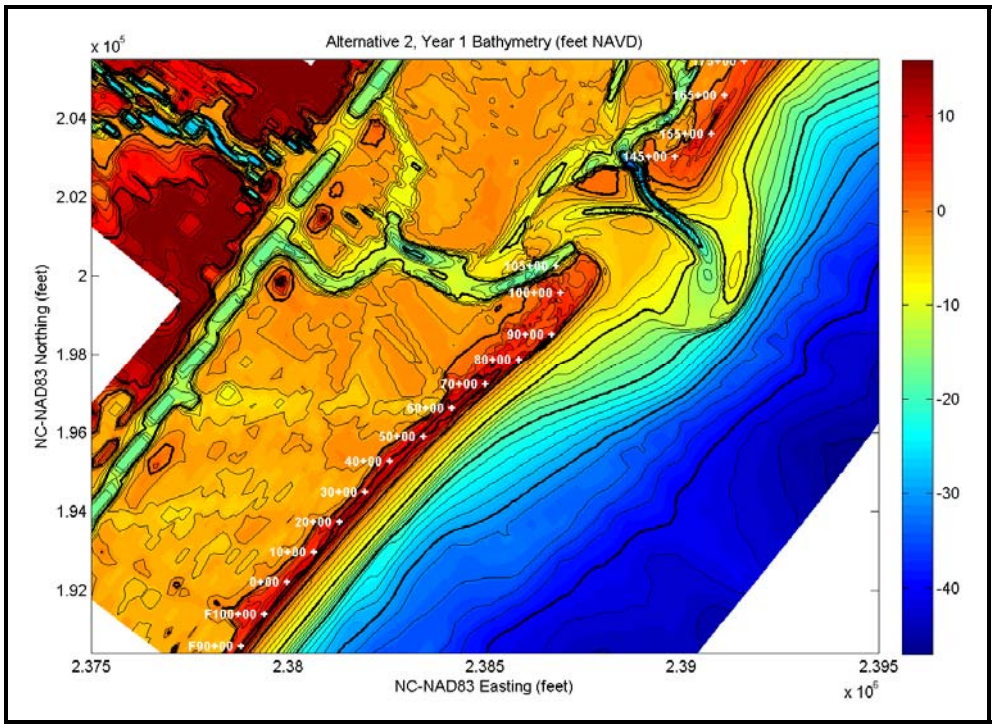


Figure 5.3. Alternative 2 – Year 1.

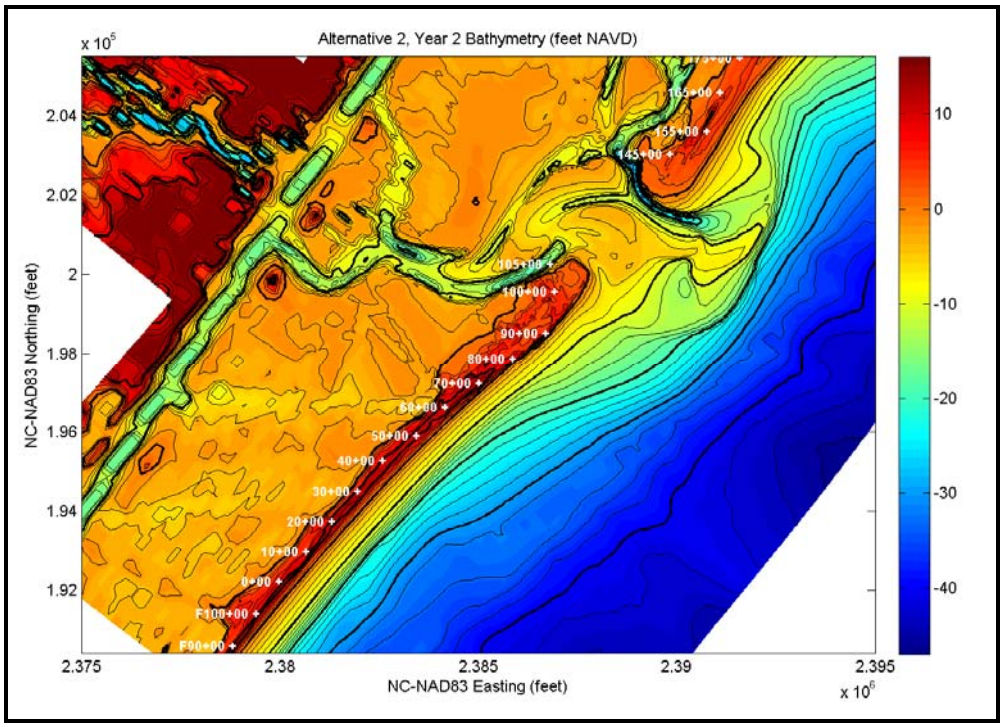


Figure 5.4. Alternative 2 – Year 2.

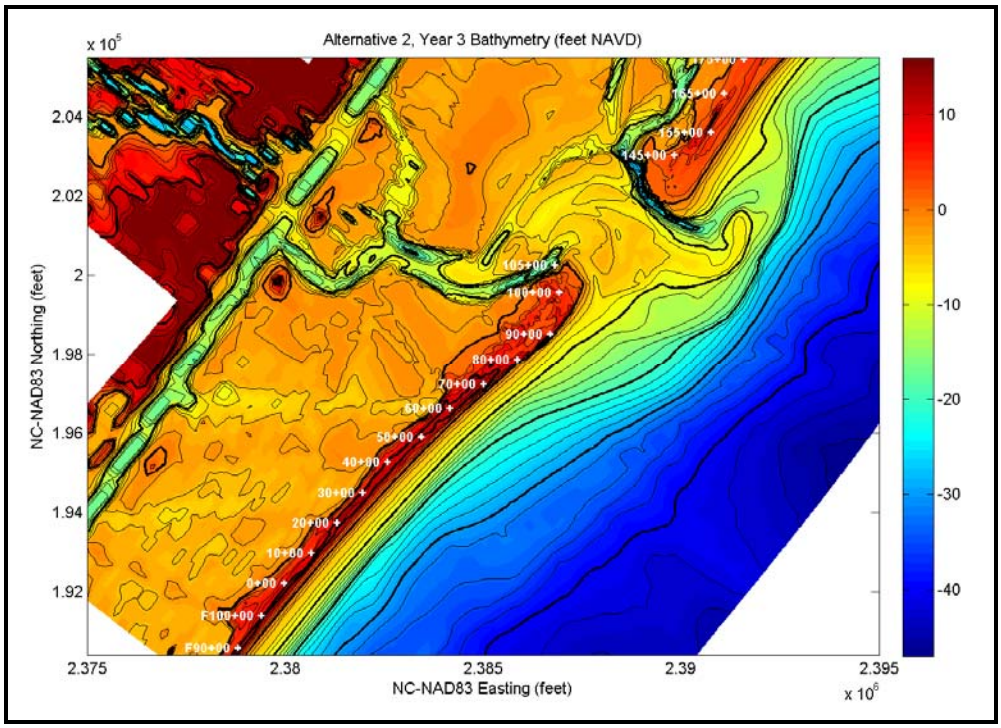


Figure 5.5. Alternative 2 – Year 3.

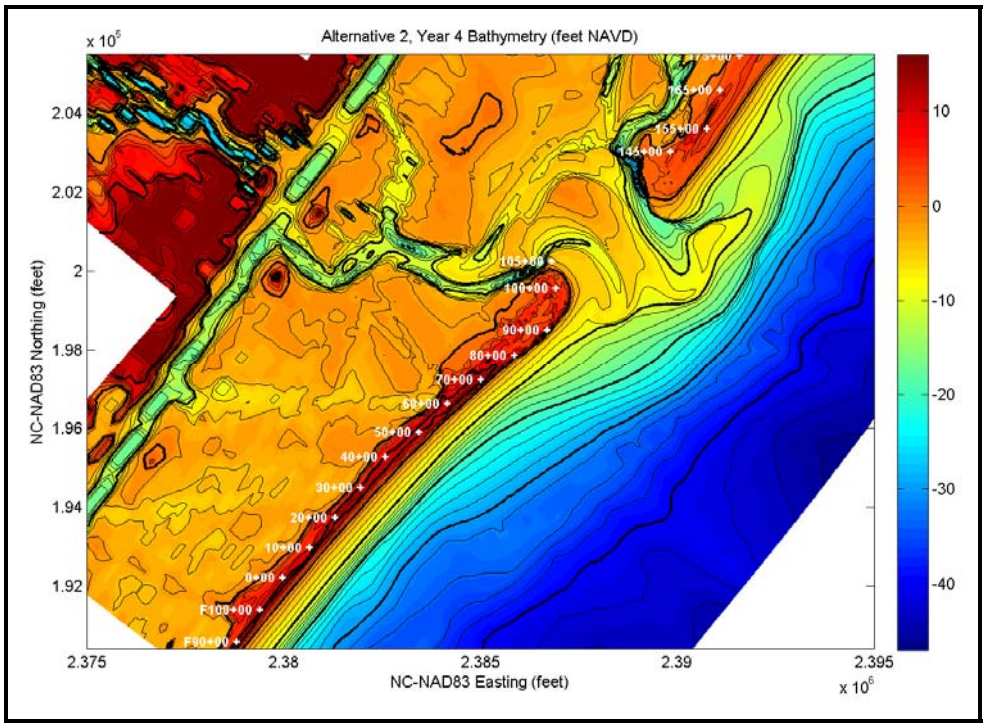


Figure 5.6. Alternative 2 – Year 4.

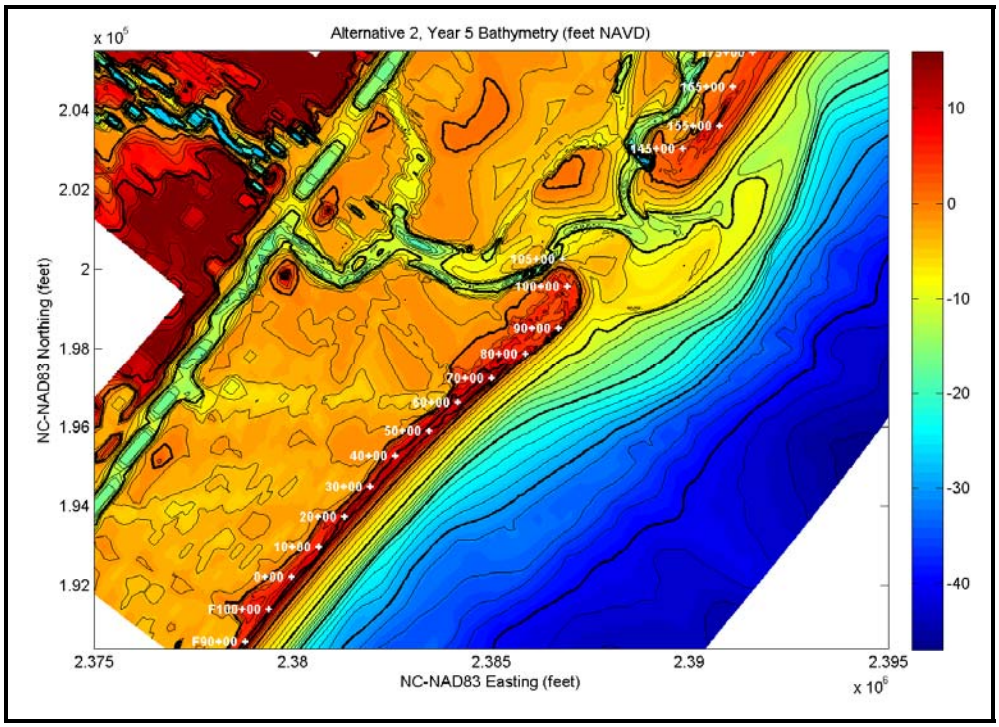


Figure 5.7. Alternative 2 – Year 5.

- Alternative 3

Alternative 3 includes beach fill along the ocean shoreline of Figure Eight Island from near Rich Inlet south to Bridge Road and along 1,800 feet of the Nixon Channel shoreline on the backside of Figure Eight Island. The impacts of the inlet channel modifications on the morphology of Rich Inlet, shoreline changes on both Figure Eight Island and Hutaff Island, and flows through the inlet and the connecting channels were simulated over a 5-year period using the Delft3D numerical model (Appendix B). The evaluation included the channel modifications with and without the closure dike next to Hutaff Island.

Shoreline changes along the ocean shoreline of Figure Eight Island under Alternative 3 focused on the performance of the beach fill as indicated by the results of the Delft3D model. Over the southern 5,000 feet of the fill (stations F90+00 to 30+00) almost 90% of the initial fill volume remained at the end of the 5-year simulation as losses were shown to be 4,900 cubic yards/year (Table 5.2). For the area between stations 30+00 and 60+00, losses were shown to be 16,800 cubic yards/year, or, approximately 45% of the initial fill after 5-years. For the area between stations 80+00 to 100+00, which is presently protected by sandbag revetments, losses included 32,900 cubic yards/year. Almost one-third of the fill remained in this area after 4 years but with the shift in the channel position back toward Hutaff Island indicated by the model results between years 4 and 5 of the simulation, erosion of the fill accelerated leaving on 7.8% of the fill in place at the end of the 5 year simulation. Even with the accelerated loss of fill form the northern 2,000-foot segment in the last year of the simulation, erosion did not encroach into the pre-nourished upland and dune area in any area located north of Bridge Road.

Under Alternative 3, the Delft3D model indicated the repositioning of the bar channel could result in the elongation of the sand spit off the north end of Figure Eight Island. The growth of the sand spit toward Rich Inlet simulated by the model mimics observed responses to similar channel modifications implemented at Oregon Inlet, Bogue Inlet, and Shallotte Inlet.

Constructing the inlet modifications with the closure dike extending off the south end of Hutaff Island will close the present entrance channel. Part of the new main inlet bar channel will occupy the present location of the flood channel on the southwestern side of the inlet. The modeled morphological changes to Rich Inlet that would occur over the 5-year simulation period for Alternative 3 are shown in Figures 5.8 to 5.13.

During the first 4 years after construction, the new bar channel gradually migrated toward the southwest with this southwesterly migration accompanied by a significant build-up of the ebb tide delta off the north end of Figure Eight Island. Between Year 4 and Year 5 of the simulation, the bar channel breached the ebb tide delta, returning to an orientation similar to the pre-project condition. As expected, the channel connecting the inlet gorge with the mouth of Green Channel shoaled significantly as the sand dike eroded and assumed the characteristics of a sand spit projecting off the south end of Hutaff Island. Most of the sand spit eventually became sub tidal. While the Nixon Channel connector

also experienced significant shoaling, the connector maintained some of its cross-sectional integrity throughout the 5-year simulation, concentrated flow away from the backside of Figure Eight Island, and continued to carry the majority of flow from the southwest side of the inlet.

The sand spit projecting into Rich Inlet from Figure Eight Island elongated substantially and remained above the low water line during the 5-year simulation. This modeled response is very similar to that which occurred on the east end of Ocean Isle Beach, NC after the USACE excavated a large area across the ebb tide delta of Shallotte Inlet for purposes of nourishing Ocean Isle Beach. Also, the same spit formation phenomenon was observed at Oregon Inlet, NC following the USACE relocating the navigation channel across the ocean bar of Oregon Inlet in 1983 and at Bogue Inlet, NC where the bar channel was moved 3,500 feet to the west in 2005 to address channel induced erosion on the west end of Emerald Isle.

Over the 5-year simulation period, the north side of the ebb tide delta diminished in size and shifted toward the southwest exposing the southern end of Hutaff Island to direct wave attack. Some of the material on the north side of the inlet migrated onshore and merged with the shoreline, however, the volume of material lost offshore due to the shifting location of the ebb tide delta overshadowed any volume gains directly on the beach resulting in a net volume loss off the southern end of Hutaff Island.

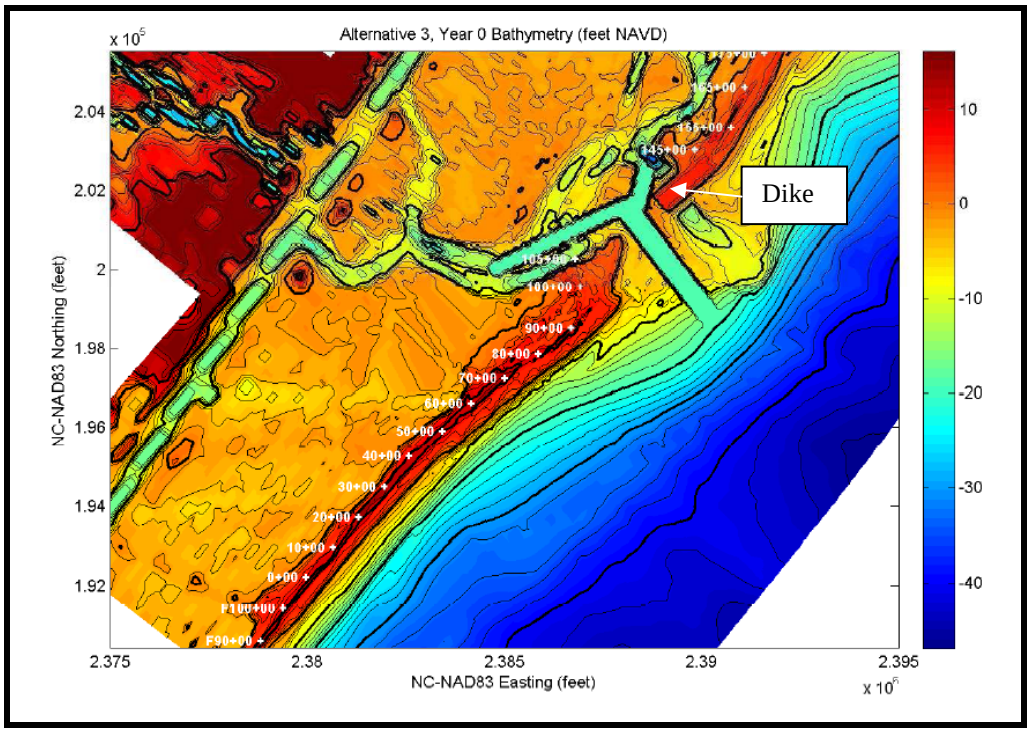


Figure 5.8. Alternative 3 – Year 0: Post-construction.

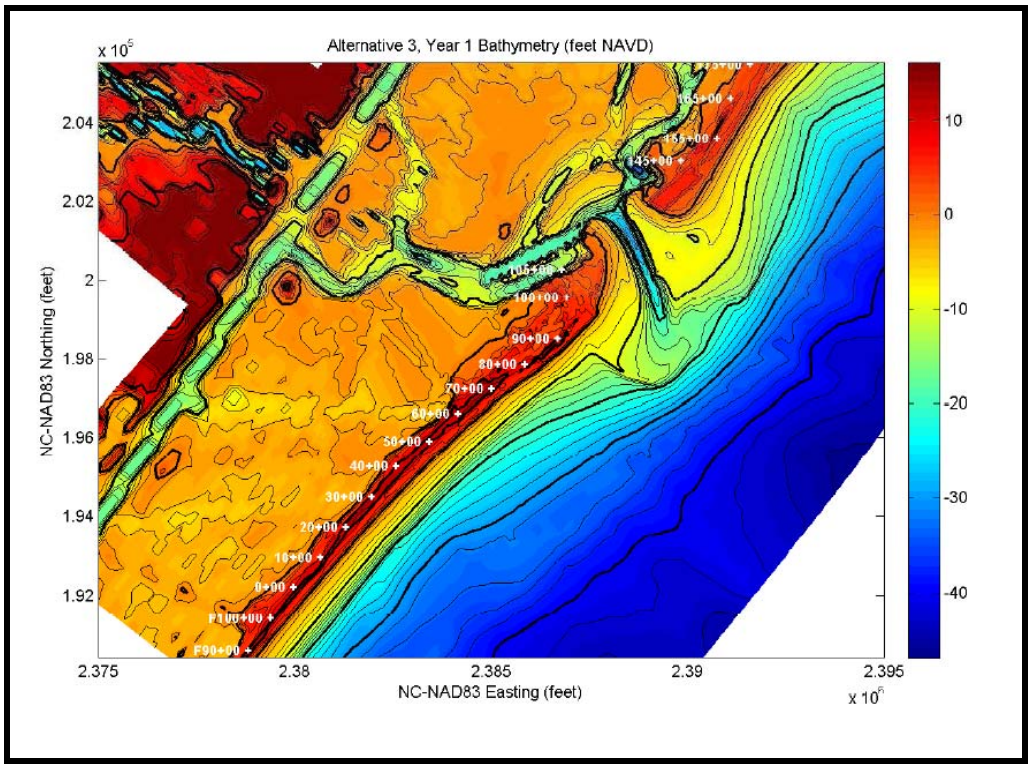


Figure 5.9. Alternative 3 – Year 1 after construction with dike installed.

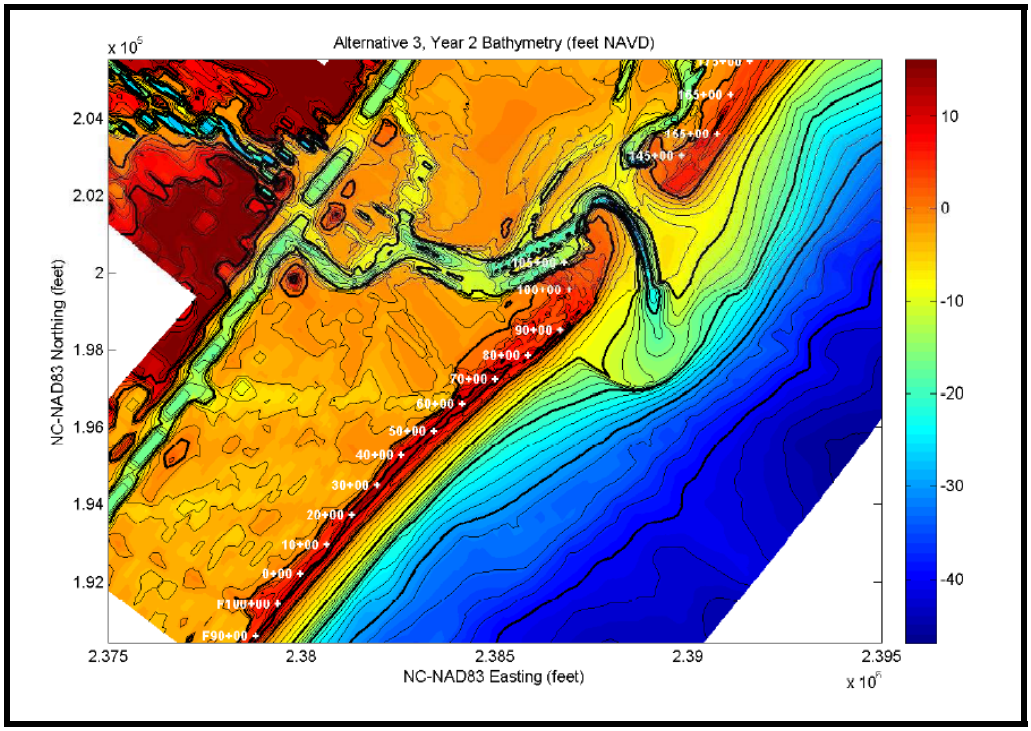


Figure 5.10. Alternative 3 – Year 2 after construction.

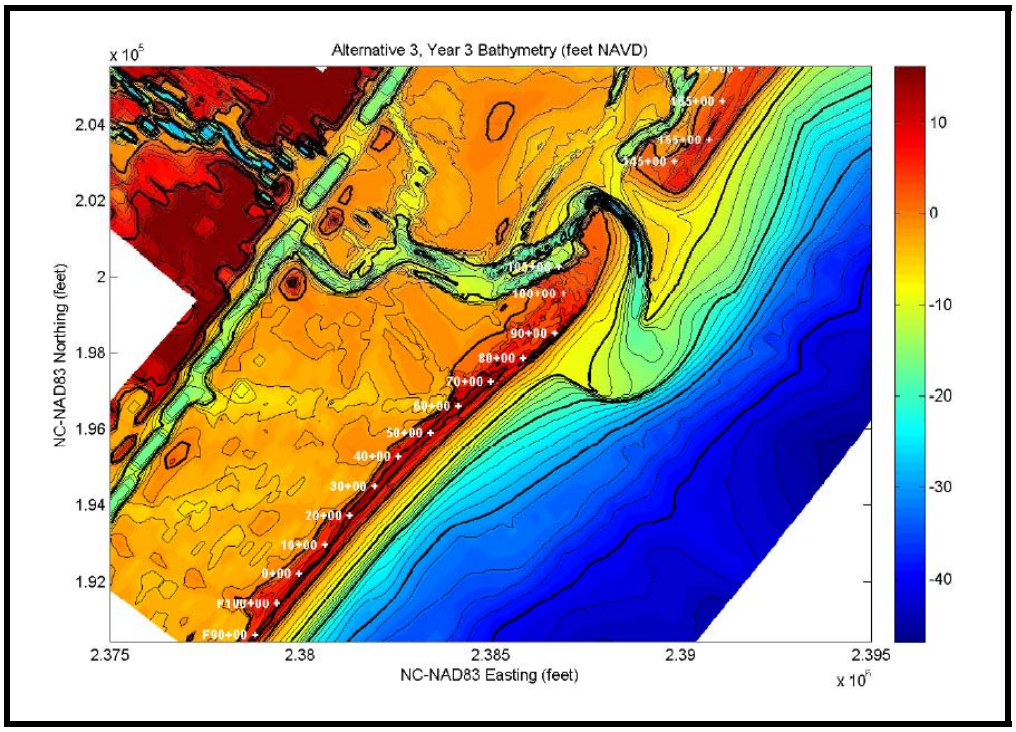


Figure 5.11. Alternative 3 – Year 3 after construction.

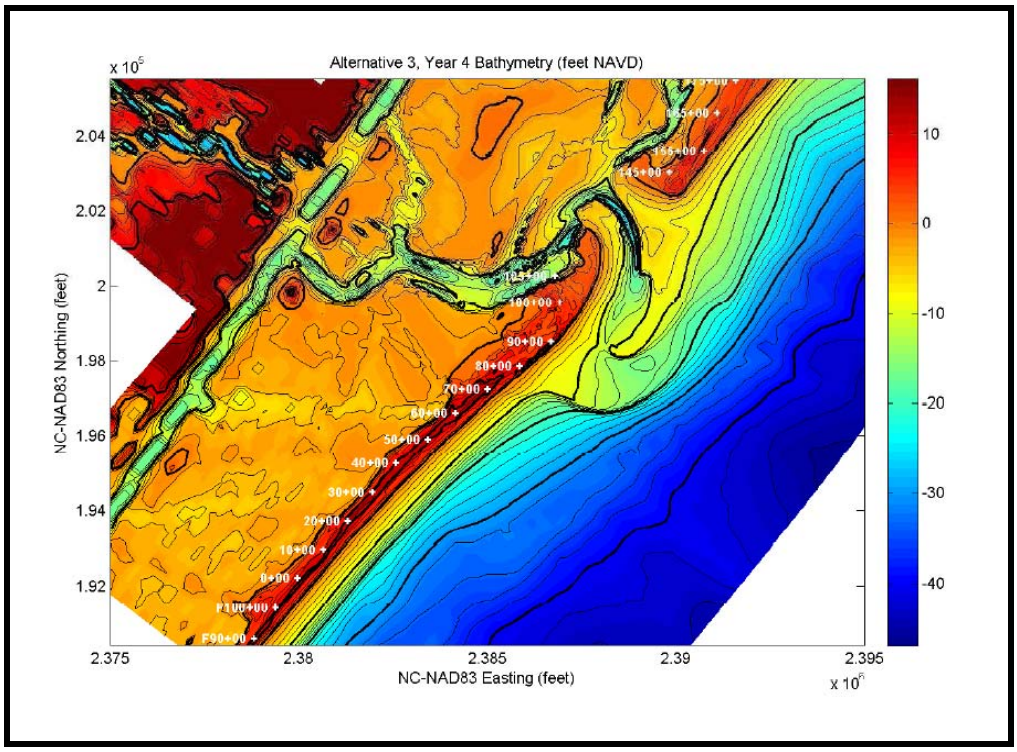


Figure 5.12. Alternative 3 – Year 4 after construction.

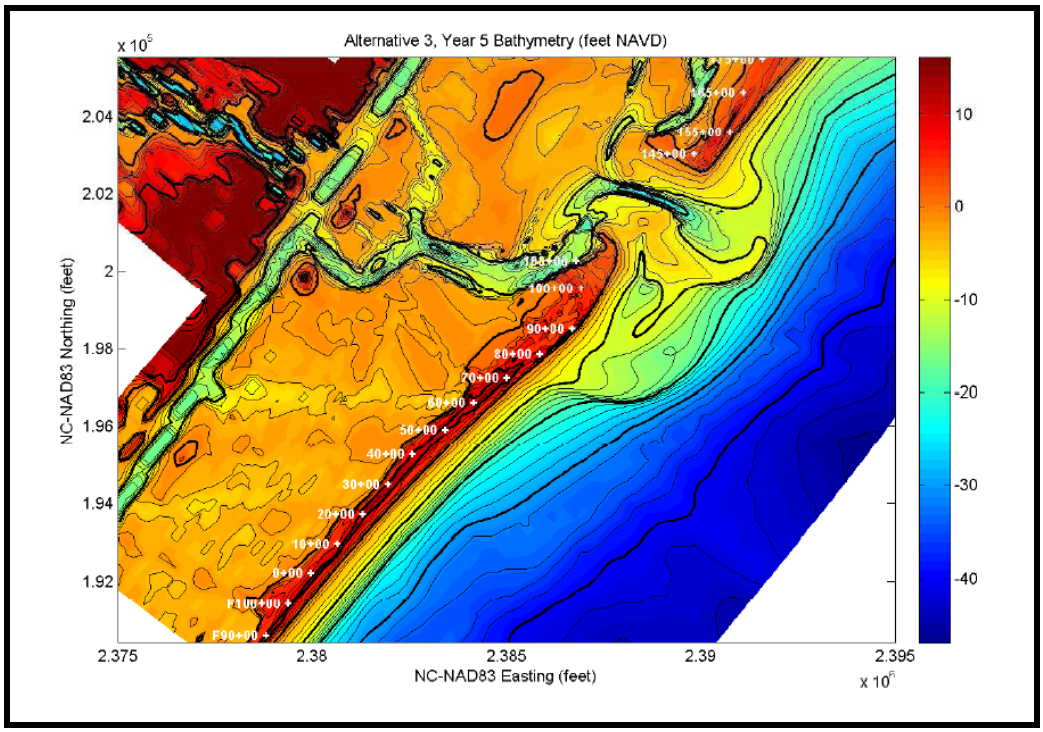


Figure 5.13. Alternative 3 – Year 5 after construction

- <u>Alternative 4</u>

Alternative 4 includes beach fill from Rich Inlet south to Bridge Road and along 1,800 feet of the Nixon Channel shoreline located behind the north end of Figure Eight Island. The beach fill along the ocean shoreline of Figure Eight Island under Alternative 4 was based on the volume of material needed to address shore erosion as indicated by the Delft3D five-year model simulation.

As with Alternative 3, the focus of shoreline changes along Figure Eight Island for Alternative 4 will be the performance of the beach fill that would be placed between Bridge Road and Rich Inlet. The Delft3D model for Alternative 4 included the existing inlet conditions as presented in Alternative 2 and included the design of the beach fill along the ocean shoreline and Nixon Channel is the same as that described for Alternative 3. The beach fill design for Alternative 3 was based on the volume of material that would be removed from the Rich Inlet complex to reposition the inlet bar channel and reconfigure the channels leading into Nixon and Green Channels not on the volume needed to address shoreline erosion issues. Therefore, as discussed below, the fill performance obtained from the Delft3D simulations for Alternative 4 was used to modify the initial fill design for Alternative 4 to reflect shore protection needs.

Volumetric changes along the southern 3,000 feet of Hutaff Island and the five (5) beach segments on Figure Eight Island determined from the results of the 5-year simulation of

Alternative 4 by the Delft3D model. The average annual volume changes over the 5-year period summarized in Table 5.3. The model results for Alternatives 2 and 3 are included in this table for comparison purposes.

Table 5.3. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 3,000 feet of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3 and 4

Alternative	Hutaff Island	Figure Eight Island Beach Segment					Fig. 8 Totals	
		F90 - 30	30 - 60	60 - 80	80 - 100	100 - 105	F90 - 100	F90 - 105
2	70,600	-4,900	-16,800	-11,800	-32,900	-25,900	-66,300	-92,200
3[(1)]	-54,900	-5,400	-31,800	-34,300	-57,400	-28,500	-128,800	-157,300
4[(1)]	85,900	-7,600	-37,900	-49,200	-86,600	-28,300	-181,300	-209,600

[(1)] A 500-foot transition or taper section extends from station 100+00 to 105+00.

Since no modifications were made to Rich Inlet or the connecting channels under Alternative 4, the south end of Hutaff Island behaved in a manner similar to Alternative 2, gaining an average of 85,900 cubic yards/year compared to 70,600 cubic yards/year computed for Alternative 3.

Volumetric losses from the beach fill for Alternative 4 between stations F90+00 and 105+00 averaged 209,600 cubic yards/year over the 5-year simulation period which is about 33% greater than Alternative 3. The biggest difference in the performance of the beach fill occurred in the beach segment between 80+00 and 100+00 where erosion removed the entire fill by year 3 of the simulation and progressed into the existing upland area.

The time history of the fill performance for Alternative 4, given in terms of the percent of fill remaining in the four beach segments between F90+00 and 100+00 and the main fill area from F90+00 to 100+00 after each year of the 5-year simulation, is given in Table 5.4. Again, this performance is based on a beach fill having the same size as Alternative 3. The negative values in this table indicate erosion into the existing upland area.

Table 5.4. Percent of Alternative 4 initial beach fill volume remaining after each year of the 5-year Delft3D model simulation

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 30	95.5%	98.6%	94.2%	92.7%	84.1%
30 to 60	57.5%	63.3%	57.9%	45.7%	35.9%
60 to 80	71.7%	64.1%	46.9%	28.9%	15.3%
80 to 100	72.6%	32.8%	-3.6%	-26.2%	-39.1%
Main Fill Area (F90 to 100)	73.3%	62.7%	46.0%	31.7%	20.4%

The Alternative 4 beach fill performed essentially the same as the Alternative 3 fill between F90 and 30, retaining almost 84% of the initial fill volume over the 5-year simulation period (Figures 5.14 through 5.19). Over the first three years of the simulation, the Alternative 4 beach fill performance between stations 30+00 and 60+00 matched that of Alternative 3; however, beginning in year 4, losses from the Alternative 4 fill began to exceed the losses of the Alternative 3 fill. Between stations 60+00 and 80+00, the Alternative 3 and 4 fills performed the same over the first two years but losses from the Alternative 4 fill began to increase starting in year 3 of the simulation. The difference of the performance of the fills between Alternatives 3 and 4 in the area from station 30+00 to 80+00 can be attributed to the changes in the configuration of the ebb tide delta induced by the repositioned channel associated with Alternative 3. The increased losses from the southern portions of the fill over time are also consistent with the loss of feeder material associated with the erosion in the northern beach segments.

For the area closest to Rich Inlet (80+00 to 100+00), the Alternative 4 fill experienced rapid losses with the entire fill disappearing sometime between year 2 and 3 of the simulation (Figures 5.16 and 5.17). By the end of year 5 of the simulation, this segment had lost 122,000 cubic yards over and above the volume of material included in the initial fill. The loss of the fill from this segment reduced the sediment transport to the south resulting in the higher rates of loss during the latter years of the simulation in the area between 30+00 and 80+00 as mentioned above. The performance of the fill between 80+00 and 100+00 mimics what has been observed following 6 pervious beach nourishment attempts on the north end of Figure Eight Island, some of which are documented by Dr. Cleary in Sub-Appendix A of Appendix B. While the 6 previous beach fills were relatively small (less than 300,000 cy) compared to the beach fill volume simulated for Alternative 4, all of the fill material included in these 6 beach fills was lost from the area fronting the sandbag revetments within a matter of months following placement.

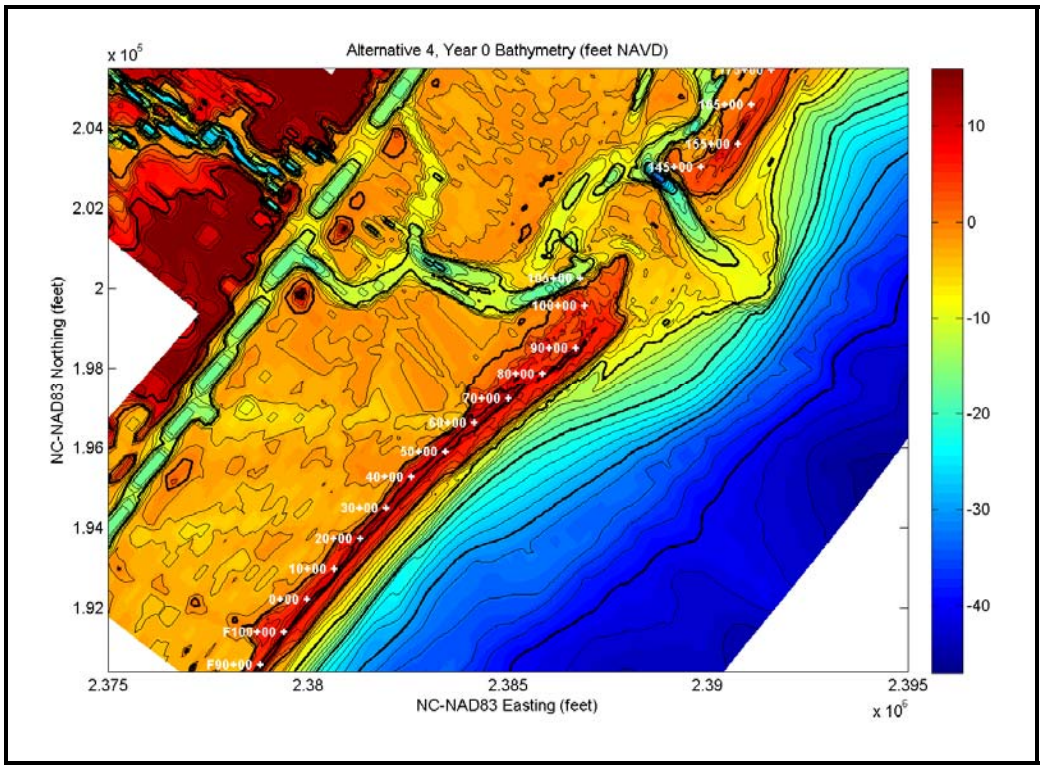


Figure 5.14. Alternative 4 – Year 0: Post-construction.

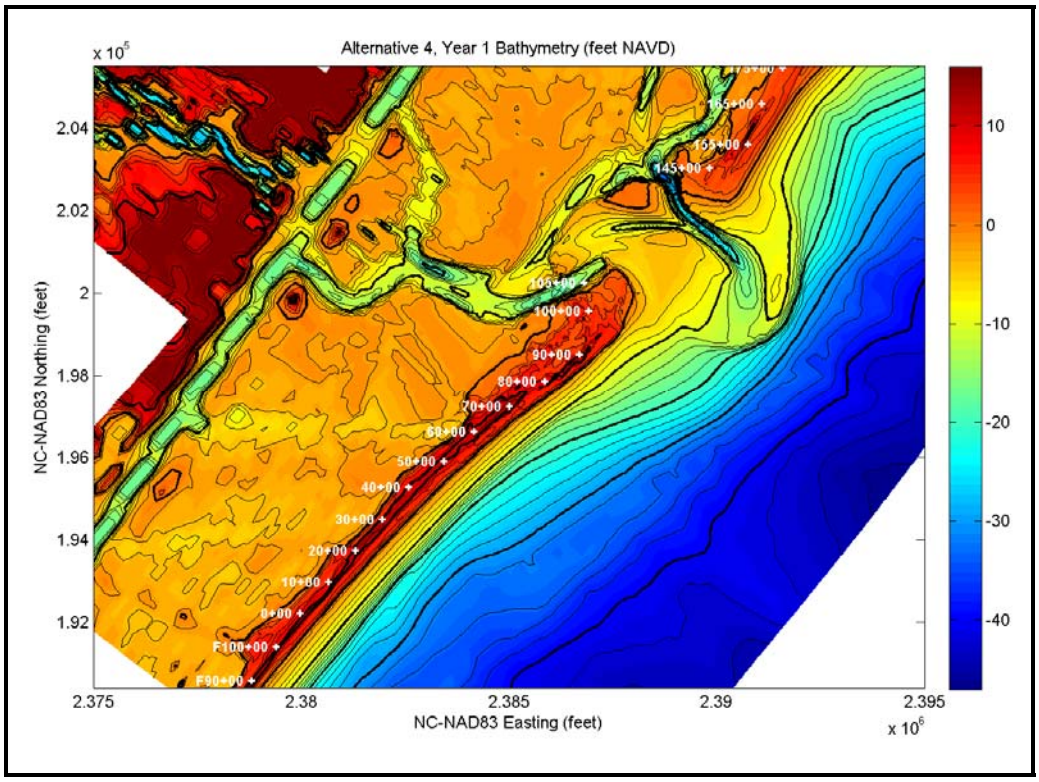


Figure 5.15. Alternative 4 – Year 1 after construction

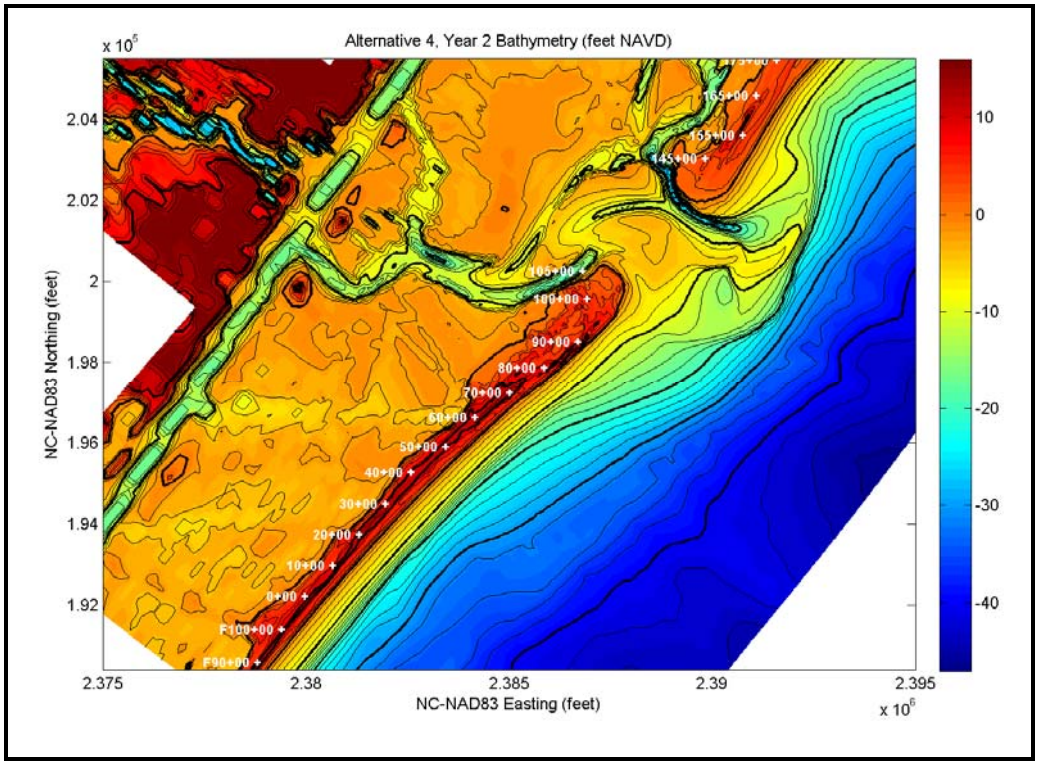


Figure 5.16. Alternative 4 – Year 2 after construction

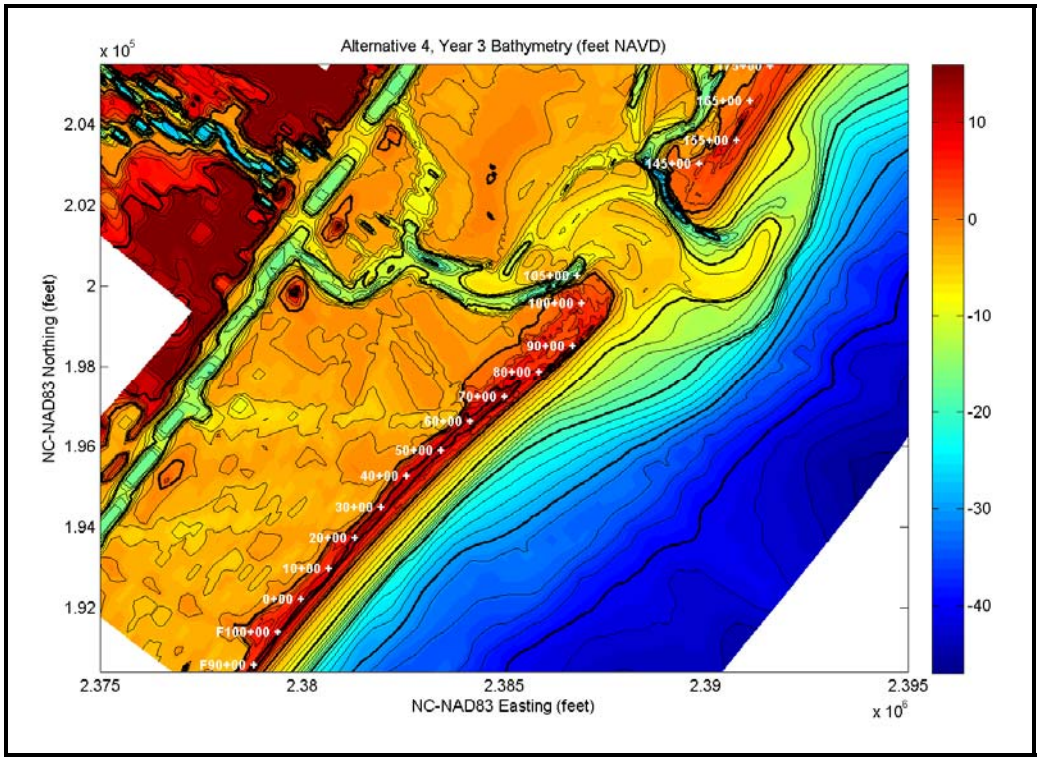


Figure 5.17. Alternative 4 – Year 3 after construction

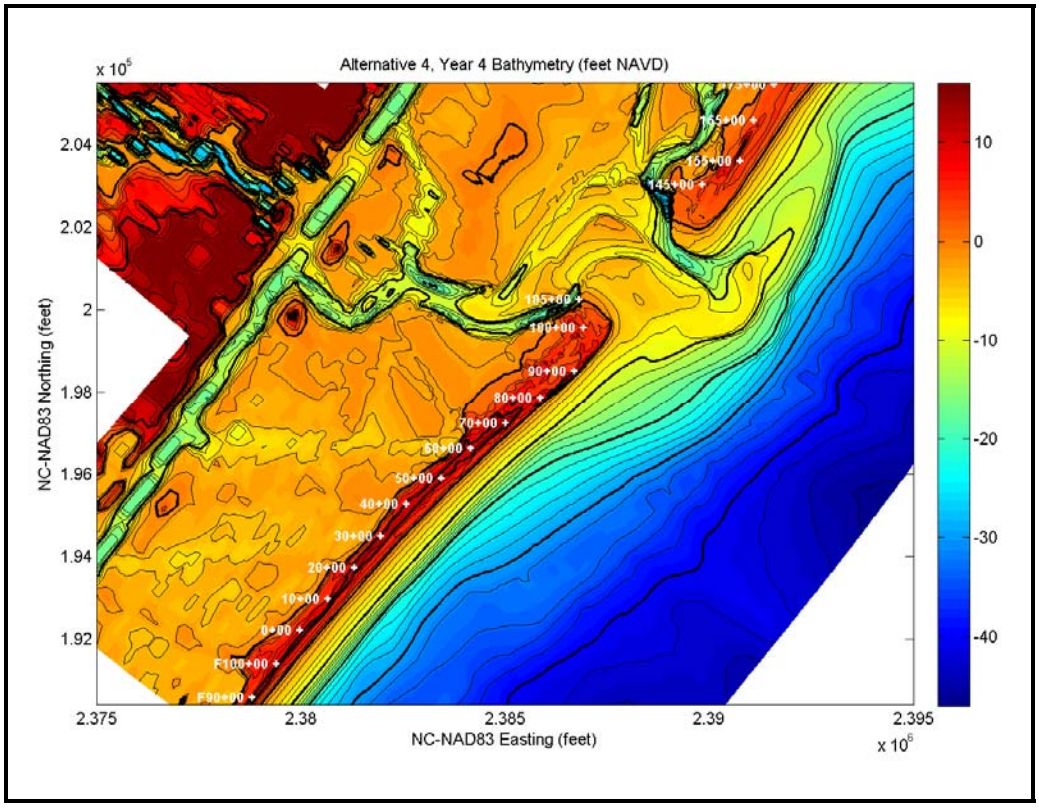


Figure 5.18. Alternative 4 – Year 4 after construction

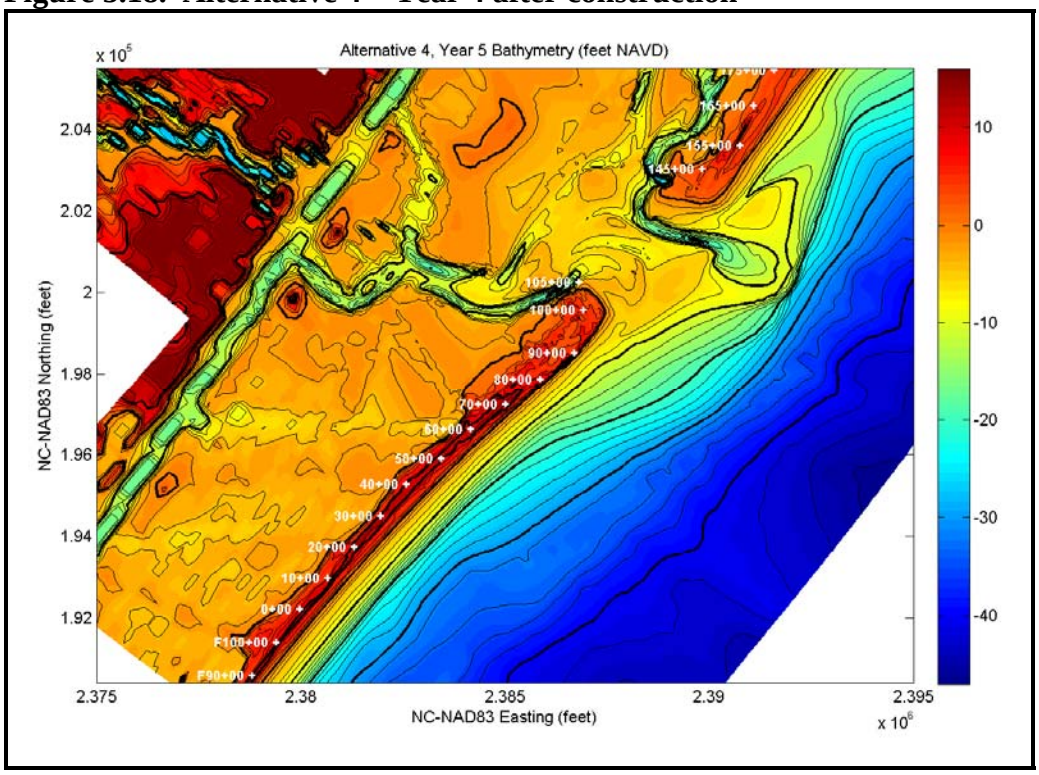


Figure 5.19. Alternative 4 – Year 5 after construction

As was the case for Alternative 2, the sand spit on the north end of Figure Eight Island disappeared over the five-year simulation converting the area into a submerged sand flat.

As mentioned above, the performance of the beach fill under Alternative 4, as presented in Table 5.3, was used to re-design the initial beach fill by reducing the initial fill volume in the area between stations F90+00 and 80+00 and increasing the volume between stations 80+00 and 100+00. Also, since the model indicated high rates of loss for the area between 80+00 and 100+00 during the first three years of the simulation, the design of the fill for Alternative 4 was based on a three-year nourishment cycle.

As shown in Table 5.11, over 50% of the fill volume remained in the area between F90+00 and 80+00 at the end of 3 years indicating the fill volume used in the model simulation was over designed and could be reduced. Likewise, the model indicated erosion into the upland area between stations 80+00 and 100+00 by the end of year 3 indicating more material would be needed in this area. The re-designed fill distribution for Alternative 4 is provided in Table 5.5 with the total fill volume along the ocean shoreline equal to 864,300 cubic yards. This is about 309,900 cubic yards less than the fill for Alternative 3 which again was based on the volume of material to be removed to reconfigure Rich Inlet. The Nixon Channel shoreline would also receive 65,000 cubic yards resulting in a total fill volume under Alternative 4 of 929,300 cubic yards.
At the end of 3 years, the amount of initial fill remaining ranged from 17.1% for the area between stations 30+00 and 80+00 to 13.6% for the area from stations 80+00 to 100+00.

Table 5.5. Alternative 4 Oceanfront Beach Fill Placement Volumes and Design Berm Widths

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

As mentioned previously, the beach fill between stations F90+00 and 30+00 performed very well and would not require periodic nourishment on a regular basis. North of baseline station 30+00, modeled losses from the fill over three years totaled 602,000 cubic yards with over 50% of the volume loss occurring north of station 80+00. Replacement of the transition section between 100+00 and 105+00 would require 50,000 cubic yards while nourishment of the Nixon Channel fill would require 18,000 cubic yards

every three years resulting in a three (3) year nourishment requirement for Alternative 4 of 670,000 cubic yards.

Changes indicated by Delft3D modeling along the southern 3,000 feet of Hutaff Island were similar to the changes computed for Alternative 2, the without project condition. The model results indicated a slight increase in the accretion rate on the south end of Hutaff compared to Alternative 2. As mentioned above, this small increase in the accretion rate may have been due to higher rates of sediment transport into Rich Inlet associated with the erosion of the artificial fill on Figure Eight Island.

- Alternative 5A

The channel connecting Nixon Channel to the inlet gorge shoaled rather rapidly during the first two years of the simulation. The channel also migrated northwest eventually merging with the channel that skirts around the landward lobe of the flood tide delta. Following this initial two year adjustment, shoaling decreased with the channel actually experiencing some scour during the last year of the simulation. The beach fill placed along the Nixon Channel shoreline did provide some erosion protection during the 5-year simulation period.

Between year 3 and year 5 of the simulation, the general response of Rich Inlet under Alternative 5A was very similar to that observed under Alternative 2 (the without project condition). This included the inlet ocean bar channel assuming an orientation towed Hutaff Island which resulted in the buildup of material in the ebb tide delta on the north side of Rich Inlet and the elongation of the south end of Hutaff Island into Rich Inlet. As was the case in model runs for Alternative 2, the sand spot projecting off the north end of Figure Eight Island morphed from a subaerial feature to a subaqueous feature. The artificially created fillet south of the terminal groin experienced some initial losses, but appeared to stabilize over the northernmost 1,000 feet by the end of year 5.

The Delft3D model shows that the beach segment between F90+00 and 30+00 gained material over the 5-year simulation (Table 5.5). This was apparently due to higher rates of sand transport to the south out of the northern beach segments. As noted previously, the fill distribution density in the area immediately south of the terminal groin would create a large seaward bulge in the shoreline that was conducive to horizontal spreading of the fill material southward of the nodal point.

Beginning in year 2, fill performance between 30+00 and 60+00 appeared to reduce sediment losses as a result of the terminal groin resulting in essentially a stable to slightly accretionary beach between years 2 and 5.

In the beach segment between 60+00 and 80+00, the beach fill only lost about 10% of the initial placement volume during the first two years of the simulation (Table 5.6). Losses from this segment began to increase in year 3 and continue through year 5 with the increased loss rate corresponding to losses from the adjacent northern beach segment and

the associated reduction in sand supply. For the most part, volume losses from the northern 2,000 feet of shoreline on Figure Eight Island occurred offshore as a relatively wide dry sand beach remained south of the terminal groin throughout the 5-year simulation.

Table 5.6. Percent of Alternative 5A initial beach fill volume remaining after each year of the 5-year Delft3D model simulation

Beach Segment	Percent of Beach Fill Remaining after:				
	1 year	2 years	3 years	4 years	5 years
F90 to 30	110.0%	112.0%	118.2%	130.4%	134.2%
30 to 60	61.8%	78.7%	80.3%	82.1%	84.4%
60 to 80	89.9%	90.6%	79.8%	68.9%	65.3%
80 to 100	77.7%	56.5%	36.9%	29.1%	17.0%
Main Fill Area (F90 to 100)	82.2%	76.6%	67.0%	63.6%	58.5%

The average annual rate of volume change in the five shoreline segments on Figure Eight Island, defined previously, and the southern 3,000 feet of Hutaff Island derived from the five (5) year Delft3D model simulation for Alternative 3 are summarized in Table 5.7. The volume changes for these same beach segments computed for Alternatives 2, 3, and 4 are also included in the table for comparison purposes.

Table 5.7. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 3,000 feet of Hutaff Island obtained from the Delft3D model for Alternatives 2, 3, and 5A

Alt.	Hutaff Island	Figure Eight Island Beach Segment					Fig. 8 Totals	
		F90 - 30	30 - 60	60 - 80	80 - 100	100 - 105	F90 - 100	F90 - 105
2	70,600	-4,900	-16,800	-11,800	-32,900	-25,900	-66,300	-92,200
3[(1)]	-54,900	-5,400	-31,800	-34,300	-57,400	-28,500	-128,800	-157,300
4[(1)]	85,900	-7,600	-37,900	-49,200	-86,600	-28,300	-181,300	-209,600
5A[(2)]	30,600	9,900	-5,500	-13,000	-67,000	-16,400	-75,700	-92,100

[(1)] A 500-foot transition or taper section extends from station 100+00 to 105+00.
[(2)] Beach fill ends at terminal groin (station 100+00).

The southern 3,000 feet of Hutaff Island accreted under Alternative 5A with the rate of accretion being about 43% less than that determined for Alternative 2 (without project condition). As was the case under Alternative 2, the accretion on the south end of Hutaff Island was due to bar channel of Rich Inlet assuming an alignment toward Hutaff Island which resulted in a significant buildup of material in offshore area off the north end of the island. However, the northward orientation of the bar channel under Alternative 5A did not develop to the same extent as Alternative 2 which deceased the rate of accretion.

Along the salt marsh shoreline facing the entrance of Rich Inlet, currents are expected to be reduced slightly as flow is shifted from the back channel into the new dredge cuts thereby reducing potential shoreline and salt marsh erosion at that location.

Figure Eight Island.
The main focus of shoreline changes along Figure Eight Island for Alternative 5A was on the performance of the beach fill that would be placed between Bridge Road and Rich Inlet.

Volumetric losses from the beach fill for Alternative 5A between stations F90+00 and 100+00 averaged 75,700 cubic yards/year over the 5-year simulation period, with the highest loss between stations 80+00 and 100+00 at year 3. As noted above, the design of the beach fill for Alternative 5A included a much higher concentration of fill north of station 75+00 to artificially create an accretion fillet south of the terminal groin. The bulbous shape of the fill induced high rates of sediment transport out of this area to both the north and south. The high rate of loss from this area indicates the width of the fill and the volume of material placed in the fillet area could be reduced without losing any functionality.

The high rates of loss for the area between 80+00 and 100+00 were primarily attributable to losses that occurred seaward of the end of the terminal groin as the upper portion of the beach remained fairly stable (see Figures 5.20 through 5.25). The model results support the movement of sediment past the terminal groin and into Rich Inlet while the retention of material in the upper part of the beach profile would provide a more-or-less permanent increase in the protective beach fronting the ocean front structures in this area.

Changes in the morphology of Rich Inlet and the adjacent shorelines over the 5-year simulation for the 700-foot groin selected for Alternative 5A are shown in Figures 5.20 to 5.25.

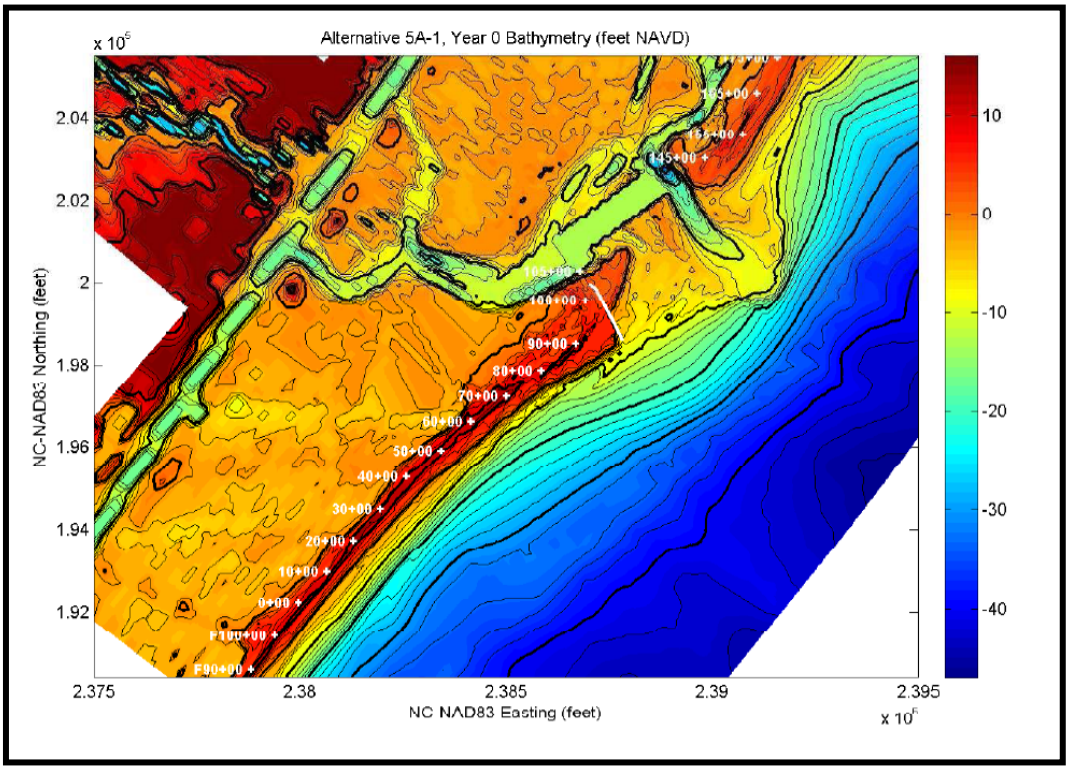


Figure 5.20. Alternative 5A – Initial post-construction condition

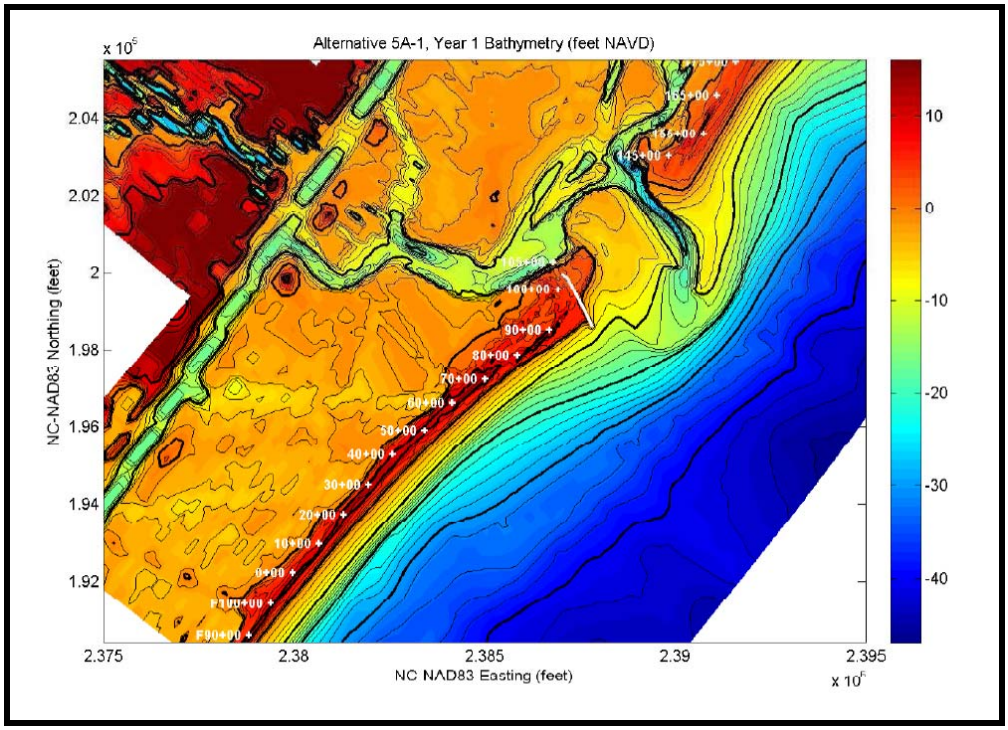


Figure 5.21. Alternative 5A– After one (1) year

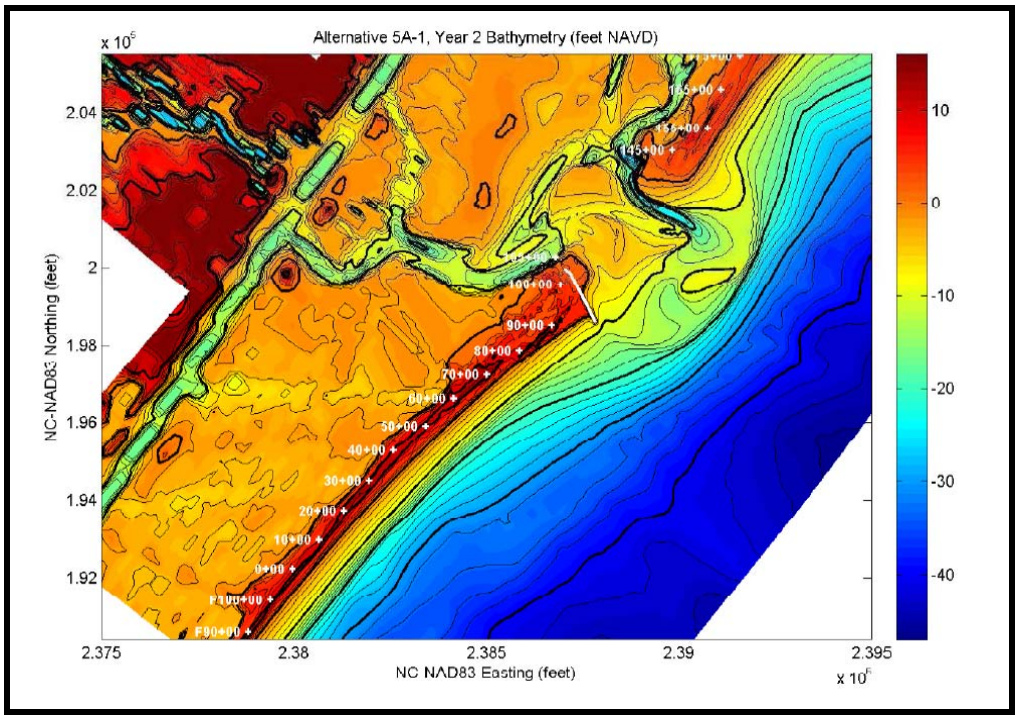


Figure 5.22. Alternative 5A– After two (2) years

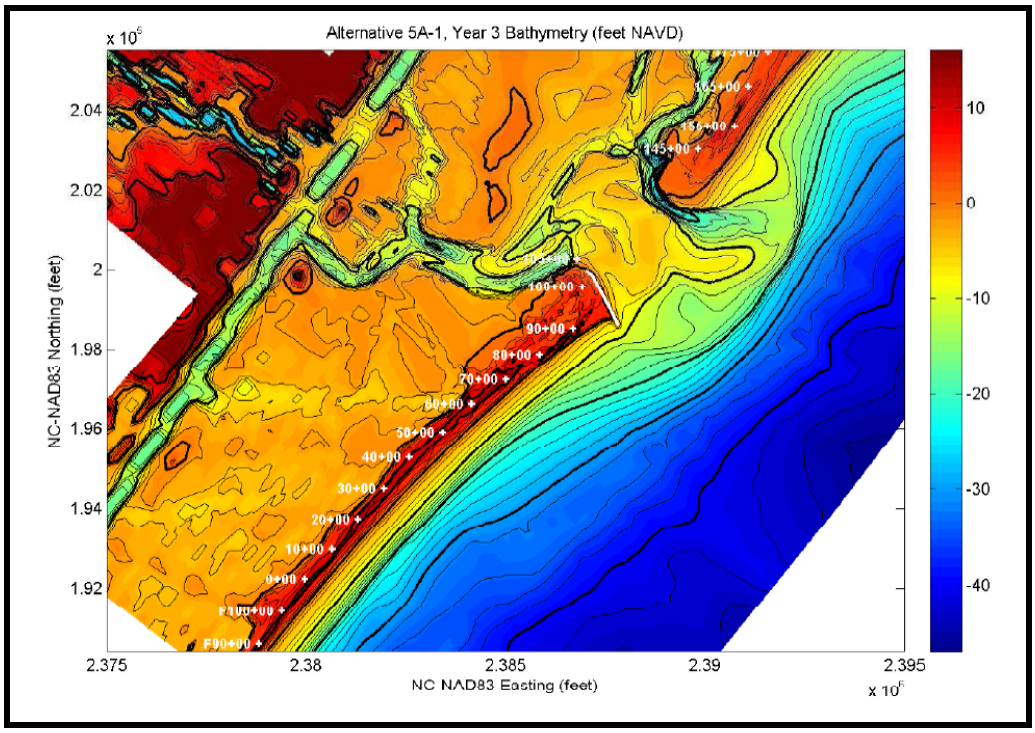


Figure 5.23. Alternative 5A– After three (3) years

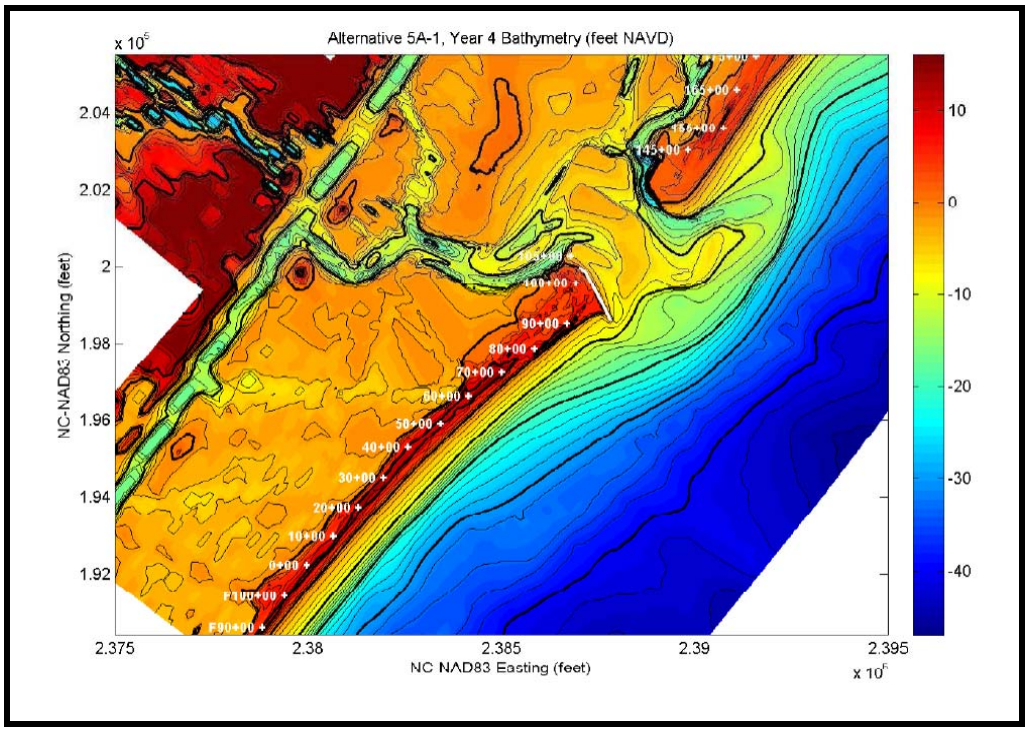


Figure 5.24. Alternative 5A– After four (4) years

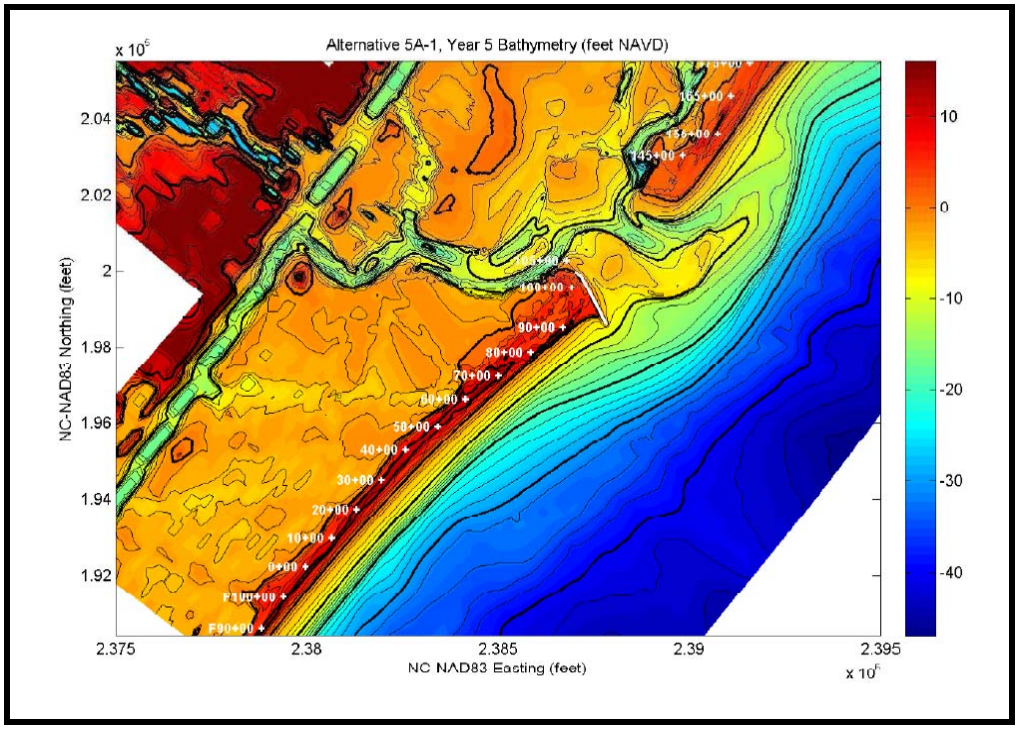


Figure 5.25. Alternative 5A– After five (5) years

In early 2010, the State of North Carolina explored the environmental impacts attributable to a series of five (5) terminal groins located in Florida and North Carolina within the "North Carolina Terminal Groin Study Final Report" (NCDENR, 2010). This report included a review of past scientific, engineering, and publicly accessible information and data related to the five terminal groin projects. Environmental natural resources evaluated included benthic resources, shorebirds and waterbirds, fisheries, coastal habitats and associated biota, and federally protected species, such as sea turtles and piping plovers. Amongst the conclusions drawn from the report, it stated that "the environmental effects of a terminal groin structure alone could not be assessed for the sites without considering the associated beach nourishment activity" (NCDENR, 2010). Because Alternative 5A includes a beach nourishment project to be constructed in conjunction of the terminal groin, the findings from the study would generally apply and are therefore included below where applicable.

One of the terminal groin structures used in the NCDENR report was the Oregon Inlet terminal groin located in the Outer Banks of North Carolina. In 1989, the North Carolina Department of Transportation (NCDOT) initiated construction of the Oregon Inlet terminal groin on Pea Island National Wildlife Refuge to provide protection from erosion occurring along the base of the Herbert C. Bonner Bridge, which spans the Oregon Inlet and connects Hatteras Island to the mainland, in Dare County. Permit stipulations required regular monitoring of the physical conditions along a six mile segment of the shoreline extending from the terminal groin southward on Pea Island. This post-monitoring was initiated after the completion of the terminal groin in 1991. As of June 2, 2011, results have shown that the project erosion rates are much less than historical rates in the first four miles of the study area (Overton, 2011). In the fifth and sixth mile, the rates are closer to the historical rate; however, they do not exceed the historical rate at any point. Overton (2011) points out that the construction of the groin has not appeared to have caused adverse impacts to the shoreline over the six-mile study area. It should be noted that since 1991, a total of 4.3 million cubic yards of material from the dredging of Oregon Inlet by the USACE has been placed on the beach or immediately offshore of the beach within the study area. It is presumed that the placement of the terminal groin has help retain a net of 18.7 million cubic yards of material on the beaches within the study area (Overton, pers. comm.). In summary, as stated above, the construction of the groin does not appear to have caused an adverse impact on the shoreline over the six mile study area (Overton, pers. comm.; Overton, 2011). Also, it may be presumed that some of this decrease of erosion can be attributed to the placement of the material along this stretch of shoreline. Following the construction of the terminal groin on Pea Island, piping plover nesting activity increased. This was, however, most likely associated with the development of an ephemeral pool created by NCDOT at the site, which provided foraging habitat. Once much of this ephemeral pool filled in and became vegetated, the piping plover numbers returned to pre-construction levels (Cameron, pers. comm., 2007).

The other terminal groin in North Carolina is located along the northeast beach at Fort Macon State Park adjacent to Beaufort Inlet, which is a federally maintained channel with an authorized depth of 47 feet. Outside of the DENR terminal groin report, no research

or studies to our knowledge have analyzed physical or biological changes associated with this structure. The groin and associated seawall was initially constructed in 1961-1962 in response to the westward migration of the inlet shoulder induced by the projection of Shackleford Point into the inlet. The beach erosion structures were built in phases and reached completion in 1970. The resulting structure included a seawall-terminal groin system 2,250 feet in length. However, the original groin only extended about 1,100 feet seaward of the pre-construction shoreline. Today, much of the groin is buried in dry beach.

- Alternative 5B

Alternative 5B includes the same terminal groin as Alternative 5A and beach fill along the Nixon Channel shoreline but a much smaller ocean shoreline beach fill in terms of volume and lineal extent. In this regard, the ocean shoreline beach fill would begin at the terminal groin and extend south to station 60+00. The portion of the fill between stations 80+00 and 100+00 (terminal groin) was designed to pre-fill the accretion fillet area that would be associated with the installation of the terminal groin. South of station 80+00, the design of the beach fill was based on the volume needed to prevent erosion from encroaching into the pre-fill beach and dune area. Based on the modeled shoreline behavior with a terminal groin, no initial beach fill would be needed south of station 60+00 to Bridge Road. However, this area would be included in the shoreline monitoring program and could be nourished in the future should conditions warrant.

The Delft3D model was run with just the terminal groin in place and no beach fill in order to evaluate the impacts of the terminal groin on shoreline changes and assist in the formulation of a beach fill design that would only address the shoreline erosion issue. The results of this simulation are, designated as Alternative 5B – no fill, provided in Table 5.8. The results for the other alternatives previously discussed are also included in Table 5.8 for reference purposes.

Table 5.8. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 3,000 feet of Hutaff Island obtained from the Delft3D for Alternatives 2, 3, 5A, and 5B.

Alternative	Hutaff Island	Figure Eight Island Beach Segment					Fig. 8 Totals	
		F90 - 30	30 - 60	60 - 80	80 - 100	100 - 105	F90 - 100	F90 - 105
2	70,600	-4,900	-16,800	-11,800	-32,900	-25,900	-66,300	-92,200
3[(1)]	-54,900	-5,400	-31,800	-34,300	-57,400	-28,500	-128,800	-157,300
4[(1)]	85,900	-7,600	-37,900	-49,200	-86,600	-28,300	-181,300	-209,600
5A[(2)]	30,600	9,900	-5,500	-13,000	-67,000	-16,400	-75,700	-92,100
5B – no fill[(3)]	29,400	2,800	-4,300	-2,100	-14,700	-20,200	-18,400	-38,600

[(1)] A 500-foot transition or taper section extends from station 100+00 to 105+00.
[(2)] Beach fill ends at terminal groin (station 100+00).
[(3)] Rates without beach fill.

Like Alternative 5A, installation of a terminal groin on the south side of Rich Inlet induced accretion of the shoreline between stations F90+00 and 30+00. Based on these

model results, no beach fill would be needed in the segment between stations F90+00 and 30+00. Also, no initial beach fill is needed between stations 30+00 and 60+00 as the computed rate of volume loss is equivalent to a shoreline retreat rate of approximately 1.2 feet/year which would not pose any immediate threat to existing ocean front development.

While the sections of the shoreline lying between stations F90+00 and 60+00 would not receive any initial fill under Alternative 5B, the Delft3D model results for Alternative 5A shows that some of the material eroded from the fill placed north of station 60+00 is likely be transported south which would serve to reduce erosion rates in these areas. In any event, the shoreline south of station 60+00 would be continually monitored and if future conditions warrant, the area between stations F90+00 and 60+00 could be included in future periodic nourishment events associated with Alternative 5B.

As was the case for Alternative 5A as well as Alternatives 2 and 4, the Delf3D model indicated the spit on the north end of Figure Eight Island would be converted to a submerged sand flat by the end of the 5-year simulation.

Under Alternative 5B, the south end of Hutaff Island would be expected to respond in a manner similar to that of Alternative 5A; that is the south end of the island should accrete but at a reduced rate compared to Alternative 2.

Sea Level Rise.

Many physical processes have the potential to influence shoreline change, sea level rise being one of them. The International Panel on Climate Change (IPCC, 2007) has concluded that global mean sea level rose at an average rate of about 1.7 ± 0.5 mm/year during the twentieth century. Recent climate research has documented global warming during the twentieth century, and has predicted either continued or accelerated global warming for the twenty-first century and possibly beyond (IPCC, 2007). This rate is anticipated to increase over the next 100 years. Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft) to 1.4 m (4.6 ft) above the 1990 level. For the State of North Carolina, The CRC is currently drafting a state policy on sea level rise rates to help the North Carolina coastal communities prepare for potential effects in the future. Presently, the predicted rate of increase used for planning purposes is 1.0 m (3.3 ft) by 2100 (Miller, pers. comm.).

According to www.tidesandcurrents.noaa.com, the regional trends in North Carolina show an increase of 0 to 3 mm/yr (0 to 0.00984 ft/yr), or a 0 to 1 ft/century. Guidelines from the USACE suggest that relevant sea level rise data should include a minimum of 40 years of data. Several monitoring stations within proximity to Figure Eight Island contain this level of data including stations located in Beaufort (collecting data since 1953), Wilmington (collecting since 1935), and Southport (collecting since 1933), North Carolina. Data from these stations show that the rate of increase in sea level rise in Beaufort is 0.84 ft/century while the rate in Wilmington and Southport are both 0.68 ft/century.

Sea-level change can cause a number of impacts in coastal and estuarine zones, including changes in shoreline erosion, inundation or exposure of low-lying coastal areas, changes in storm and flood damages, shifts in extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems (e.g., CCSP, 2009). North Carolina has been identified by NOAA as one of three states with significant vulnerability to sea level rise. The state possesses the largest estuarine system on the U.S. Atlantic coast, with an extensive barrier island chain, and over 2,300 square miles of coastal land vulnerable to a 1 m rise in sea level (Poulter et al, 2009).

The impacts of historic rates of rise in sea level are implicitly included in the historic shoreline change data used for Figure Eight Island. By extrapolating data from long term sea level monitoring sites located in Wilmington, NC, Southport, NC, and Beaufort, NC, rate of rise in sea level applicable to the project area is shy of 1 foot per century. Some projections suggest the rate of sea level rise could double within the next 50 to 100 years however since only a portion of the observed shoreline change rates are associated with sea level rise, doubling the rate of sea level rise would not double the historic rate of shoreline change.

No direct or indirect impacts are expected to occur as a result of sea level rise for any of the project alternatives. If sea levels continue to increase as predicted, then unmanaged areas of the dry beach and dune communities may become more vulnerable to erosion leading to negative cumulative impacts to these habitats. However, the project alternatives involving beach nourishment may help protect from these cumulative impacts. As an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these project have been in existence since 1965 (44 years) and have been subjected to the same rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects with and without sea level rise shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects.

4. What other projects occurring or being implemented within the vicinity of Figure Eight Island may cumulatively affect this project?

There are a number of shoreline protection activities which have occurred or are scheduled to occur on or in proximity to Figure Eight Island. These activities, as listed below, have or could impose cumulative impacts on resources within the Permit Area.

- Maintenance of Mason Inlet with Beach Nourishment
- Maintenance of the AIWW
- Maintenance of Banks Channel
- Nixon Channel Maintenance with Beach Nourishment

Refer to Appendix F, the Cumulative Effects Assessment, for more information regarding each project.

What are Direct, Indirect, and Cumulative Impacts?

The CEQ regulations (40 CFR §§ 1500 -1508) define the impacts and effects that must be addressed and considered by Federal agencies in satisfying the requirements of the NEPA process.

Direct impacts are caused by the action and occur at the same time and place.

Indirect impacts are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable.

Cumulative impacts are the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions.

5. What are the general environmental impacts associated with the project?

The various environmental consequences associated with the alternatives are described within the section. While each alternative contain unique features, several of these alternatives include similar actions which will elicit comparable environmental consequences. These include dredging and/or beach nourishment, which are associated with Alternatives 1, 3, 4, 5A, and 5B. The environmental impacts associated with these actions are described below.

General Environmental Consequences Related to Dredging

The general environmental impacts of dredging include a direct temporary increase in turbidity and TSS within the water column. Sediment loading increases turbidity and TSS, which can result in a decrease in biological productivity, clogging of fish gills, and reduced recruitment of invertebrates. Furthermore, turbidity can suppress SAV growth, cause low oxygen events leading to fish kills, and cause mortality of organisms in the substrate, including oysters. High concentrations of suspended solids can cause many problems for aquatic life. High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight (Mitchell and Stapp, 1992).

Dredging within the permit area is expected to result in temporary increases in suspended sediment or particulates and turbidity in the immediate area of construction activity. Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates.

Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Turbidity values at control sites located approximately 10,000 feet from the location of the fill operation averages 7.7 NTU while TSS values averaged 47.7. During the Bogue

Inlet Channel Erosion Response Project, turbidity levels were shown to remain within ambient conditions (9.7 to 35.2 NTUs) during the dredging operations. The State standard for turbidity is 25 NTU while TSS does not have a defined standard. Any increase in turbidity associated with the excavation of the channels to the oceanfront shoreline should be of short duration. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area. Storm events are known to increase these levels due to the resuspension of sand and fine materials. These fluctuating turbidity levels would continue with or without the dredging efforts proposed with these alternatives. No cumulative effects are expected to occur from the dredging and placement activities. Turbidity would be anticipated to be elevated only immediately adjacent to the dredge operation and would only persist while dredging and the subsequent beach filling occurs. These short term direct impacts could result in the clogging of fish gills.

Dredging activity will also impact infaunal resources. Dredging results in a direct mortality of all organisms present within the dredged material (Posey and Alphin, 2002). Although the recruitment pattern is altered, the recovery of species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Street *et al*., 2005; Posey and Alphin, 2002). At dredge sites monitored off the coast of New Jersey, infaunal assemblages recovered within one year after disturbance, while biomass and taxonomic richness took 1.5 to 2.5 years to recover (Street *et al*., 2005). The diversity of micro and macrofauna tend to be dominated by opportunistic species that recover quickly when affected by natural causes (Mallin *et al*., 2000; Street *et al*., 2005; Posey and Alphin, 2002). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). Posey and Alphin (2002) suggests that effects of beach nourishment from dredging of an offshore borrow area is minimal compared to the natural variability of the system. The temporal spacing between the periodic maintenance events within the proposed dredged areas should allow for full recovery of benthos populations.

Dredging activities are scheduled to occur between November 16th and March 31st. 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, and the seabeach amaranth flowering period. Fish and larval biota which utilize the channel within the inlet are not anticipated to be impacted during dredging because the dredge will be positioned outside of the main channel utilized by these resources for ingress and egress from the inlet. Also, sand placement and dredge operation conducted outside of primary invertebrate production and recruitment periods (spring and fall) limit impacts to amphipods, polychaetes, crabs and clams.

A hydraulic cutter-suction pipeline dredge (pipeline dredge) would be used for Alternatives 1, 3, 4, 5A and 5B. In addition to the pipeline dredge, Alternative 4 would involve the use of a hopper dredge with direct pumpout capabilities to transport material to the beach from the offshore borrow site(s). As opposed to hopper dredges, pipeline

cutterhead dredges are mounted (fastened) to barges and are not usually self-powered. Rather, they are towed to the dredging site and secured in place by special anchor piling, called spuds. A pipeline dredge sucks dredged material through one end, the intake pipe, and then pushes it out the discharge pipeline directly into the disposal site. Hopper dredges dredge material into their containment areas. The water portion of the slurry is drained from the material and is discharged from the vessel during operations. When the hoppers are full, dredging stops and the ship travels to a pump-out station located on an offshore barge. The dredge locks up with the station and empties the sediment via pipeline and the material is pumped to the onshore disposal site. The use of hopper dredges often results in a higher rate of turbidity and TSS.

Compared to similar types of dredging methodologies, a pipeline dredge creates minimal disturbance to the seafloor resulting in lower suspended particulates 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., pipeline dredge) 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. The utilization of a pipeline dredge minimizes safety and navigational concerns as the dredge will be well lit, stationary, and will include usage of buoys to mark the location of anchors. Unlike a hopper dredge, no incidences of sea turtle takes from a pipeline 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.

DREDGEPAK® or similar navigation and positioning software will be used by the contractor to accurately track the dredge location. 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 will also provide a display of theoretical volume quantities removed during actual dredging operations.

As with typical dredging and beach nourishment activities, the work includes the use of a dredge plant, pipelines, support barges, and bulldozer equipment. In the case of hopper dredges, a mooring barge would be position just offshore to allow the dredge to connect with pipelines leading to the beach. Work generally occurs on a 24 hour/7 days a week schedule within the dredging window resulting in the presence of equipment within navigable waters and along the shoreline. During that time, navigation within the work zone is prohibited for safety reasons disrupting use of certain travel areas. Dredgers are required to operate within United States Coast Guard requirements to reduce the potential of boat accidents. In addition to navigation, the presence and operation of the equipment on the land and water can result in an increase of noise and aesthetics within the localized area. This is expected to last for the extent of the operation.

General Environmental Consequences Related to Beach Fill

Along with dredging activities, the placement of beach compatible material will also impact several resources. The placement of beach fill material will impact the infaunal resources found within the wet beach community as well as nesting turtles and nesting, resting, and foraging birds found along the dry beach community. The addition of beach fill to Figure Eight Island will cause short-term direct impacts to the adjacent wet beach community. Beach fill material will equilibrate offshore where it will, at least temporarily, cover the softbottom community. As an example, results from an infaunal monitoring following the beach nourishment associated with the Bogue Inlet Channel Relocation Project at Emerald Isle, NC demonstrated that infaunal species found in the marine intertidal (wet beach) environment decreased in population immediately following construction (Carter and Floyd, 2008). Amphipods, an important food source for fisheries and bird resources, showed the slowest recovery, as it was documented that they had not reached pre-construction population levels until 17 months following the beach fill project. During the same time frame, coquina clam populations found along beach filled areas had converged with populations in nearby control sites indicating recovery (Carter and Floyd, 2008). Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. This may support the reasoning for some organisms to withstand burial up to 10 cm. Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species are capable of burrowing through sand up to 40 cm. Although the wet beach infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate, short-term negative impacts specifically in areas where beach fill will exceed 40 cm in conjunction with the compaction or pushing of fill from bulldozers leveling the material as it is being placed on the beach. Although the marine intertidal infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate, short-term negative direct impacts. Rakocinski *et al.* (1996) found that the mole crab populations exhibited a pattern of initial depression after being covered by sediment but fully recovered in less than one year after beach nourishment. Temporary burial of infaunal organisms could indirectly affect the birds and fish that forage on these organisms in the short and long-term. Negative cumulative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events if the events are occurring within short time periods of each other and/or if the material placed on the beach is less compatible with the native beach sediment. A study by Van Dolah *et al.* (1994) found the use of fill sediments that closely match the native sediments showed an ecological recovery of infaunal species within eight months. Thus, the use of borrow area sediments that are compatible with the native beach and the proper temporal spacing between events should prevent any negative long-term cumulative impacts to the marine intertidal communities, however direct impacts may occur. Based on the documented recovery of infaunal organisms, the time intervals between

nourishment operations and the compatibility of fill material are essential to allow for the complete recovery of the organisms.

Beach nourishment presents both positive and negative effects on nesting sea turtles. In most cases where beach nourishment has taken place, the oceanfront shoreline has been greatly eroded with tidal fluctuation occurring at the base of the dune. This reduces the suitable nesting areas for sea turtles and destroys nests with eggs that have been established. As a result of beach fill, wider beaches can benefit sea turtles since they require dry beaches to nest, preferring to nest along wide sloping beaches or near the base of the dunes. Potential adverse effects on nesting habitat include alteration of beach substrate characteristics and modification of the natural beach profile. Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange can affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). Substrate alteration may affect the ability of female turtles to nest, the suitability of the nest incubation environment, and the ability of hatchlings to emerge from the nest. Escarpments formed during and after beach nourishment may prevent nesting females from reaching suitable nesting habitat, result in the selection of marginal or unsuitable nesting sites in front of escarpments, or result in nest exposure as escarpments recede landward. Numerous studies have described the effects of beach nourishment on nesting success (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999). These studies indicate a reduction in nesting success during the first post-nourishment year, followed by a return to normal levels by the second or third year. Declines in nesting success have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile. Beach nourishment also has the potential to improve poor quality nesting habitats associated with chronically eroded beaches (Brock et al. 2009). Davis et al. (1999) and Byrd (2004) documented increases in nesting success immediately following the nourishment of eroded beaches. Increases in nesting success were attributed to the addition of dry beach habitat.

Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment, leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995). Nourished beaches often retain more water than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996). Uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures. Dark sediments may produce nest temperatures that are too high for successful embryonic development (Matsuzawa et al. 2002). Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2004). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects

on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000), negative effects (Ehrhart 1995, and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009).

The turbidity plume at the disposal end of the pipeline does not usually increase above ambient conditions when the material being dredged is of a coarse grain size as this material typically settles rapidly compared to finer material, as observed during the dredging and inlet relocation at Bogue Inlet in 2005. The increase in dry beach as a result of beach nourishment is also expected to positively affect the shorebirds, water birds and colonial birds that utilize this habitat. Several bird species utilize this habitat for roosting, foraging and nesting. Typically, the placement of beach compatible material serves to protect the dunes and beaches thereby causes positive direct and indirect impact. These events generally do not occur on a regular basis and the periodic loss of habitat utilized for foraging/resting shorebirds will continue.

6. What are the environmental and economic impacts associated with each specific alternatives?

The following sections describes the additional environmental and economic impacts anticipated for each alternative being considered.

A: IMPACTS ASSOCIATED WITH ALTERNATIVE 1: NO ACTION

Under Alternative 1, the Figure 8 HOA and individual property owners would continue to respond to erosion threats in the same manner as in the past. These measures include beach scraping (or bulldozing) to create and/or repair damaged dunes, intermittent beach nourishment, and the deployment of sandbags (Figure 1.1). As stated earlier, 19 homes currently have installed sandbags and several intermittent beach nourishment projects have involved varying volumes of fill ranging from 50,000 to 350,000 cubic yards along various northern reaches of the oceanfront shoreline on Figure Eight Island since 1993 (Table 5.9).

Table 5.9 Figure Eight Island's Historical Beach Nourishment on the North End

Project Date	Volume (c.y.)	Source	Profiles
Feb. 1993	274,000	Nixon Channel	60+00 to 105+00
January 1997	Not avail.	Nixon Channel	15+00 to 105+00
March 2001	350,000	Nixon Channel	0+00 to 90+00
November 2005	261,235	Nixon Channel	30+00 to 95+00
Spring 2009	295,000	Nixon Channel	67+00 to 95+00
Spring 2011	275,000	Nixon Channel	0+00 TO 95+00

The impacts associated with a continuation of existing conditions, as defined by Alternative 1, are described below.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: The salt marsh resources within the Permit Area are located primarily along the sound sides of Figure Eight, Hutaff, and the marsh islands in proximity to the Atlantic Intracoastal Waterway (AIWW). As depicted in aerial photographs taken by Geofiny, Inc. between 2006 and 2010, large quantities of sand has entered the estuary and subsequently built a very large shoal. Dr. Cleary's shoreline analysis suggests that portions of shoreline behind Rich Inlet, portions of which contain salt marsh habitat, have experienced erosion in response to the development of this large flood tide delta. While the erosion rates in this area are significantly greater than the pre-1993 rates, this increase cannot be directly attributable to dredging in Nixon Channel due to the influence of the migrating sand lobes into Nixon Channel associated with the morphological changes that have occurred to Rich Inlet since 1993. Regardless, this erosion of the salt marsh shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). Additional erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion is related to movement of the Nixon Channel thalweg toward the island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct or indirect impacts to salt marshes are expected to continue.

Cumulative Impacts: As stated earlier, the gorge within Rich Inlet has remained in place for approximately 20 years. With the main inlet being stable, it is expected that the salt marsh communities will continue to respond to naturally evolving shorelines. Salt marsh resources found along the sound side of Figure Eight and along the northern portion of the Nixon Channel shoreline could be negatively impacted due to the erosion over time.

Areas further east along this shoreline may gain salt marsh as the sand spit and large shoal migrates in response to the inlet configuration.

For Hutaff Island, some oceanfront areas may experience breaches in the primary dune due to storms and high wave action, resulting in the formation of natural washover features which may extend into adjacent high salt marsh. In this natural process, these washover areas may cause salt marsh to become inundated and transition into intertidal habitats, causing potential corresponding shifts in infaunal community composition, as well as shifts in finfish and bird community composition. Little is known about how resident species adapt to irregularly flooded marshes which are inundated for weeks at time. These resident species include, among other species, several types of fish (*e.g.*, killifish and mummichogs), brownwater snakes, crustaceans (various species of crabs), birds (yellowthroat, marsh wren, harrier, swamp sparrow, and five species of rails), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Washover events may increase if the predicted increase in the rate of sea level is validated. Therefore, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 1.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: Three confirmed and 17 probable SAV occurrences have been identified within the Permit Area (Figures 4.3a and 4.3b in Chapter 4). The three confirmed occurrences are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channel. Because the confirmed locations of existing SAV resources occur removed from to the areas experiencing erosion along Rich Inlet and Nixon Channel, impacts to SAV resources are not expected. SAV resources require light to penetrate the water column for healthy growth. A prolonged increase in turbidity and TSS would serve to decrease the amount of available light. Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. No measurements were taken in proximity to the dredge site within Nixon Channel. Temporarily increased values would not be anticipated to affect the natural long-term growth of SAV. Furthermore, cumulative impacts are not expected to be incurred as SAVs are expected to migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Direct, Indirect, and Cumulative Impacts: Due to the remote location of shellfish resources from Rich Inlet and Nixon Channel, no impacts are anticipated to shellfish resources with the implementation of the No Action alternative.

UPLAND HAMMOCK

Direct and Indirect Impacts: The activities associated with No Action alternative is not anticipated to cause direct or indirect impacts to the upland hammock resources located within the Permit Area due to the distance of the resource from the oceanfront shoreline. The closest upland hammock is located on Figure Eight Island approximately 305 m (1,000 ft.) from Rich Inlet as shown in Figure 4.1 in Chapter 4.

Cumulative Impacts: The elevation of the upland hammock communities relative to sea level will minimize direct and/or indirect impacts to occur. However, if sea level rise predictions are validated and increase at a rate of close to or less than 1 foot over the next hundred years, this community may become more vulnerable to salt water inundation leading to cumulative impacts.

INLET DUNES AND DRY BEACHES

Direct and Indirect Impacts: The current rate of erosion on the north end of Figure Eight Island is reducing habitat for shorebirds, including the endangered piping plover, and reducing recreational area for humans. The material from the dredging of the existing permit area in Nixon Channel has been utilized for periodic beach nourishment along the oceanfront shoreline of Figure Eight Island north of Bridge Road. Because these dredging activities occur sporadically and are not part of a dedicated beach nourishment project, the amount of material placed on Figure Eight Island has not been enough to overcome the current high rate of erosion. Delft3D modeling results for Alternative 2, which contains similar conditions as Alternative 1, suggest the sand spit on the north end of the island will be subject to considerable erosion over the next 5 years which will result in the loss of inlet dunes and reduction in dry beach width in the area immediately adjacent to Rich Inlet. This will result in the reduction of habitat for nesting turtles and foraging/resting shorebirds on the Figure Eight Island side of the inlet but not necessarily on the Hutaff Island side. In fact, model results suggest accretion along the north side of Rich Inlet. As a result of the sporadic beach nourishment activity on Figure Eight Island, negative impacts associated with the direct burial of infaunal species and disruption of nesting and foraging habitat will occur within the inlet dunes and dry beach areas on Figure Eight Island. Temporary burial of infaunal organisms could indirectly affect the birds that forage on these organisms. Therefore, as described above under General Environmental Consequences Related to Beach Fill, negative direct impacts to the Inlet Dunes and Dry Beaches on Figure Eight Island are anticipated with the No Action alternative.

A number of homes in proximity to the inlet beach along the extreme north end of Figure Eight Island are protected by sandbag revetments. Although these bags are anticipated to be removed in the future, the existing condition of the inlet beach is not compatible to beach users. Delft3D model results suggest that shoreline erosion will result in indirect impacts of 0-5 acres of Inlet Dunes and Dry Beaches.

Along the southern tip of Hutaff Island, the Inlet Dunes and Dry Beaches are anticipated to expand allowing for additional habitat for shorebirds and nesting sea turtles (Figure 4.19) on Hutaff Island. This is anticipated to result in positive direct impacts to the Inlet Dunes and Dry Beaches along Hutaff Island.

Cumulative Impacts: As shown by Dr. Cleary's geomorphic analysis of Rich Inlet, the habitats associated with the inlet undergo significant changes in response to the reorientation of the ebb tide delta. Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). Therefore, both positive and negative cumulative impacts to the Inlet Dunes and Dry Beaches will be incurred as part of the natural reorientation of the ebb tide delta and inlet over time.

The continued negative shoreline impacts on the north end of Figure Eight Island, including along its inlet dunes and dry beaches, will depend on how the inlet bar channel behaves. While the present orientation of the bar channel toward Hutaff Island has persisted since the mid-1990's, how long the channel will remain in this condition is impossible to predict. Based on past behavior, the bar channel is likely to naturally shift to the south and assume an alignment toward the north end of Figure Eight Island. Should this occur, the high rates of erosion on the north end of the island and the destruction of homes and infrastructure in this area could be abated for an unknown time period and the negative aesthetic impacts associated with the erosion reduced.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: As mentioned in Chapter 4, shorebirds, colonial waterbirds and other waterbirds will utilize intertidal flats and shoals in the inlet complex for foraging while traveling to their wintering and nesting grounds. Breeding and non-breeding federally threatened species and species of special concern also utilize intertidal shoals (Table 4.5). Macroinfaunal species found within intertidal flats and shoals are a primary food source for several migratory and resident shorebirds, waterbirds, as well as for many commercially and recreationally important fish. These unconsolidated communities lack structure and are dynamic in nature. Therefore, the unconsolidated and unvegetated communities that occur in the inlet complex are expected to continue to be naturally redistributed. Periodic storms and seasonal climatic changes influence abundance and diversity of micro- and macrofauna, tending toward a more opportunistic community (Mallin *et al*., 2000; Street *et al*., 2005).

Because the permitted dredging area associated with Alternative 1 does not include intertidal areas, this alternative is not expected to have direct impacts on intertidal flats and shoals. However, due to maintenance dredging-related increases in suspended sediment and turbidity (which could be transported to the interior of the inlet complex during flood stages of the tidal cycle); it could introduce minor secondary impacts. The

intertidal flat biotic community's density and abundance may fluctuate over time, but overall would remain persistent. During flood stages of the tidal cycle, dredged material that remains in suspension could be transported into the interior portions of the inlet complex and settle on the intertidal flats and shoals. However, the material shoaling the Nixon channel has a low silt content, and is fairly coarse, will result in only minor and ephemeral increases in both suspended sediment and turbidity. Delft3D modeling suggests that intertidal flats or shoals will not be impacted by this alternative. Therefore, beyond existing natural processes and the effects of navigation channel maintenance activities, no additional impacts are anticipated with Alternatives 1.

Indirect Impacts: Activities associated with Alternative 1 are anticipated to cause minimal indirect impacts to the intertidal flats and shoals due to the dynamic nature of this habitat. The infaunal species which utilize them are not anticipated to be impacted due to their resilient nature. The relatively small volume of material removed from Nixon Channel for sporadic beach fill events is anticipated to result in an impact of approximately 0-5 acres of intertidal flats and shoals within the inlet complex. Overall, the existing condition of abundant intertidal flats and shoal would be expected to persist.

Cumulative Impacts: Although intertidal flats and shoals within the permit area may be reduced during certain time periods in response to storms, the habitat will persist because the intertidal flats and shoals are considered to be ephemeral and dynamic.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct and Indirect Impacts: The direct and indirect impacts associated with Alternative 1 are expected to include a continuation of natural shoreline changes in the Permit Area. As a result, the dune community along portions of Figure Eight Island that exhibit higher erosion rates is expected to be highly susceptible to regular storm events. Currently, high tides extend to the first line of oceanfront structures on the north end of the island with 19 structures presently protected by temporary sandbag revetments installed along the seaward toe of the dune. With the State's requirement to remove the sandbags after a certain period, it is expected that the erosion will accelerate in this stretch of beach and will degrade the dune system. Continuation of erosion over the next 30 years could result in an additional 21 homes on the extreme north end of Figure Eight Island being protected by new sandbag revetments. The footprint of the sandbag revetments has a direct negative impact on the natural dunes in this area by preventing the growth of vegetation. These new sandbag structures will also have a state permit expiration date and when required to be removed, the dune communities will again be susceptible to erosion. The existing dune system along Figure Eight Island south of 302 Beach Road North has been maintained with the help of beach scraping activities which provides some beneficial protection to these dune communities.

The natural dune communities located on Hutaff Island are anticipated to migrate westward as natural processes influence the environment. Although the physical location of the dune system may change as natural overwashing and other storm-induced events occur, the dune communities at Hutaff Island are expected to remain intact with minimal direct and indirect impacts.

Cumulative Impacts: The long-term result of beach scraping, rebuilding of dunes following storms, installation of sandbag revetments, and disposal of navigation maintenance material on portions of the Figure Eight Island shoreline are not anticipated to provide adequate protection to the dune communities. As these resources remain vulnerable to storm damage, dune vegetation would most likely be threatened resulting in a degraded habitat used by several species, such as seabeach amaranth. Seabeach amaranth prefers overwash flats at accreting ends of islands and lower foredunes and upper strands of non-eroding beaches; these preferred habitats are located on the middle and southern portions of Figure Eight Island. As mentioned in Chapter 4, seabeach amaranth is an effective sand binder, building dunes where it grows. Due to lack of long-term protection against storm influenced damage, negative cumulative impacts to the dune-stabilizing seabeach amaranth, and subsequently the dune communities at Figure Eight Island in general, are expected.

The dune communities located on Hutaff Island would be expected to migrate westward as natural processes influence the environment, but the dune communities are expected to remain intact. However, if predicted increase in rates of sea level rise (Miller, pers. comm.; IPCC, 2007) is validated, this will potentially threaten the long term viability of dunes within the permit area as storm surges could degrade these resources.

Oceanfront Dry Beach Communities

Direct Impacts: The dry beach area is a high energy area that does not support much vegetation; however this habitat is utilized by several species of sea turtles and shorebirds. Beaches, as well as inshore and offshore waters, along the Atlantic Coast of the United States are important developmental habitats for many of the threatened and endangered species of sea turtles (Shoop and Kenney, 1992; Ehrhart, 1983; Keinath et al., 1987); which includes the oceanfront shoreline of Figure Eight Island (Figures 4.11-4.20).

The dry beach community along Figure Eight Island may be directly impacted differently during and following all beach nourishment, beach scraping, and sandbag installation events associated with Alternative 1. Beach nourishment activity will initially disturb the dry beach habitat due to the use of bulldozers, however ultimately it will serve to increase the amount of dry beach habitat. As described above previously General Environmental Consequences Related to Beach Fill, the infaunal communities will be directly impacted due to burial, however due to the resilient nature of these organisms and the use of compatible material, the impacts will be temporary. Beach scraping affects dry beach by

relocating sand from the lower portion of the beach (including the wet beach) to a higher area on the berm thereby causing a disturbance to the infaunal communities and the nesting and resting habitats for shorebirds including plovers, willets, and sanderlings provided by the dry beach. While sandbags may provide protection to the structures behind them, they are impermeable structures and therefore will not absorb wave energy which could cause local beach scour to accelerate. The acreage of this impacted area would be determined by the specific fill plan, which has varied in the past.

No direct impacts are anticipated to occur along Hutaff Island as a result of Alternative 1.

Indirect Impacts: Delft3D model results suggest indirect impacts of approximately 0-5 acres of oceanfront dry beach habitat would be incurred. Of this, some areas of loss would be expected on Figure Eight Island while some accretion would be expected on the extreme southern end of Hutaff Island. Although sea turtles have continued to nest along the eroding oceanfront shoreline of Figure Eight Island, the number of nests would be expected to decline due to the continued loss of suitable dry nesting beach habitat, particularly in the areas with sandbag revetments, despite sporadic beach nourishment events. Furthermore, the survival rate of hatchlings could be reduced due to possible inundation of encroaching mean high water marks through severe erosion. The reduction in dry beach habitats could also reduce the availability for humans to recreate in this environment as well as suitable habitat for the protected plant species, seabeach amaranth.

Cumulative Impacts: Although the periodic beach nourishment activities associated with Alternative 1 result in the increase of dry beach, the events are not enough to abate the chronic erosion along portions of Figure Eight Island; therefore a loss of dry beach habitat would be expected to continue over time. This would therefore result in an overall reduction of adequate turtle nesting habitat, shorebird and water bird habitat, and recreational opportunities along the oceanfront portion of the island. The continued negative shoreline impacts on the north end of Figure eight Island will depend on how the inlet bar channel behaves. While the present orientation of the bar channel toward Hutaff Island has persisted since the mid-1990's, how long the channel will remain in this condition is impossible to predict. Based on past behavior, the bar channel is likely to naturally shift to the south and assume an alignment toward the north end of Figure Eight Island. Should this occur, the high rates of erosion on the north end of the island and the destruction of homes and infrastructure in this area could be abated for an unknown time period and the negative aesthetic impacts associated with the erosion reduced. In addition, periodic dredge and fill operations would be required at a less frequent rate.

If sea levels continue to increase as predicted, then unmanaged areas of the dry beach community may become more vulnerable to erosion leading to negative cumulative impacts to the dry beach. However, an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these project have been in existence since 1965 (44 years) and have been subjected to the same

rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects with and without sea level rise shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects.

WET BEACH COMMUNITIES

Direct and Indirect Impacts: The marine intertidal community along Figure Eight Island, which includes macro infaunal species such as polychaete worms (Phylum Annelida), coquina clams (*Donax variabilis and D. paruvula*) and mole crabs (*Emerita talpoida*), will be directly impacted during and following all beach nourishment and beach scraping events associated with Alternative 1. These infaunal communities will be directly impacted due to immediate burial. However due to the rapid recruitment of these organisms and compatible beach fill material, the impacts should be temporary. Indirect impacts will affect shorebird, crustacean and fish foraging, and will impact recreational fishing through a temporary reduction in bait species during and immediately after construction.

Sandbags used to provide storm protection for threatened structures on Figure Eight Island may reduce the area of wet beach by providing a temporary barrier to the migration of wet beach along the active beach profile. These structures are generally installed when the mean hide tide is within twenty feet of a home or other infrastructure, which is the state requirement prior to authorizing oceanfront sandbags. This leaves minimal or no wet beach habitat to support infaunal communities. While the expiration of the sandbag permits may result in the removal of some of the sandbag revetments, future erosion threats to other ocean front structures could lead to the installation of an additional 21 sandbag revetments over the 30-year planning period. This is expected to have negative indirect impacts to the wet beach areas along certain sections of the Permit Area. Based on future shoreline change analysis, approximately 15-20 acres of marine intertidal are anticipated to be indirectly impacted within the Permit Area, specifically along the oceanfront shoreline and in proximity of Rich Inlet on Figure Eight Island.

The marine intertidal communities on Hutaff Island are not anticipated to be impacted.

Cumulative Impacts: The periodic beach nourishment activities occurring on Figure Eight Island, will temporarily impact the marine intertidal communities, but is not expected to result in long term impacts. However, beach scraping and sandbag placement could potentially result in cumulative impacts on wet beaches along the ocean shoreline of Figure Eight Island over a longer period if intermittent nourishment events are not taking place.

MARINE HABITATS

Softbottom Communities

Direct and Indirect Impacts: Softbottom communities are dynamic in nature where periodic storms and seasonal climatic changes influence abundance and diversity of micro and macrofauna, tending toward a more opportunistic community (Mallin *et al*., 2000; Street *et al*., 2005). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). Despite their dynamic state, softbottom resources could directly be impacted by increased levels of turbidity, immediate removal, and immediate burial of infaunal biota during dredging operations. These effects would occur during and following the dredging within maintenance events within Nixon Channel. The permitted dredging area within Nixon Channel encompasses 44.7 acres of softbottom habitat, and therefore up to that amount could be impacted with each event.

Because the beaches along Hutaff Island will not receive disposal material, impacts to softbottom resources outside of natural shifting processes on or around Hutaff Island in response to Alternative 1 are not anticipated.

Indirect impacts include the temporary loss of prey for foraging fish and invertebrates from the softbottom habitats within the 44.7 acre footprint of the previously permitted area within Nixon Channel. Additional indirect impacts to the softbottom habitat could be incurred as a result of the placement of material on the existing dry beach as the profile reaches equilibrium.

Cumulative Impacts: Activities associated with Alternative 1 are not anticipated to cause cumulative impacts to the softbottom communities due to the short recovery period of the infaunal species which utilize them. Furthermore, these habitats are dynamic in nature and due to continued sediment transportation through Rich Inlet; they will reform following dredging operations.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: Excessive sediment loading increases turbidity and sedimentation, which can result in the clogging of fish gills and reduced recruitment of invertebrates. Furthermore, turbidity can suppress SAV growth, cause low oxygen events leading to fish kills, and cause mortality of organisms in the softbottom community, including shellfish. Dredging of Nixon Channel and the placement of beach fill material along stretches of Figure Eight Island is expected to result in temporary increases in suspended sediment and turbidity. Areas of increase are expected along the nearshore environment where placement occurs and within Nixon Channel where the cutterhead is

suctioning. As stated previously in the General Environmental Consequences Related to Dredging section, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001. Cleary and Knierim (2001) determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values returned to ambient conditions rapidly. Therefore, any increase in turbidity associated with the dredge and fill activities associated with Alternative 1 would be of short duration, as also observed during the Bogue Inlet Channel Relocation Project in Emerald Isle, NC. Any increase of turbidity or TSS will be minimized further because the silt content of the material in the existing permit area in Nixon Channel is relatively low, averaging about 1%.

Cumulative Impacts: Natural conditions within the Permit Area exhibit extreme fluctuations in turbidity and TSS levels as a result of the winnowing away of exposed peat and mud layers near the soundside shoreline along northern Figure Eight Island. Under the Alternative 1, erosion of the soundside shoreline would continue with minimal changes in turbidity levels as a result. Turbidity and TSS levels would be expected to increase during storm events. Therefore, naturally fluctuating turbidity and TSS levels would continue with or without beach nourishment and dredging efforts proposed under Alternative 1, therefore no cumulative impacts are anticipated.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 1 is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The simulated change to the tidal prism within the permit area was not specifically modeled for Alternative1; however it was simulated for Alternative 2 (Abandon and Retreat) which is similar to this alternative, but without beach nourishment and dredging. Based on the modeled changes to the tidal prism for Alternative 2, the tidal prism of the inlet as a whole decreased by approximately 13% over the 5-year simulation period as the inlet channels reconfigure themselves in response to the prescribed environmental conditions imposed on the model. Nixon Channel and Green Channel presently carry 49% and 39% of the flow through the inlet, respectively, with the balance of the flow moved through the marsh areas behind the inlet. It is known that the natural conditions within a tidal inlet are highly dynamic and that the tidal prism may become altered as conditions change. The estimated decrease of 13% in tidal prism is strictly based off the Delft3D modeling results which calculated these values based on data input into the model and should not be interpreted as a predication of future changes. Despite modeled alteration in tidal prism, hydrodynamics and salinity are not expected to

be impacted in response to Alternative 1 due to the large volume of water moving through the system.

Larval Transport

Direct Impacts: The sporadic dredging and beach fill operations associated with Alternative 1 are not anticipated to impact larval transport into Rich Inlet. Larvae are expected, however, to be entrained within the dredge while operating in Nixon Channel. Due to the time of the year when dredging will take place combined with the limited duration of dredging and the relative small volume of water pumped through the dredge, impacts to larvae are expected to be minimal.

Indirect and Cumulative Impacts: No indirect or cumulative impacts are anticipated.

PUBLIC SAFETY

Direct and Indirect Impacts: The current erosion rate along the ocean shoreline and the back side of the northern portions of Figure Eight Island is presently threatening the integrity of nineteen (19) homes and may pose an imminent threat to an additional twenty-one (21) homes over the next 30 years. If these homes and the associated infrastructure were to become severely damaged or destroyed due to erosion or storm induced impacts, public safety could be compromised as structural debris and leaking sewage from destroyed septic systems could present hazardous conditions. The activities associated with Alternative 1 will provide some level of protection from storm induced erosion in the near term, and thereby provide positive direct and indirect impacts to public safety. However, the sporadic temporal nature and geographic extent of the shoreline protection measures associated with Alternative 1 will not ensure adequate protection for all areas experiencing erosion; therefore some direct and indirect impacts may occur in regards to public safety. Although Figure Eight Island is a private island with restricted access, homeowners and authorized visitors would continue to access the impacted areas and the general public would continue to have access by boat. These impacts may include the release of sewage and other hazardous materials onto the beach and into the coastal waters as well as closed areas of beach impeding recreation.

Cumulative Impacts: The activities described within Alternative 1 are anticipated to only provide short-term protection from erosion and storm induced damage to Figure Eight Island's infrastructure. Ultimately, demolition activities, road undermining, and exposure of utilities would continue as long as the erosion continues to threaten the infrastructure. The longer the situation exists, the higher the risk of personal injury. These impacts may be further exasperated if the predicted rise in sea level occurs over the next thirty (30) years.

AESTHETIC RESOURCES

Direct Impacts: During dredging and fill events, the presence of construction equipment would temporarily detract from the aesthetics of the waterways and beach of Figure Eight Island. The aesthetic resources are also expected to be impacted by the continued presence of sandbags on the oceanfront and Nixon Channel shoreline

Indirect and Cumulative Impacts: The chronic erosion experienced along portions of Figure Eight Island would be expected to continue despite the sporadic beach fills, beach scraping, and sandbag activities. The threatened homes and infrastructure could eventually succumb to the threat of damage and destruction associated with the loss of the protective shoreline resulting in negative impacts to the natural beauty of the beach. Continued erosion along the oceanfront shoreline along the northern portion of Figure Eight Island could also result in a significant loss of land, personal property, and roads, which would negatively affect the aesthetic quality of Figure Eight Island. These impacts may be further exasperated if the predicted rise in sea level occurs over the next thirty (30) years. It is expected that the presence of sandbags will persist over a long period of time.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access by land, however public access is available by boat. The recreational opportunities along the oceanfront shoreline are primarily utilized by private homeowners and visitors to the island. Visitors can also access the inlet, adjacent waterways and beach via boat. Negative direct impacts will include the reduction of recreational opportunities such as sunbathing, beachcombing, surf fishing, and walking along the beach during beach scraping and beach fill events. Impacts to recreation are expected to be minimal since scraping and filling activities are generally taking place during winter months when recreational activities are at their lowest levels.

Indirect and Cumulative Impacts: As the erosion continues along the affected stretch of shoreline on Figure Eight Island, recreational opportunities such as beachcombing, sunbathing, surf fishing, and walking along the beach may be negatively impacted. Furthermore, access along the stretch of beach with high erosion may be restricted during the time of high tide due to the presence of sandbags.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: The continued sporadic maintenance activities in Banks Channel, AIWW, and Nixon Channel, will benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within the waterway. At no time will complete restriction of navigation occur in Nixon Channel

during dredge operations. Restrictions will be determined by the United States Coast Guard (USCG) and will be limited to the areas where the dredge and the pipelines are located.

INFRASTRUCTURE

Direct and Indirect Impacts: Alternative 1 is expected to have a positive direct and indirect impact on existing infrastructure located on Figure Eight Island due to the short-term protection provided by beach nourishment, beach scraping projects, and sandbags.

Cumulative Impacts: The implementation of Alternative 1 will have a negative cumulative impact on the sustainability of existing infrastructure on Figure Eight Island due to the ineffectiveness of historical beach nourishment projects along the northern section of the island over time. Past nourishments at this location have proven to provide short term protection due to the inability for the material to persist on the nourished beach. Therefore, the continuation of beach nourishment events, beach scraping, and sandbags are anticipated to afford only temporarily protection to those homes and infrastructure located on the northern end of Figure Eight Island. Several of the homes located on the northern portion of Figure Eight Island with protective sandbags are considered to be unsafe during storm events. Based on Delft3D and other analysis, it is anticipated that 40 homes could be lost due to erosion along the northern portion of the island.

SOLID WASTE

Direct Impacts: No direct impacts will be anticipated due to the short term protection provided by beach nourishment, beach scraping, and installation of sandbags.

Indirect and Cumulative Impacts: The continued chronic erosion of the oceanfront and soundside shoreline along the north end of Figure Eight Island could result in the degradation and destruction of residential homes, public roads, and service utilities. Alternative 1 provides imminently threatened structures with only temporary protection and therefore, they may ultimately need to be demolished in the event of a severe storm or the continuation of chronic erosion. The debris generated from the demolition of these structures could indirectly and cumulatively impact the amount of solid waste deposited in local sanitary landfills. The volume of material to be placed in the landfill may have to be accounted for in the New Hanover County's long range plan for solid waste facilities.

Cumulative impacts could also result from the gradual deterioration of the sandbag revetments. While permits restriction may dictate future removal of the existing and future sandbag structures, removal of all of the sandbag debris is problematic as the material settles deep into the sand. Over time, any remaining material could be uncovered and become flotsam which could pose a threat to marine animals.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: The continuation of erosion would result in economic loss to New Hanover County and the State in the form of reduced revenues from property taxes should homes become inhabitable due to damage induced by erosion and/or storms. Along with the loss of tax value, property value of adjacent homes would decrease as well. Table 5.10 depicts the summary of the average annual economic impact associated with Alternative 1. Over the 30-year analysis period, the total cost associated with Alternative 1 would be about $115.7 million. This total cost includes $25.7 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, $57.9 million for the loss of land, $0.8 million for temporary sandbag revetments, and $27.5 million for beach nourishment.

Table 5.10- Summary of Average Annual Economic Impact of Alternative 1 Over a 30 Year Period

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$3,010,000	$290,000	$1,164,000	$4,464,000

NOISE POLLUTION

Direct Impacts: Sporadic maintenance dredging in Nixon Channel and the AIWW, which are included in Alternative 1, would temporarily raise the noise level in the areas of the dredge and the discharge point on the beach. Homes within proximity of the discharge point would experience higher noise levels due to ongoing usage of bulldozers leveling the material. This would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the low frequency of beach nourishment events and the time of year.

B. IMPACTS ASSOCIATED WITH ALTERNATIVE 2: ABANDON/RETREAT

For Alternative 2, the Figure 8 HOA and the individual property owners would not take any action to slow erosion or appeal the removal of existing sandbags. This would include the beach scraping/bulldozing or intermittent beach nourishment projects described above in Alternative 1. Once structures become imminently threatened or the owners are required to remove existing sandbags, the structures would either be abandoned (demolished) or moved to another lot on the island.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: Similar to Alternative 1, Alternative 2 assumes a continuation of existing erosion and accretion rates along portions of Figure Eight Island and the southern tip of Hutaff Island, respectively. This erosion of the salt marsh shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). Additional erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion is related to movement of the Nixon Channel thalweg toward the island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct and indirect impacts to salt marshes are expected to continue.

Erosion along the Nixon Channel Shoreline

Cumulative Impacts: As stated earlier in the discussion within Alternative 1, the gorge within Rich Inlet has remained in place for approximately 20 years. With the main inlet being stable, it is expected that the salt marsh communities will continue to respond to naturally evolving shorelines. Where salt marsh resources found along the sound side of Figure Eight along the northern portion of the Nixon Channel shoreline could be negatively impacted due to the erosion over time, areas further east along this shoreline may gain salt marsh as the sand spit and large shoal migrates in response to the inlet configuration.

For Hutaff Island, some oceanfront areas may experience breaches in the primary dune due to storms and high wave action, resulting in the formation of natural washover features which may extend into adjacent high salt marsh. In this natural process, these washover areas may cause salt marsh to become inundated and transition into intertidal habitats, causing potential corresponding shifts in infaunal community composition, as well as shifts in finfish and bird community composition. Little is known about how resident species adapt to irregularly flooded marshes which are inundated for weeks at time. These resident species include, among other species, several types of fish (*e.g.*, killifish and mummichogs), brownwater snakes, crustaceans (various species of crabs), birds (yellowthroat, marsh wren, harrier, swamp sparrow, and five species of rails), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Washover events may increase if the predicted increase in the rate of sea level is validated.

Therefore, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 2.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: As with Alternative 1, three confirmed and 17 probable SAV occurrences have been identified within the Permit Area (Figures 4.3a and 4.3b). The three confirmed occurrences are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channel. Because the confirmed locations of existing SAV resources occur removed from to the areas experiencing erosion along Rich Inlet and Nixon Channel, impacts to SAV resources are not expected. SAV resources require light to penetrate the water column for healthy growth. With no dredge or fill activities associated with Alternative 2, the potential for elevated turbidity or TSS is not a factor with this alternative outside of natural storm events. Cumulative impacts are not expected to occur as a result as these resources would naturally migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Impacts to shellfish habitat for Alternative 2 are the same as those discussed above for Alternative 1.

UPLAND HAMMOCK

Impacts to upland hammock habitat for Alternative 2 are the same as those discussed above for Alternative 1.

INLET DUNES AND DRY BEACHES

Direct Impacts: No direct impacts are expected unless a single storm event occurred directly resulting in changes to the inlet dune and beaches. Predictions of storms and their magnitude are unable to be determined.

Indirect and Cumulative Impacts: Delft3D modeling results suggests that approximately 0-5 acres of Inlet Dunes and Dry Beaches will be indirectly impacted. These model results show portions of the sand spit on the extreme north end of Figure Eight Island being converted to intertidal and subtidal habitat within 5 years. The conversion of inlet dune and beach habitat to subtidal habitat would reduce the area available for nesting shorebirds (including the endangered piping plover) and colonial waterbirds. However, the Delft3D model results indicate accretion of Inlet Dunes and Dry Beaches on the southern portion of Hutaff Island. This accretion is expected to offset the impacts indicated on Figure Eight Island thereby preserving nesting habitat for sea turtles and shorebirds. This shift may be cumulatively more beneficial for nesting due to the absence of homes and more restricted access on Hutaff Island.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: Intertidal flats and shoals have developed in a dynamic inlet system and therefore tend to be ephemeral in nature, especially with regard to dynamic island formations within the Inlet. Alternative 2 is not expected to result in direct impacts to these habitats.

Indirect Impacts: Delft3D modeling suggests that by year five, Alternative 2 results in a net increase of 130,043 cubic yards of sediment in the inlet complex (Figure 5.26). With this influx of material, the extent of the intertidal flats and shoals may increase over time. As the sand spit on the north end of Figure Eight Island evolves into intertidal sand flats within 5 years as shown by the model, the increased sedimentation within the inlet complex is expected to facilitate the development of additional intertidal flats and shoals as stated previously with the conversion of inlet dunes and/or dry beach. Despite this net influx of material, the model results also indicate that approximately 0-5 acres of intertidal flats and shoals within the inlet complex may be indirectly impacted. Despite these changes and natural adjustments, foraging and resting bird species utilizing the intertidal flats and shoals are expected to be minimally effected.

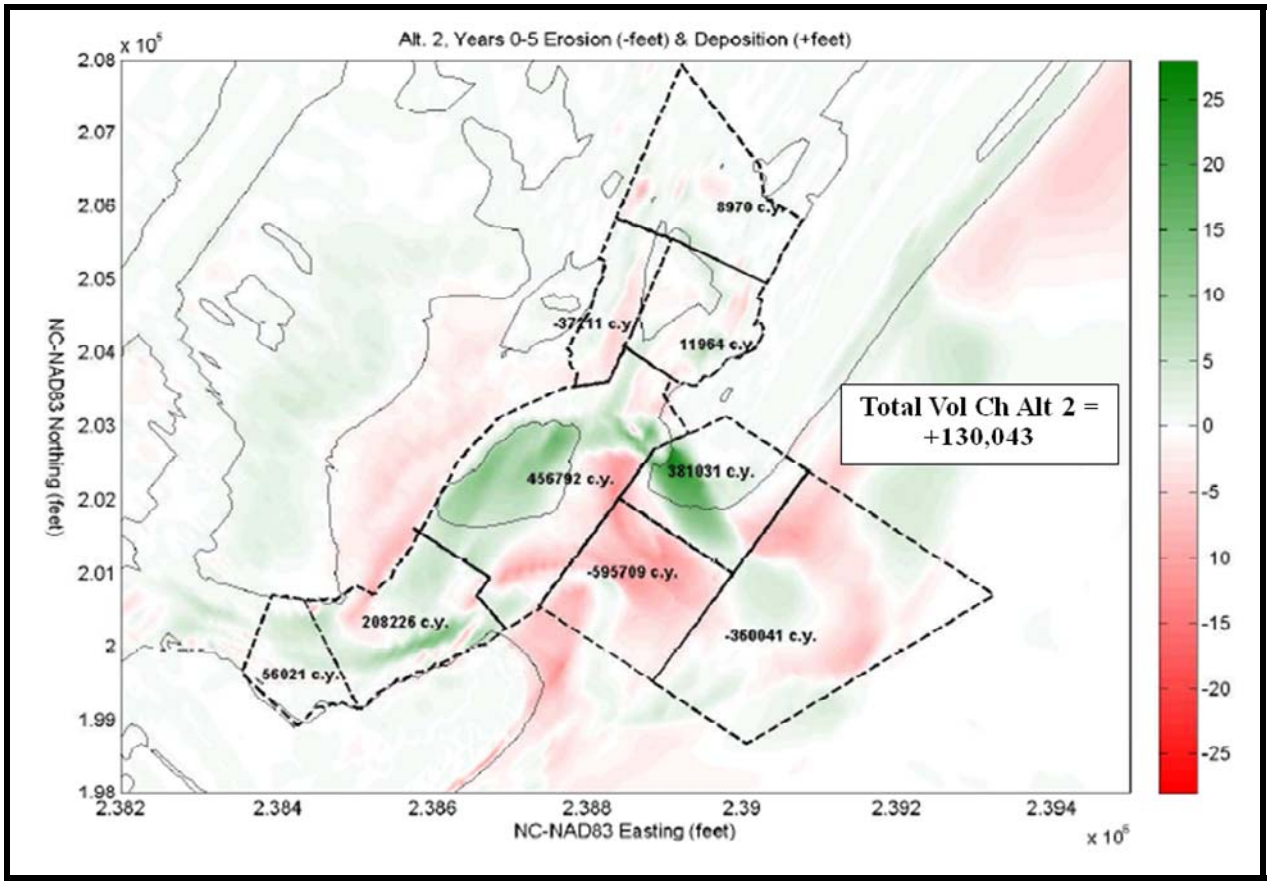


Figure 5.26- Modeled shoaling volumes within discrete areas within the Permit Area under Alternative 2.

Cumulative Impacts: Although intertidal flats and shoals may undergo considerable change within the permit area, the habitat will persist because the intertidal flats and shoals are considered to be ephemeral and dynamic.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct Impacts: The implementation of Alternative 2 will not impose any direct impacts to the oceanfront dune communities.

Indirect and Cumulative Impacts: The existing dune system along a portion of Figure Eight Island has been maintained through beach scraping activities and the installation of sandbag revetments. Without a continuance of these actions, which is the case under Alternative 2, negative indirect and cumulative impacts could occur within the dune community due to unabated erosion of the foredune and dune system along the northern 3.8 km (2.4 mi) of oceanfront shoreline of Figure Eight Island. The chronic erosion experienced along the north end of Figure Eight Island will continue under Alternative 2 and will impact the existing dune system on the island, particularly in the area north of 302 Bridge Road North. The sandbag revetments protecting 19 homes will eventually fail or be removed by the property owners. As a result, the remaining dunes could be subjected to direct impacts of waves and storm tides which will gradually erode any remaining vestige of the dunes in this area.

The dune communities located on the southern portion of Hutaff Island would be expected to migrate westward as natural processes including rolling over, or transgression, will influence the environment. Although the location of the dunes may change as overwash and other storm-induced events influence the environment, the anticipated indirect and cumulative impacts to the dune community on Hutaff Island in response to Alternative 2 would be negligible as these processes occur under natural conditions.

Oceanfront Dry Beach Communities

Direct Impacts: During the interim period in which the existing sandbag revetments remain in place, the dry sand beach along the northern section of Figure Eight Island will decrease as the shoreline erodes up to the seaward toe of the temporary structures. Once the sandbags are removed, the dry sand beach area should increase but at the expense of erosion into the remaining dune along this stretch of the island. Consequently, no long-term direct negative impacts are anticipated to the dry beach communities as a result of Alternative 2.

No direct impacts are anticipated to occur along Hutaff Island as a result of Alternative 2.

Indirect and Cumulative Impacts: With Alternative 2, the erosion of the Figure Eight Island and shoreline is expected to continue, resulting in net impact of approximately 0-5 acres of oceanfront dry beach habitat. The average annual rates of volume change for the various beach segments determined from the model over the five (5) year simulation for Alternatives 2 are summarized in Table 5.11.

Table 5.11. Average annual rate of volume change (cubic yards/year) - Figure Eight Island and the southern 3,000 feet of Hutaff Island obtained from the Delft3D model for Alternatives 2.

Hutaff Island	Figure Eight Island Beach Segment					Fig. 8 Totals	
	F90 - 30	30 - 60	60 - 80	80 - 100	100 - 105	F90 - 100	F90 - 105
70,600	-4,900	-16,800	-11,800	-32,900	-25,900	-66,300	-92,200

The volumetric change computed from the results of the Delft3D model for Alternative 2 from Bridge Road to Rich Inlet averaged -92,200 cubic yards/year of erosion over the 5-year simulation period. This computed rate of change agrees well with the observed rate of volume loss for the September 1999 to April 2007 time period which was -97,600 cubic yards/year. This would result in a reduction of adequate turtle nesting habitat, shorebird and water bird habitat, and recreational opportunities along Figure Eight Island.

However, engineering analysis suggests that the southernmost 3,000 foot portion of the oceanfront shoreline on Hutaff Island is expected to accrete with an average of 70,600 cu yds of material per year over a 5-year period. This would serve to offset the majority of impacts indicated on Figure Eight Island thereby preserving most of the nesting habitat for sea turtles and shorebirds.

Rahmstorf (2007) predicts that global sea level in 2100 may rise 0.5 m (1.6 ft) to 1.4 m (4.6 ft) above the 1990 level. Local monitoring stations suggest that this rise may be on the order of less than 1 foot over the next century. Should the sea levels continue to rise at this predicted rate, unmanaged areas of the dry beach community may become more vulnerable to overwash events and lead to additional cumulative impacts. However, an example of how sea level rise may or may not affect the performance of a beach nourishment project, the Wrightsville Beach and Carolina Beach federal storm damage reduction projects can be evaluated. Both of these project have been in existence since 1965 (44 years) and have been subjected to the same rate of sea level rise applicable to Figure Eight Island. A review of the nourishment rates for these two projects with and without sea level rise shows no significant change in the volume or frequency of periodic nourishment needed to maintain the projects.

WET BEACH COMMUNITIES

Direct, Indirect, and Cumulative Impacts: Without storm protection activities, such as beach scraping, beach nourishment, or the use of sandbags, impacts to macro infaunal species within the wet beach would only occur under natural conditions.

MARINE HABITATS

Softbottom Communities

Direct, Indirect, and Cumulative Impacts: Impacts to the softbottom communities outside of natural processes including storms are not expected with Alternative 2.

WATER QUALITY

Turbidity and TSS

Direct, Indirect, and Cumulative Impacts: Natural conditions within the Permit Area support extreme fluctuations in turbidity levels as a result of the winnowing away of exposed peat and mud layers on the soundside shoreline of the northern portion of Figure Eight Island. Under Alternative 2, erosion of the soundside shoreline would continue with minimal changes in turbidity levels as a result. Turbidity and TSS levels would be expected to temporarily increase during storm events but would decrease quickly due to the content of the natural sediment and the short duration of most storms.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 2 is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The existing hydrodynamic regime of Rich Inlet and the interior channels are represented by the Delft3D model results for Alternative 2. As discussed under Alternative 1, the tidal prism of Rich Inlet decreased by approximately 13% at the end of the 5-year model simulation. This computed reduction was due to changes in the overall morphology of the inlet produced by the Delft3D simulation as there are no man induced changes to the inlet or its environs under Alternative 2. Even though the tidal prism of the inlet could naturally decrease, the percentage of the total tidal prism carried through Nixon Channel and Green Channel, along with salinity content, are not expected to change significantly over this time. The tidal prism and flow distributions determined for Alternative 2 were used to assess any potential changes in hydrodynamics and salinity throughout the inlet complex associated with the other alternatives.

Larval Transport

Direct, Indirect, and Cumulative Impacts: Outside of natural conditions or periodic storm events, the transport of larvae is not expected to be disrupted.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: The current erosion rate along the ocean shoreline and the soundside of the northern 3.8 km (2.4 mi) of Figure Eight Island is presently threatening the integrity of approximately nineteen (19) homes and would have direct, indirect and cumulative impacts to public safety. Over the next 30 years, an additional 21 homes are expected to be imminently threatened. Alternative 2 includes both the abandonment and the relocation (retreat) of these homes and their supporting infrastructure. The activity associated with demolition of abandoned homes could expose workers to risk of injury. There is also a strong possibility that some debris could fall into the nearshore which could pose health threats to swimmers or boaters. As the erosion undermines existing roads and sanitary systems, exposes electrical lines, and ruptures or requires the relocation and rerouting of the water supply system, the public would be exposed to increased risk of injury and/or infection. Ultimately, demolition activities, road undermining, and exposure of utilities would continue as long as the erosion continues to threaten the infrastructure. The longer the situation exists, the higher the risk of personal injury.

There would be no safety concerns with dredge and beach nourishment activities since these actions are not included within Alternative 2.

AESTHETIC RESOURCES

Direct and Indirect Impacts: Alternative 2 would allow for the continued erosion along portions of Figure Eight Island. The threatened homes and infrastructure, particularly if abandoned, could be destroyed due to the eventual loss of the protective shoreline. The advanced state of disrepair of the threatened homes would continue to distract from the aesthetic setting of the island along the oceanfront shoreline until such time the threatened homes are removed. Along the Nixon Channel shoreline, all existing homes have sandbags. Once removed, no additional sandbags are expected to be deployed. During those times when demolition activities are underway, the presence of construction equipment would have potential to temporarily detract from the aesthetics of Figure Eight Island. However, this would be no different aesthetically than current and future on-going construction of homes.

Cumulative Impacts: Continued loss of oceanfront shoreline could lead to the loss of multiple residences and infrastructure. Continued erosion along 3.8 km (2.4 mi) of oceanfront shoreline along the northern portion of Figure Eight Island could also result in a significant loss of land, personal property, and roads. Alternative 2 would potentially

negatively affect the aesthetic quality of Figure Eight Island. However, this would be no different aesthetically than current and future on-going construction of homes.
The continued negative shoreline impacts on the north end of Figure Eight Island will depend on how the inlet bar channel behaves. While the present orientation of the bar channel toward Hutaff Island has persisted since the mid-1990's, how long the channel will remain in this condition is impossible to predict. Based on past behavior, the bar channel is likely to naturally shift to the south and assume an alignment toward the north end of Figure Eight Island. Should this occur, the high rates of erosion on the north end of the island and the destruction of homes and infrastructure in this area could be abated for an unknown time period and the negative aesthetic impacts associated with the erosion reduced.

RECREATIONAL RESOURCES

Direct, Indirect, and Cumulative Impacts: Figure Eight Island is a private island with limited public access by land, however public access is available by boat. The recreational opportunities along the oceanfront shoreline are primarily utilized by private homeowners and visitors to the island. Visitors can also access the inlet, adjacent waterways and beach via boat. If homes are demolished and removed or relocated, recreational activities such as sunbathing beachcombing, surf fishing, and walking along the beach will be affected during the demolition and removal activities, but would be expected to resume once the work is completed. Therefore, impacts are likely to be short term.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: Over the five year model simulation for Alternative 2, the channel connecting Nixon Channel to the inlet gorge, which skirts around the landward side of the flood tide delta, experienced considerable shoaling and was virtually closed by the end of the 5-year simulation. Another channel connecting Nixon Channel to the inlet gorge opened closer to the back side of Figure Eight Island. The new channel was rather narrow with depths ranging from 8 to 12 feet NAVD. The mouth of Green Channel also experienced some significant shoaling while the interior portions of Green Channel located behind the southern end of Hutaff Island did not change significantly. The ocean bar channel initially deflected toward a southwesterly orientation but over the course of the 5-year simulation, the channel eventually assumed an alignment toward the northeast essentially paralleling the southern end of Hutaff Island.

The shoaling, as indicated by the Delft3D model results, led to the eventual closure of the channel connecting Nixon Channel with the inlet gorge which would render the channel impassible to most recreational craft that normally use Rich Inlet and the connecting channels. While the new channel that opened behind the island appeared deep enough for recreational craft, the width could pose problems as waves entering the channel would be running broach to the direction of travel of the vessel. The shoaling at the mouth of

Green Channel was relatively minor and did not appear to be severe enough to impede boat traffic. The deflection of the ocean bar channel toward the northeast would be a significant navigation issue as boats would be required to travel parallel to the crest of waves. This situation could become particularly severe during ebb which would amplify the height of the waves.

It should be noted that these changes are based off the results computed by the Delft3D modeling results and should be interpreted with caution. Historically, Rich Inlet has been a relatively stable inlet and has provided access to the ocean for recreational boaters for decades. Despite the changes indicated by the model, navigation will most likely continue. However, as shoaling does increase, navigation may become more challenging.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: The natural chronic erosion of the oceanfront shoreline could result in the abandonment and the ultimate destruction of up to 40 homes, roads, and service utilities. If threatened structures are not moved, they will presumably be demolished and the debris would be deposited in local sanitary landfills. The same would apply to damage to the roads and service utilities. Alternative 2 would therefore have a negative direct, indirect and cumulative impact on existing infrastructure located on Figure Eight Island.

SOLID WASTE

Direct and Indirect Impacts: The continued erosion of the oceanfront and soundside shoreline is expected to result in the destruction of homes, roads, and service utilities. If threatened structures are not moved, they may ultimately need to be demolished with the debris deposited in local sanitary landfills.

Cumulative Impacts: The cumulative effect of demolition and removal of homes and infrastructure debris could reduce the amount of space available at the local landfill over the next thirty (30) years. The volume of material that may have to be placed in the landfill is not likely to be considered significant, but ultimately this additional material may have to be accounted for in New Hanover and Pender County's long range plan for solid waste facilities.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Currently there are 93 vacant lots on Figure Eight Island. Of these vacant lots, 16 are for sale with an average market value of $1,560,812 (O'Mahoney, 2009). It is unknown if additional owners of the vacant lots would be willing to sell their land to satisfy the need of homeowners looking to relocate their homes. While the prices for vacant lots are significantly lower on nearby Topsail Island, moving any of the existing homes from Figure Eight Island over land to a new location off the island would not be possible given the width and height restrictions

imposed by the draw bridge over the AIWW. Moving the structures over water would also not be practicable given the absence of facilities that are needed to place the structures on barges. Furthermore, the homes on Figure Eight Island are relatively large and therefore would present difficulties when attempting to move via barge. As a consequence of these difficulties, of the 40 homes that are imminently threatened or may become imminently threatened over the next 30 years, 16 have the possibility to relocate to one of the existing vacant lots on Figure Eight Island. The remaining homes would most likely be abandoned and demolished with the waste material placed in landfills. The equivalent average annual cost for relocating and abandoning the 40 homes under Alternative 2 would be $215,000 per year over a 30-year period.

The abandonment and demolition of homes on Figure Eight Island would result in economic loss to New Hanover County and State in the form of reduced revenues from property taxes. Alternative 2 would result in the loss of the same 40 structures as Alternative 1; however, the lost tax value would occur earlier during the 30-year analysis period as temporary erosion response measures such as temporary sandbag revetments would not be used to delay the demise of the structures and land. There is a potential of delay in loss if the inlet bar channel orients itself in a more favorable location that reduces the erosion rate along Figure Eight Island. It is unknown at this time if this reorientation will occur and if so, it is not known how long it would maintain this favorable orientation. Table 5.12 depicts a summary of the average annual economic impact associated with Alternative 2. Over the 30-year analysis period, the total cost associated with Alternative 2 would be about $87.4 million. This total cost includes $25.7 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, and $57.9 million for the loss of land.

Table 5.12. Summary of Average Annual Economic Impact of Alternative 2

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$4,364,000	$844,000	$215,000	$5,423,000

NON-RELEVANT RESOURCE ISSUES

Hazardous, Toxic, and Radioactive Waste

Direct, Indirect, and Cumulative Impacts: There are no known hazardous, toxic, or radioactive wastes in the Permit Area that would be affected by Alternative 2.

NOISE POLLUTION

Direct, Indirect, and Cumulative Impacts: The demolition of homes on Figure Eight Island would temporarily raise the noise level in the areas due to the use of heavy machinery, however this level would be short-term and minimal. It is expected that a

typical home on Figure Eight Island would take several days to demolish and remove the debris.

C. IMPACTS ASSOCIATED WITH ALTERNATIVE 3: RICH INLET MANAGEMENT WITH BEACH FILL

The main bar channel of Rich Inlet would be relocated from its present position immediately adjacent to the south end of Hutaff Island to a position closer to the north end of Figure Eight Island and oriented along an alignment essentially perpendicular to the adjacent shorelines. The relocation of the main ebb channel (dredged to a depth of -19 ft NAVD) would be accompanied by new channels connecting the main ebb channel with Nixon Channel and Green Channel. Approximately 1.77M cubic yards of material removed to relocate the channel and construct the new connecting channels, construct a closure dike across the existing ebb channel located next to Hutaff Island, provide beach fill along 548.6 m (1,800 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 new inlet bar channel position would be periodically maintained with maintenance episodes dictated by shoaling of the new channel or natural shifts in the channel position outside the preferred channel corridor. Based on the Delft3D model results, approximately 716,000 cubic yards would have to be removed from the new bar channel every 5 years to maintain the preferred position and alignment. Shoaling of the Green Channel connector ceased after year two of the simulation while shoaling in the Nixon Channel connector moderated considerably. These reduced rates of shoaling in the two channel connectors indicate they had achieved some equilibrium and would probably not need to be maintained as frequently as the bar channel. For planning purposes, future maintenance of the channels would be limited to just the bar channel. 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.

ESTUARINE HABITATS

Salt Marsh Communities

Direct Impacts: No salt marsh resources are anticipated to be directly impacted through dredge or fill operations in association with Alternative 3. The preferred dredging option included with this alternative has been designed to minimize the potential for shoreline erosion and subsequent impacts to salt marsh area facing the entrance of the inlet.

The geotechnical investigation of the 92.4 acre channel corridor between Nixon Channel and the inlet gorge determined that two (2) vibracores contained approximately 29,700 cubic yards of incompatible clay material above the designed -19.0 ft. NAVD 88 bottom of the channel. This material will be excavated and placed in an upland disposal site

located at the junction of the Intracoastal Waterway and Nixon Channel. Erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent salt marsh resources (Figure 5.27). Therefore, no direct impacts to salt marshes are anticipated as a result of sedimentation during the dredge, beach fill placement, and disposal of incompatible material operations.

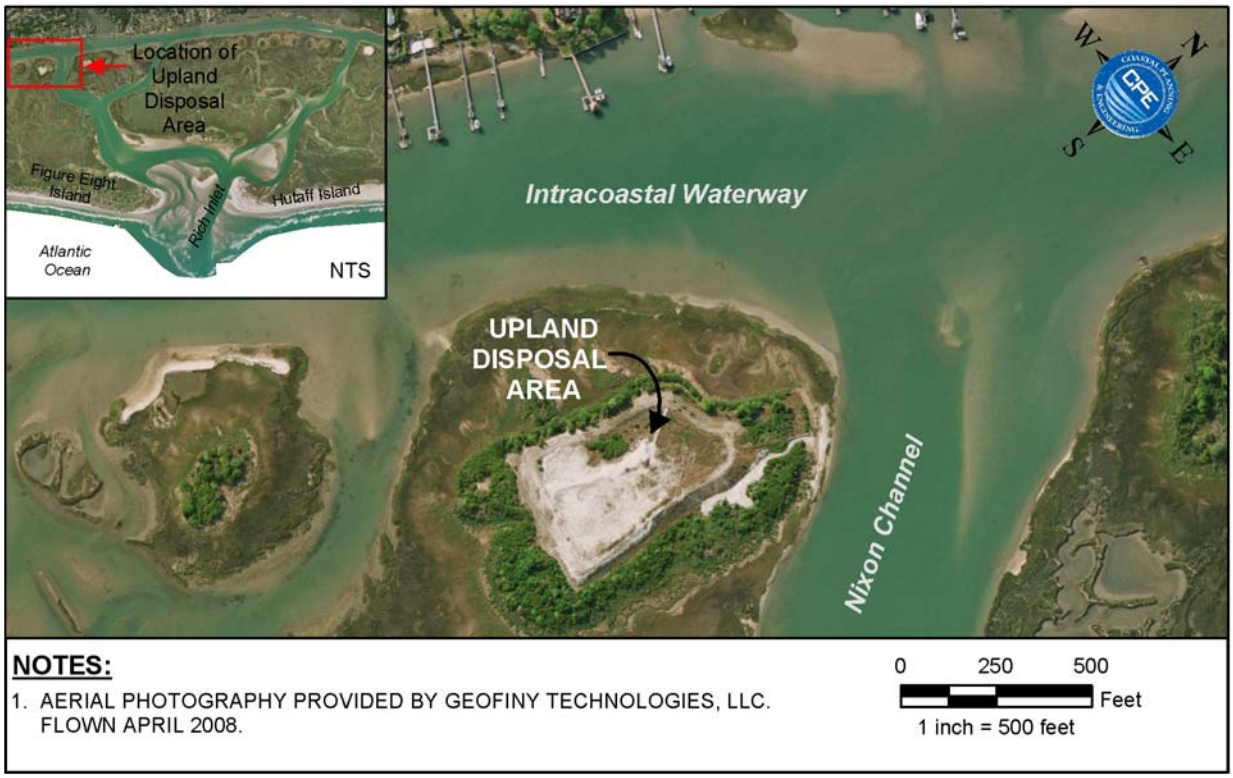


Figure 5.27. Map depicting the upland disposal area, located at the junction of the Intracoastal Waterway and Nixon Channel, in which incompatible material from the Alternative 3 channel will be deposited.

Indirect Impacts: Immediately following construction of the new bar channel and cuts into Nixon and Green Channel, the newly established flow pathways are expected to follow the alignments of the dredge cuts and positively benefit the salt marsh resources which are currently eroding behind Rich Inlet. However, model results suggest that by Year 5, the flow pathways into and out of the inlet will tend to follow the curved shorelines on either side of the inlet which could reduce this protection. Within Nixon Channel, flow is anticipated to be centered near the middle of the channel instead of its southern bank, which should also serve to reduce the erosional stress near the north end of Beach Road. This, along with the placement of 65,000 cubic yards of beach fill, will reduce the potential for the eventual erosion of the salt marsh in this area. Along the salt marsh shoreline west of the entrance of Rich Inlet, currents will be reduced as flow is shifted from the back channel along the salt marsh into the new dredge cuts.

Engineering model results for the proposed modification of the Rich Inlet do not show any significant impact on flow circulation patterns between the inlet and the AIWW (refer to Appendix B—Engineering Analysis). Additionally, material from the closure dike is anticipated to be transported into the inlet complex which could result in erosion of sediment within the salt marsh habitat. Although unrelated to the marsh system in proximity to Figure Eight Island, no significant changes were observed following three (3) years of salt marsh monitoring designed to evaluate the changes to the salt marsh in response to a similar inlet channel relocation project within Bogue Inlet in 2005 (CPE, 2008).

Cumulative Impacts: Barrier island management practices such as inlet stabilization, and maintenance dredging may prevent inlet migration and the formation of flood tide deltas upon which marshes typically may form (Hackney and Cleary, 1987). Alternative 3 includes the maintenance of the new Nixon Inlet bar channel every five (5) years with maintenance of the Nixon and Green Channel connectors possible sometime in the future. These actions, along with other inlet modification and inlet maintenance projects in southeast North Carolina have the potential to create a cumulative deficit of inorganic sediment accumulation in the back barrier marsh habitat. Natural vertical accretion rates as high as 2.4 to 3.6 mm per year have been measured within salt marsh communities in North Carolina, however the maximum rate at which wetlands can accrete is not well understood (Craft e*t al.*, 1993). Without the accumulation of sediment, the salt marsh habitat may subside and lose its important habitat value for species such as rails, bitterns, wading birds and marsh sparrows, several of which are species of conservation concern according to Partners in Flight (Hunter et al. 2001, Pashley et al. 2000, Rich et al. 2004, and Johns 2004). Other species which may be impacted include several types of fish (*e.g.*, killifish and mummichogs), brownwater snakes, crustaceans (various species of crabs), and several species of mammals (nutria, cotton rat, and raccoon) (CCSP, 2009). Due to the potential reduction of sediment through Rich Inlet, salt marshes may incur significant cumulative impacts.

Submerged Aquatic Vegetation

Direct and Indirect Impacts: SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as increase in turbidity and TSS. Relocation of the channel and construction of the sand dike are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however, turbidity is expected to remain within the State standard of 25 NTUs. The construction of the dike is anticipated to last approximately one month while the relocation of the inlet channel is anticipated to last approximately 10 weeks. Despite the duration of these activities, the low silt percentage and the well-sorted sands in the inlet are expected to keep turbidity and TSS levels below the state standard outside the immediate area of construction. In 2005, Bogue Inlet was relocated and utilized a similarly designed closure dike as a part of that project. Turbidity measurements were recorded on a regular basis during the construction of that dike and

results indicated that levels never exceeded the State standard. The highest recorded levels of turbidity was 16.4 NTU.

The relatively coarse grain size and low silt content (approximately 1.18%) of the material to be removed to reconfigure the channels in the Rich Inlet complex will limit the movement of the sediment plume during construction of the dike to the confluence of the inlet channel with Nixon and Green Channels, that is, the plume is not expected to travel any appreciable distance into the sound (see Appendix B). As previously mentioned above, 29,700 cubic yards of clay material detected within Cut 1 will be removed and transported to an upland disposal area during the dredging of the connector channel between Nixon Channel and the inlet gorge. This fine material will pass close to identified SAV resources (Figures 4.3a and 4.3b); however it will be contained in a pipeline during transportation reducing the likelihood of any SAV resources being covered.

Since the dimensions of the new channel were selected to maintain a similar tidal exchange through the inlet that presently exists, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted (see Appendix B). Furthermore, dredging activity would occur during winter months when SAV resources are biologically less active. Therefore, there are no anticipated SAV impacts due to changes in water quality.

Cumulative Effects: Turbidity and TSS levels are predicted to remain localized and below the state standard soon after all channel maintenance events, as observed following dredging in Nixon Channel in 2001 (Cleary and Knierim, 2001). The highest weekly average of turbidity and TSS recorded at the discharge site on Figure Eight Island was 44.0 mg/l and 301.0 mg/l, respectively, during this monitoring (Cleary and Knierim, 2001). Maintenance events will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Cumulative impacts to SAV under Alternative 3 are not expected.

Shellfish Habitat

Direct and Indirect Impacts: The relocation of the channel and construction of the sand dike are predicted to cause a short term increase in turbidity and sedimentation levels. However, due to the low silt percentage and the well-sorted sands in the inlet, the turbidity levels are expected to remain below the state standard outside the immediate area of dike construction. Therefore, shellfish resources are not anticipated to be impacted by sedimentation within the inlet complex due to their remote location in relation to the proposed activity associated with Alternative 3. As mentioned above, 29,700 cubic yards of clay material detected within Cut 1 will be removed and transported to an upland disposal area during the dredging of the connector channel between Nixon Channel and the inlet gorge. This fine material will pass close to identified shellfish resources (Figure 4.4a and 4.4b); however it will be contained in a

pipeline during transportation reducing the likelihood of any shellfish resources being covered.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard. Salinity throughout the inlet complex will remain unchanged as Nixon Inlet, with the new channel, is expected to maintain a similar tidal prism as what is observed within the existing inlet. Therefore, cumulative impacts to shellfish habitat under Alternative 3 are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: The activities associated with Alternative 3 are not expected to cause any direct, indirect, or cumulative impacts to the upland hammock resources located within the Permit Area due to the distance and relative elevation of the resource from the proposed activities. Furthermore, if Alternative 3 is constructed, there will be little change in the tidal prism of the inlet as whole at Year 0. The 5-year modeling simulation suggests that on average, the flow through Nixon Channel is anticipated to account for 52.9% of the tidal prism while flow through Green Channel will account for 35.9% with the remaining balance flowing through the marshes. This is similar to the anticipated flow observed with Alternative 2, the Abandon/Retreat Alternative. Because these alterations to the flow and tidal prism are minimal they are not expected to allow for salt water intrusion to the adjacent upland hammocks (refer to Appendix B - Engineering Analysis). Sea level rise is forecasted to increase in rate and may result in a rise as much of 1 meter by the year 2100 (Miller, pers. comm.). However, local monitoring stations suggest this rate will be less than 1 foot per century. If predictions are validated for this increase in sea level rise, a potential cumulative impact to coastal upland hammocks may occur. However, outside of this natural effect, no impacts on upland hammocks are anticipated with Alternative 3.

INLET DUNES AND DRY BEACHES

Direct Impacts: The current rate of Island of erosion, approximately 16.8 feet/year, on the north end of Figure Eight is reducing habitat for shorebirds and seabeach amaranth while also reducing recreational areas for humans. Meanwhile, accretion has occurred on the south end of Hutaff Island providing increased habitat for seabeach amaranth and shorebirds while providing more area for human recreation. Several biological resources, including seabeach amaranth and shorebirds which utilize the inlet beaches and dunes as foraging and nesting habitat may be impacted during and immediately following the construction of the dike and placement of sand upon the beach due to the disruption of this habitat and burial of infaunal prey. The placement of material along the inlet beach will also provide a direct benefit to the inlet dunes along the south side of Rich Inlet due to the increase in protection to this resource. Sea turtle nesting habitat will not be directly impacted as activities associated with Alternative 3 will not coincide with sea turtle nesting season and only beach compatible material will be utilized.

Some negative impacts associated with the burial of infaunal species will occur during and immediately after the placement of beach fill material along the inlet beach of Figure Eight Island and along the Nixon Channel Shoreline. The fill within these areas are expected to directly impact 7.4 acres. Impacts will also occur in along the inlet beaches in response to the construction of the containment dike on the southern portion of Hutaff Island. In addition to the anticipated 7.4 acres impacted on Figure Eight Island, the 36.5 acre sand dike will span across the existing inlet channel and onto the inlet beach on Hutaff Island. This will induce positive effects to the Inlet Dunes and Dry Beaches as it will provide increased foraging and nesting habitats on the southern portion of Hutaff Island as well as provide protection to the inlet dunes. Negative impacts to these habitats at this location are expected due to the burial of infaunal resources. In total, Alternative 3 would directly affect an estimated 40-50 acres of Inlet Dunes and Dry Beaches.

Indirect Impacts: Delft3D modeling results suggest that within five years of construction, the inlet beach and dune system will expand along the northern portion of Figure Eight Island as the sand spit migrates northward (Figure 5.28). This will result in positive impacts to the birds and sea turtles which utilize this habitat for nesting and foraging. Under Alternative 3, the south end of Hutaff Island will become erosional. However, Delft3D modeling results suggest that the closure dike is expected to take on the characteristics of a sand spit projecting off the south end of Hutaff Island maintaining the habitat within one year following construction (Figure 5.29). Much of that material is expected to be transported into the inlet system as the dike degrades and welds onto the southern portion of Hutaff Island. However, in comparison to the modeled response to Alternative 2, the extent of the habitat is anticipated to be larger. With a shift of wider beaches from Hutaff Island to Figure Eight Island, it is anticipated that wintering plovers would use the Figure Eight Island inlet beaches more often. Wintering plovers on the Atlantic coast prefer wide beaches in the vicinity of inlets (Nicholls and Baldassarre, 1990; Wilkinson and Spinks, 1994). This may result in an increase of interactions between humans and wintering plovers because Hutaff Island has greater access restrictions.

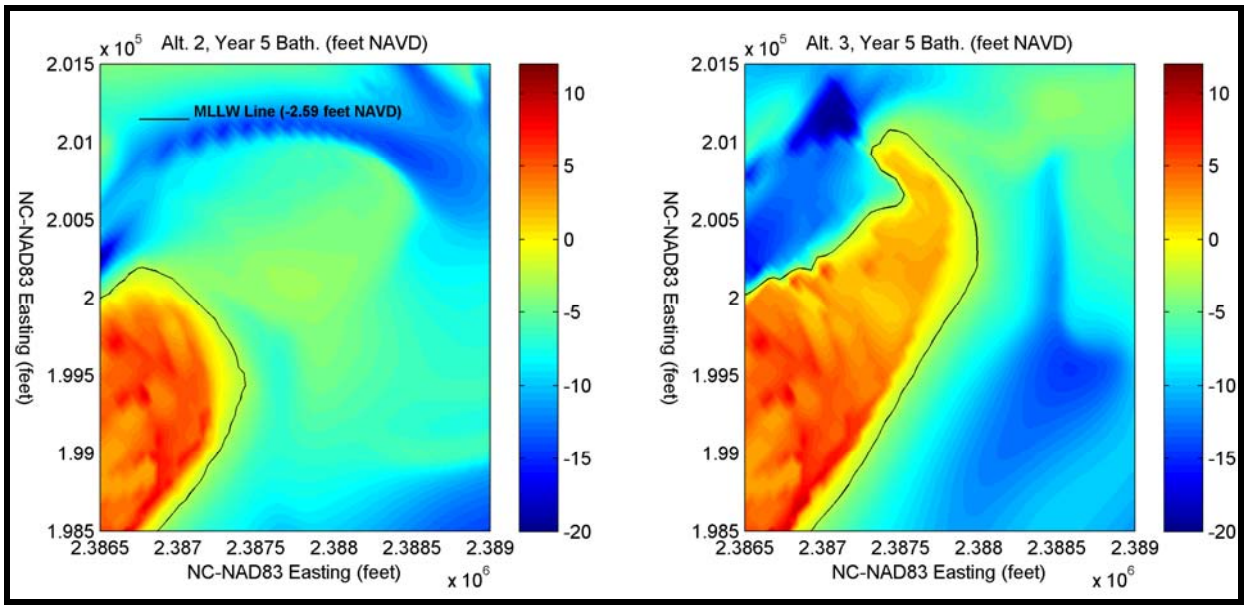


Figure 5.28. Year 5 topography and bathymetry of the northeastern portion of Figure Eight Island as depicted by Delft3D model results for Alternatives 2 and 3.

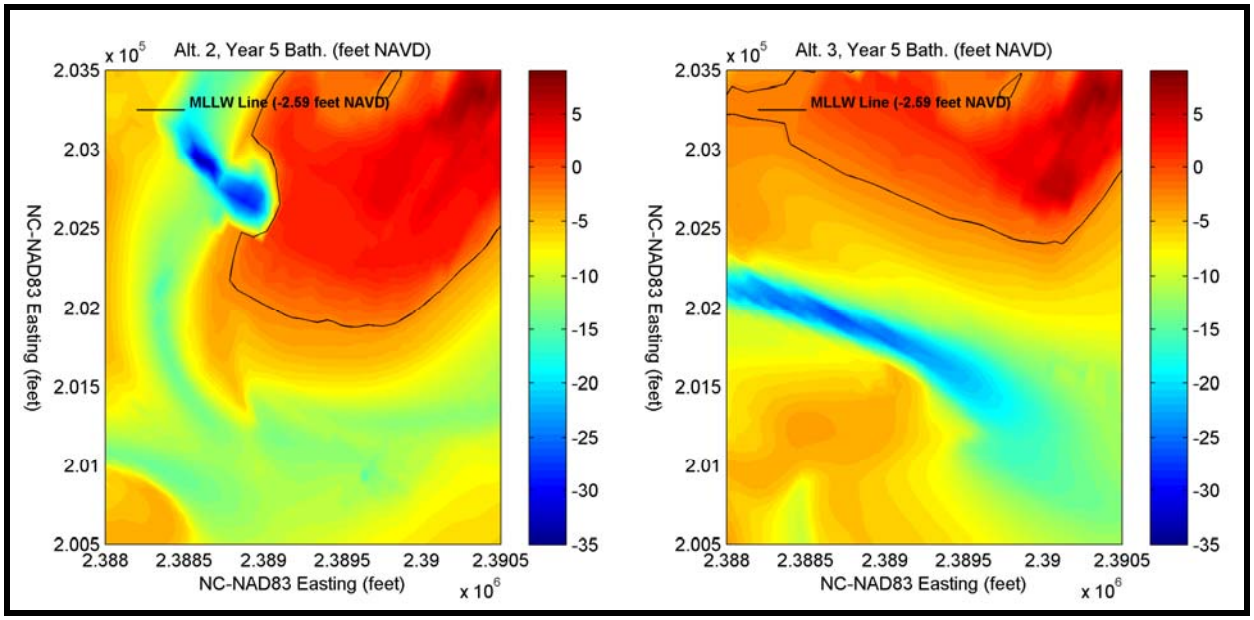


Figure 5.29. Year 5 topography and bathymetry of the southwestern portion of Hutaff Island as depicted by Delft3D model results for Alternatives 2 and 3.

Cumulative Impacts: Alternative 3 includes channel maintenance and beach renourishment every five (5) years. The need for channel maintenance would be dictated by shoaling of the bar channel or migration of the channel outside the channel corridor. These activities will assure the continued favorable position and alignment of the bar channel in terms of its impacts on the shoreline on the north end of Figure Eight Island and should provide a favorable environment for the continued existence of the sand spit

off the north end of Figure Eight Island. However, due to the relocation of the inlet channel, much of the ebb tide delta that currently provides protection to Hutaff Island's Inlet Dunes and Dry Beaches is expected to diminish as the ebb tide delta is expected to reorient southward. Therefore, as shown by Delft3D model results, the inlet beaches along Hutaff Island are expected to erode within 5 years.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: Direct impacts to the intertidal flats and shoals will be incurred as a result of dredging activities within the inlet complex as well as the construction of the closure dike. Dredging within the permit area is expected to directly impact approximately 15-20 acres of intertidal flats and shoals. Of this, approximately 11 acres of intertidal flats and shoals will be impacted within the footprint of the closure dike. These impacts will result in the conversion of intertidal flats and shoals to alternate habitat types; namely subtidal habitat and dry beach habitat. The removal of this habitat is expected to affect various foraging bird species who utilize the intertidal flats and shoals. Fish are also known to forage upon the infaunal communities within the intertidal flats. Therefore, impacts to the intertidal flats will affect foraging fish as well.

Indirect Impacts: Indirect impacts may occur as a result of dredging within Rich Inlet, Nixon Channel, and Green Channel as well as the construction of the closure dike. Impacts to the 15-20 acres of intertidal flats and shoals within this area will cause the direct mortality of macroinfaunal species which is a prey source for foraging birds and fish populations. Studies of dredging and disposal effects on nearshore and estuarine fish populations have reported rapid recovery or minimal effects (Courtenay *et al.*, 1980; de Groot, 1979a; de Groot, 1979b; Posey and Alphin, 2000). These effects are anticipated in part due to the winter time construction when biological activity is lowest. Topographic changes in both inshore and offshore borrow areas have also shown to positively affect certain fish by creating refuge or forage areas (Lalancette, 1984).

Over the 5-year Delft3D simulation period, the sand dike off the south end of Hutaff Island eroded with some of the material moving into the area near the mouth of Green Channel. From the mouth of Green Channel across the middle ground shoals immediately behind the inlet and into Nixon Channel, there was an overall net gain of 246,353 cubic yards relative to Alternative 2 (Figure 5.30). However, the construction of the connectors into Nixon and Green Channels will remove a total of 864,300 cubic yards which would leave a net deficit of approximately 618,000 cubic yards of material relative to Alternative 2. The net loss of material on the inside of the inlet complex could reduce the extent of intertidal flats and shoals relative to the without project condition. Therefore, indirect negative impacts to the foraging and resting bird species utilizing the intertidal flats and shoals within the inlet complex are anticipated. The unconsolidated and unvegetated communities that remain in the inlet complex would continue to redistribute as they lack structure and are dynamic in nature.

Other major changes in the inlet shoal system under Alternative 3 would be associated with the reconfiguration of the ebb tide delta as it responds to the new bar channel position and alignment. These changes include the loss of material on the north side and outer portions of the ebb tide delta and shoaling of the new bar channel.

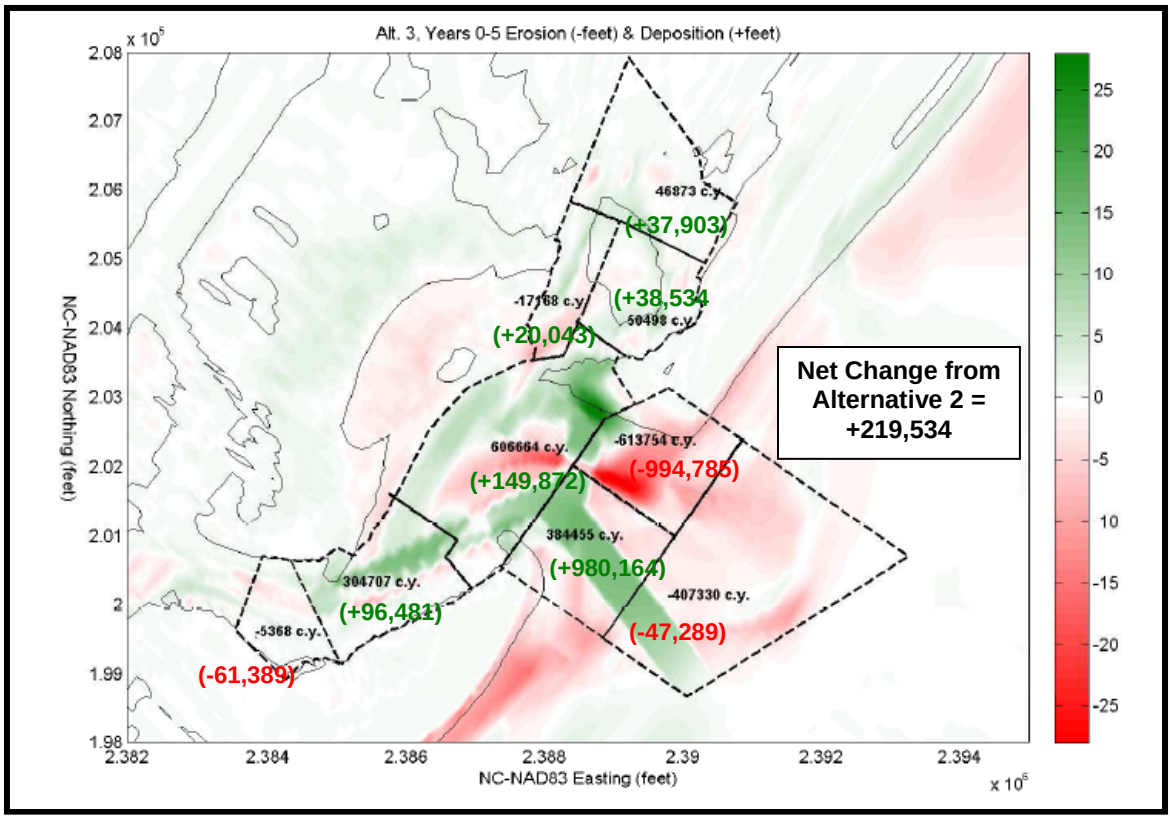


Figure 5.30 Modeled volume changes within discrete areas within the Permit Area for Alternative 3. Values in red indicate loss in material compared to existing conditions (Alternative 2). Values in green and red indicate an increase or decrease in material volume, respectively, compared to existing conditions.

Cumulative Impacts: These habitat types are abundant within the inlet complex of many of North Carolina's 19 inlets. Although some intertidal flats and shoals will be converted to subtidal habitat within the permit area following construction, volume changes determined from the results of the Delft3D model suggest much of this initial habitat loss will recover elsewhere in the inlet as the ebb tide channel begins to fill in. Assuming the ebb tide channel may need maintenance dredging to maintain its desired location, the previous projects direct and indirect impacts to this habitat would reoccur with the exception of a the construction of the closure dike and dredging within Nixon Channel and Green Channel. Maintenance dredging within Nixon Channel and Green Channel would be infrequent. Cumulative impacts for the habitats are not expected or should be minimal due to the presence of intertidal flats and shoals outside the dredging

footprint and in other sections of Nixon and Green Channels and their surrounding tributaries.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct and Indirect Impacts: The existing dune system along the northern portion of Figure Eight Island has been maintained through the use of sandbags and some beach scraping activities. A dune with a crest elevation of 4.6 m (15.0 ft) NAVD would be provided in the area from baseline station 77+50 to 95+00 or in the area presently devoid of a dune and where homes are presently protected by sandbag revetments. With the implementation of Alternative 3, Delft3D model results suggest short-term impacts will incur to 0.3 acres of dune communities on Figure Eight Island due to temporary disturbances to the fauna which potentially utilizes this habitat for roosting, foraging, and nesting. This 0.3 acres of impact is considered to be negligible due to the compensation occurring with beach nourishment along Figure Eight Island to help stabilize the dune system and provide long term storm protection. These stabilization measures will allow for long term growth and development of dune vegetation and provide habitat for roosting, foraging and nesting shorebirds. The dune communities located on Hutaff Island are not expected to be directly impacted by the implementation of Alternative 3. However; as the ebb tide delta of Rich Inlet reconfigures in response to the new bar channel position and alignment, the dunes on the south end of Hutaff Island could be indirectly impacted due to a higher degree of exposure to wave attack.

Cumulative Impacts: Alternative 3 includes renourishment every five (5) years. Therefore, the project will serve to provide long-term protection of the dunes along Figure Eight Island resulting in the protection of the nesting, foraging, and resting habitat for wildlife utilization

After the inlet is relocated, the current position of the ebb tide delta should shift to the southeast. The protection of the ocean shoreline along the southern end of Hutaff Island currently provided by the ebb tide delta will diminish and leave the dunes in this location more susceptible to storm-induced damage increasing the potential for overwash. Therefore, Alternative 3 may lead to cumulative impacts to the oceanfront dunes along Hutaff Island.

Oceanfront Dry Beach Communities

Direct Impacts: The beach nourishment plan included in Alternative 3 would benefit the dry beach communities on the north end of Figure Eight Island shoreline through the expansion of the dry beach habitat. Beach nourishment would restore the dry beach habitat along 12,500 feet of Figure Eight Island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). Direct impacts are expected to increase 150-200 acres of existing dry beach habitat along the oceanfront shoreline on

Figure Eight Island. The design beach width of the oceanfront dry beach, following anticipated adjustments in response to wave action, will vary along the length of the 12,500-foot fill area. Within the area where the sandbags are present and erosion rates are highest, the design width of the dry beach will be 124 feet. The remaining areas will average a design beach width of 46 feet, including the existing dry beach.

As mentioned in Chapter 4, wider beaches in the Permit Area will benefit several natural resources including seabeach amaranth, shorebirds, and sea turtles. The widening of the dry beach footprint will immediately benefit sea turtles by increasing their nesting habitat area. Although nesting activity still occurs within the current oceanfront shoreline, nesting numbers are expected to be higher with additional dry beach containing beach compatible sediment. While widening the beach itself is beneficial, using suitable material for successful nesting is essential in providing natural conditions.

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Street *et al*., 2005). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. The grain size of the native beach along Figure Eight Island is 0.18mm while the grain size of the fill material will range from 0.22mm to 0.25mm. Substrate alteration may affect the ability of female turtles to nest, the suitability of the nest incubation environment, and the ability of hatchlings to emerge from the nest. Escarpments formed during and after beach nourishment may prevent nesting females from reaching suitable nesting habitat, result in the selection of marginal or unsuitable nesting sites in front of escarpments, or result in nest exposure as escarpments recede landward. Numerous studies have described the effects of beach nourishment on nesting success (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999). These studies indicate a reduction in nesting success during the first post-nourishment year, followed by a return to normal levels by the second or third year. Declines in nesting success have been attributed to substrate compaction, escarpment formation, and/or modification of the natural beach profile. Beach nourishment also has the potential to improve poor quality nesting habitats associated with chronically eroded beaches (Brock et al. 2009), such as the northern portion of Figure Eight Island. Davis et al. (1999) and Byrd (2004) documented increases in nesting success immediately following the nourishment of eroded beaches. Increases in nesting success were attributed to the addition of dry beach habitat.

Embryonic development and hatching success are influenced by temperature, gas exchange, and moisture content within the nest environment (Carthy et al. 2003). Changes in substrate characteristics such as grain size, density, compaction, organic content, and color may alter the nest environment, leading to adverse effects on embryonic development and hatching success (Nelson and Dickerson 1988, Nelson 1991, Ackerman et al. 1991, Crain et al. 1995). Nourished beaches often retain more water

than natural beaches, thus impeding gas exchange within the nest (Mrosovsky 1995, Ackerman 1996). Uncharacteristically dark sediments absorb more solar radiation, thus potentially resulting in warmer nest temperatures. Dark sediments may produce nest temperatures that are too high for successful embryonic development (Matsuzawa et al. 2002). The wet and dry Munsell colors found on the native beach were compared by CPE geologists to the material identified in the inlet and channel borrow areas. The results of the comparison indicate that the color of the potential fill material is similar to the material currently found on the beach. The hue indicates only slight variations in the amount of red and yellow between the native and fill material. The native beach and fill chromas are within the same range. The average wet and dry Munsell color along Hutaff Island and Figure Eight Island were determined to be 5 and 6, respectively (refer to Appendix D- Geotechnical Investigations). The average Munsell color within Nixon Channel and Rich Inlet (fill material) were determined to be 6 and 7, respectively. The fill material value is, on average, within one shade of the value of the native beach. The variations in color found between the fill sources and the native beach are not considered to be significant (Larenas, pers. comm.). Therefore negative effects to sea turtle nesting from the fill are not anticipated due to the compatible quality of material used to expand the dry beach area on Figure Eight Island. Higher temperatures may significantly reduce incubation periods and contribute to a higher incidence of late-stage embryonic mortality (Ernest 2001). Nest temperature also influences sex determination in hatchlings, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2004). Consequently, dark sediments may alter hatchling sex ratios. Investigations of beach nourishment effects on hatching success have reported variable results; including positive effects (Broadwell 1991, Ehrhart and Holloway-Adkins 2000), negative effects (Ehrhart 1995, and no effect (Raymond 1984, Nelson et al. 1987, Broadwell 1991, Ryder 1993, Steinitz et. al. 1998, Herren 1999, Brock et al. 2009). The variation in findings has been attributed to differences in the physical attributes of individual projects, the extent of erosion on the pre-nourishment beach, and construction techniques (Brock et al. 2009). As stated above, the grain size, color, and other attributes of the material placed along the northern portion of Figure Eight Island as part of Alternative 3 will comply to the State sediment criteria which will help reduce potential impacts.

Indirect and Cumulative Impacts: Overall, by moving the channel and inducing movement of the ebb shoal southward, Alternative 3 is expected to enhance the performance of most of the beach fill placed north of Bridge Road. The only exception is the fill along the northern 2,000 feet which could experience high rates of loss between the fourth and fifth years after channel realignment due to the movement of the channel back toward Hutaff Island. In general, the improved performance of the fill as indicated by the model results will enhance the oceanfront dry beach for Figure Eight Island.

As a result of the construction of Alternative 3, the south end of Hutaff Island may become erosional. This occurs due to the migration of the ebb shoal towards the south. The amount of erosion between Profiles 145+00 and 175+00 will be about 275,000 cubic yards over 5 years. Most of the volume loss computed for Hutaff Island was in the

offshore area off the extreme south end of the island which was associated with the reconfiguration of the ebb tide delta in response to the new channel position and alignment. This change in the configuration of the ebb tide delta would also expose the southern end of Hutaff Island to direct wave attack which would increase the potential for sediment transport off the south end of the island and into Rich Inlet. This is expected to leave the south end more vulnerable to storm erosion with reduced offshore protection due to the migration of the ebb tide delta to the southeast.

Although the construction of the closure dike across the existing entrance channel which would add 513,700 cubic yards of material on the southern end of Hutaff Island, Delft3D modeling results suggest that 0-5 acres of coastal dry beach habitat would be indirectly impacted by Alternative 3.

According to Greene (2002), beach nourishment can benefit endangered and threatened sea turtles by restoring habitat along eroded beaches. Some studies have found no significant difference between nourished and non-nourished beaches in the number of eggs per nest, as well as, hatching and emergence success (Nelson *et al*., 1985; Ryder, 1991). Other projects have shown increased numbers of nests, hatchlings, and survival rate of young turtles (Raymond, 1984). The wider beach will benefit sea turtles since they require dry beaches to nest, preferring to nest along wide sloping beaches or near the base of the dunes. The increase in dry beach on Figure Eight Island is also expected to positively affect the shorebirds, water birds and colonial birds that utilize this habitat. However, dry beach habitat supporting these birds is expected to be reduced on Hutaff Island. Therefore, Alternative 3 is expected to provide beneficial impacts to birds and turtles for foraging and nesting as well as recreational space for residents and visitors on Figure Eight Island while negative impacts may be incurred along Hutaff Island.

WET BEACH COMMUNITIES

Direct Impacts: The addition of beach fill to Figure Eight Island will cause short-term impacts directly to approximately 60-70 acres of the wet beach community. These communities will be buried with up to seven feet of dredged fill material along 12,500 linear feet of shoreline. This will occur along all areas receiving beach fill including portions of the Nixon Channel shoreline, oceanfront shoreline of Figure Eight Island, and the southern portion of Hutaff Island where the closure dike will be constructed. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Also, as previously stated, with the use of beach compatible material, infaunal organisms are expected to recruit in the newly formed wet beaches at a quicker rate, reducing the recovery period. This will, in turn, reduce the affects to bird and fish species that prey upon the benthic community.

Indirect Impacts: Delft3D model results show indirect impacts of approximately 20-25 acres occurring along the ocean shoreline of Figure Eight Island. These changes will affect shorebird, crustacean and fish foraging, and could impact recreational fishing

through a temporary reduction in bait species during and immediately after construction. The shifting of the marine intertidal beach habitat is expected to be gradual over a five year period, providing enough time and at a slow enough rate such that infaunal organisms can adjust. Thus, impacts to shorebirds, crustaceans, and fish foraging on these infaunal organisms are expected to be minimal. This in turn will also result in minimal, if any, impacts upon recreational fishing. Furthermore, impacts will be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing impacts to infaunal communities and sea turtle nesting. In addition, dredging will occur during the winter months while biological activity is reduced.

Cumulative Impacts: As a result of the inlet maintenance and subsequent renourishment activity every five (5) years, negative cumulative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As stated above, Nelson (1985) has demonstrated the adaptability and rapid recovery for organisms residing in the marine intertidal zone. With a minimum five year period between any maintenance events, there is expected to be ample time for any species to recover, thus cumulative impacts to these resources are not appreciable.

MARINE HABITATS

Softbottom Communities

Direct and Indirect Impacts: The activities associated with Alternative 3, would result in direct impacts to approximately 120-130 acres of softbottom community within the Permit Area. This includes an estimated 92.3 acres within the dredge area and 36.5 acres within the fill footprint of the closure dike (Figures 3.4a and 3.4b). Excavating the new channel alignment will cause an immediate removal of infaunal and non-motile epibenthic organisms from the softbottom community that will cause the loss of prey for foraging fish and invertebrates within Rich Inlet, Nixon Channel, and Green Channel. Target excavation depths are -19ft NAVD for all dredge areas and the fill depth of the dike will be 31-34 feet over present bottom elevation (currently -25 to -28 feet NAVD). Construction of the beach would result in the direct deposition of material from the dune or berm crest seaward to the construction toe-of-fill, which covers softbottom habitat. Over time, the slope of the fill would adjust and equilibrate seaward. Therefore, softbottom habitats located landward of the toe of fill would be directly and indirectly impacted by project activities. It should be reiterated that the material placed over the softbottom habitat area meets the State's sediment criteria requirements and is considered to be compatible to the native sediment. As previously described, the adaptive nature of the infaunal species will limit impacts. Recolonization of these infaunal species typically

tends to occur within the order of several months. Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). Both direct and indirect impacts are expected to be minimal.

Cumulative Impacts: With a minimum five years between any maintenance events within Rich Inlet, softbottom communities should have sufficient time to recover. This is due to the resilient nature of the constituents of softbottom habitat and the time it takes for full recovery. Therefore, cumulative impacts are not anticipated.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: The dredging of Rich Inlet, Nixon Channel, Green Channel, the construction of the sand dike, and placement of material on the ocean and estuarine shoreline will result in the suspension of silt and fine fractions in the water column. However, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001. It was determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values returned to ambient conditions rapidly. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Clearly and Knierim, 2001). In addition, turbidity monitoring during the construction of the closure dike at Bogue Inlet in 2005 revealed that turbidity levels never exceeded the State standard of 25 NTUs as the highest reading was recorded at 16.4 NTU. There is no State standard for turbidity. The low sit/clay content of the material within the areas being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging, dike construction, and placement of material on the beaches.

Cumulative Impacts: Dredging of the new bar channel and renourishment of the Figure Eight Island beach are anticipated to occur at a maximum, approximately once every five (5) years. Each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. Due to factors described above, no cumulative impacts regarding suspended particulates and turbidity are expected.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 3 is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: For Alternative 3, as shown by Delft3D modeling results, the tidal prism of the inlet throat decreased by 4.2% which was less than the decrease obtained for Alternative 2, the without project condition. The smaller reduction in tidal prism for Alternative 3 was expected given the excavation of the new inlet bar channel and the two channels connecting the inlet throat with Nixon and Green Channels. Flow through Nixon Channel increased to around 53% compared to 49% for Alternative 2 while the flow through Green Channel was about 36% or 3% less than Alternative 2. Again the balance of the flow, 11% in this case, moved through the marsh areas.

The increase in flow through Nixon Channel observed for Alternative 3 was partially due to the shoaling of the new channel connecting the inlet throat to Green Channel. Shoaling of Green Channel occurred fairly rapidly during the first two years of the simulation as the sand dike across the existing inlet channel eroded and morphed into a sub-tidal sand spit. Nixon Channel also shoaled rapidly during the first two years, however, the rate of shoaling decreased allowing the channel to maintain some of its cross-sectional integrity.

The magnitude of the changes in tidal flow and the overall hydrodynamics in the inlet complex that would accompany the implementation of Alternative 3 are relatively small and any changes in salinity levels within the project area will be minimal. Therefore, hydrodynamics and salinity are expected to be similar to natural or current levels during and after construction and following any subsequent maintenance events.

Larval Transport

Direct Impacts: The sporadic dredging and beach fill operations associated with Alternative 3 are not anticipated to impact larval transport into Rich Inlet. Larvae is expected, however, to be entrained within the dredge while operating in Nixon Channel and the connecting channel. Due to the time of the year when dredging will take place combined with the limited duration of dredging and the relative small volume of water pumped through the dredge, impacts to larvae are expected to be minimal.

Indirect and Cumulative Impacts: No indirect or cumulative impacts are anticipated.

PUBLIC SAFETY

Direct and Indirect Impacts: During the construction of Alternative 3, public safety will be temporarily impacted due to the usage of heavy machinery within Rich Inlet, Nixon Channel and Green Channel, and along the oceanfront shoreline of Figure Eight Island. The implementation of Alternative 3 will alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of Figure Eight Island thereby protecting the nineteen (19) imminently threatened homes on the island. Without the threat of these homes being

damaged or demolished, public safety will be positively indirectly impacted due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, would be covered by the placement of fill material during nourishment or removed and replaced with a nourished beach tapered from a developed dune ridge. Public safety hazards would increase on Hutaff Island with the use of heavy machinery during the construction of the dike and dredging within the inlet. This risk would be low since there are no residences on Hutaff Island and access is only by boat. Furthermore, construction will take place within the dredging window of November 16th through March 31st when public use of Nixon Channel, Green Channel, Rich Inlet, and Hutaff Island is at its lowest peak.

Cumulative Impacts: Public safety within Rich Inlet, Nixon Channel and Green Channel and along the oceanfront shoreline of Figure Eight Island will be temporarily impacted during each maintenance event scheduled approximately every five (5) years. These impacts will be similar in nature as those described above. No impacts are anticipated along Hutaff Island as the construction of the closure dike is a one-time event.

AESTHETIC RESOURCES

Direct Impacts: Temporary negative impacts to aesthetic resources will result from the implementation of Alternative 3 due to the visual presence of heavy machinery within the natural settings of Nixon Channel, Green channel, Rich Inlet and the oceanfront shorelines of Figure Eight Island and Hutaff Island. Following completion of the construction phase of Alternative 3, the aesthetic resources will be as they were prior to construction. Currently 19 structures have sandbags present along the ocean and Nixon Channel shorelines. With the removal of the sandbags along the northern portion of Figure Eight Island, the aesthetic quality of the island is expected to improve.

Indirect and Cumulative Impacts: Cumulative impacts will occur due to the anticipated on-going maintenance of Rich Inlet with the placement of dredged material on Figure Eight Island. These events will occur no more than once every five (5) year cycle. However, no dike construction will occur. Due to the time length in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access. General public access is restricted to boat access only. However, the shorelines and shoals of Nixon Channel, Green Channel, Rich Inlet, and the northern spit of Figure Eight Island are heavily used by the general public, especially during the summer months. The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be

temporarily affected during the construction activities associated with Alternative 3. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted to these areas.

Indirect and Cumulative Impacts: Immediately following construction, recreational resources and opportunities are expected to benefit from the increased size and extent of the nourished beaches along the oceanfront and Nixon Channel shoreline. As the closure dike welds to Hutaff Island, the dry beach community that forms will offer additional area for surf fishing, bird watching, and other recreational opportunities.

NAVIGATION

Direct Impacts: Navigation will be temporarily impacted due to the presence of the dredge and pipeline during the implementation of Alternative 3. The dredging involved with Alternative 3 will effectively close the present entrance channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located.

Indirect and Cumulative Impacts: Over the next 5 years, the "Y" shaped dredge cut will assume a more curved shape, and both sides of the entrance channel will assume a more gradual slope. As part of this process, the offshore end of the entrance channel will migrate approximately 500 ft to the southwest by the end of year 4 but, based on the model results, the channel will breach through the ebb tide delta and re-establish a position closer to Hutaff Island after 5 years. This change in channel position could trigger realignment back to its preferred position.

Figure 5.16 indicates shoaling of the Entrance Channel would approach the 60% shoaling threshold three years after initial construction. However, the shoaling percentage fluctuated around 60% between the third and fourth year after construction and did not exceed 60% until the fifth year of the simulation. The model indicated the new bar channel would breach the ebb tide delta and assume an alignment 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, as shown in Figure 5.31. This rapid 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, the Green Channel connector stabilized with some slight scour occurring in the channel during years 3 and 4 of the simulation. The Nixon Channel connector also experienced some rapid shoaling during the first year, accumulating 117,000 cubic yards or about 20% of the initial construction volume. Beyond year 2, the rate of shoaling moderated to around 50,000 cubic yards/year over the

final four years of the simulation. These reduced rates of shoaling in the two channel connectors indicate they had achieved some equilibrium and would probably not need to be maintained as frequently as the bar channel.

For planning purposes, future maintenance of the channels would be limited to just the bar channel with 716,000 cubic yards being removed every 5 years. 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. With regard to the Nixon Channel connector, its effectiveness in moving flow away from the shoreline and reducing erosion stress along this segment of the sound shoreline should be evaluated prior to initiating restoration of the new channel.

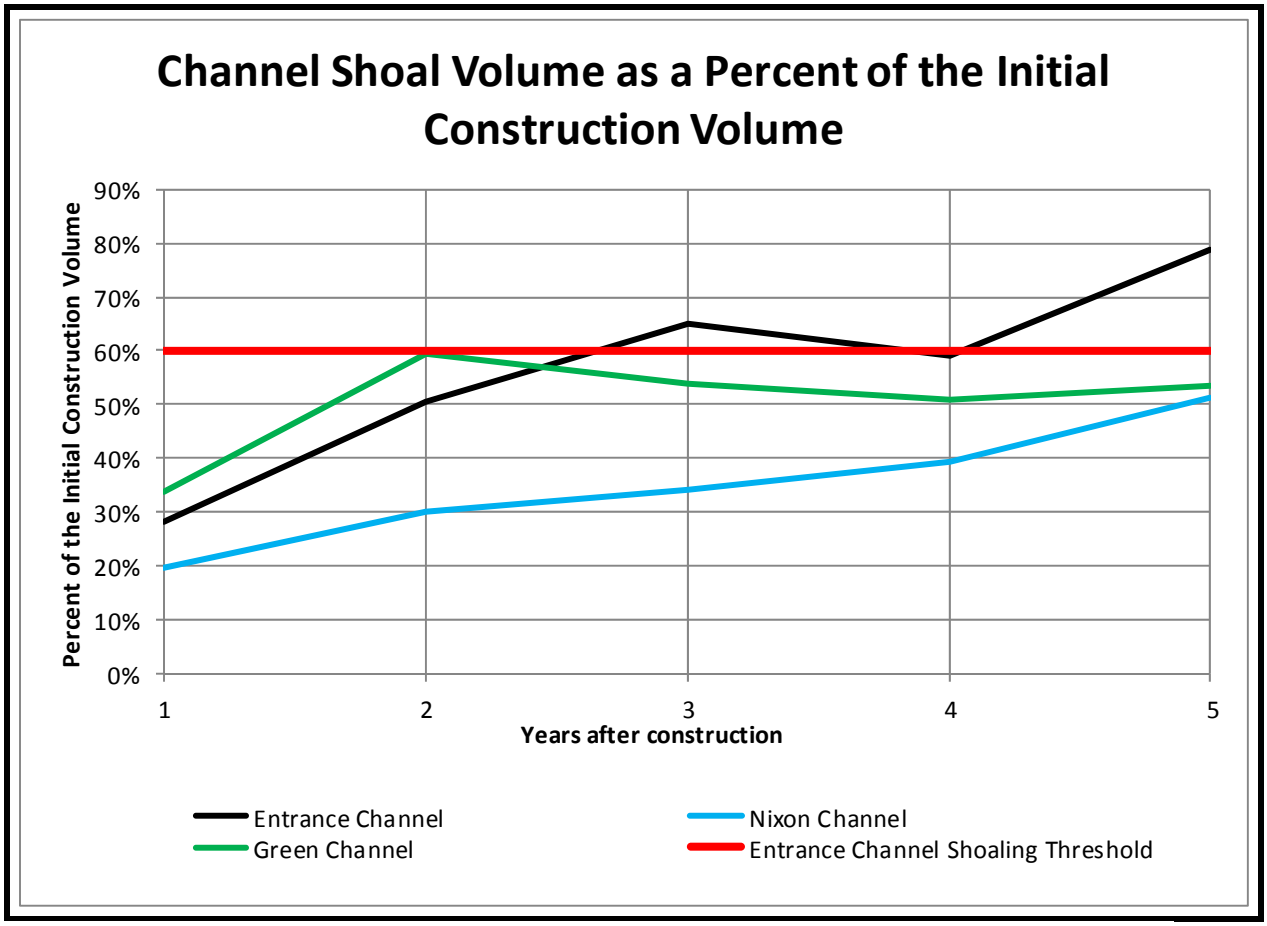


Figure 5.31. Alternative 3 - Cumulative channel shoal volumes over the 5-year model simulation expressed as a percent of the initial construction volume.

At the end of the 5-year model simulation, the channel leading from Nixon Channel to the inlet gorge maintain depth of 10 feet or greater and a width of approximately 100 feet both of which are adequate for the size vessel that normally uses Rich Inlet. On Hutaff Island, the southern half of the closure dike will erode, filling in the former entrance

channel on either side of the dike. Navigational use of the channels is generally not anticipated to be impacted.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 3 is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 3 would include the use of approximately 1.2M cubic yards of material as beach fill along 12,500 linear feet of the Figure Eight Island shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). The design width of the oceanfront dry beach, following anticipated adjustments in response to wave action, will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the design width of the dry beach will be 124 feet. The remaining areas will average 46 feet, including the existing dry beach. In addition, the alternative includes a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). These two locations will be renourished approximately every five years providing the long term protection.

Overall, by moving the channel and inducing movement of the ebb shoal southward, Alternative 3 is expected to enhance the performance of most of the beach fill placed north of Bridge Road by reducing the erosion rate. The only exception is the fill along the northern 2,000 feet which could experience high rates of loss between the fourth and fifth years after channel realignment due to the movement of the channel back toward Hutaff Island. These actions will provide protection to up to 40 homes and the infrastructure located behind this beach fill yielding positive impacts to this resource. It should be noted that no structures are present on Hutaff Island.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Both short and long-term benefits are expected from the reduction of solid waste with the implementation of Alternative 3. This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Alternative 3 would effectively prevent the loss of homes and infrastructure on the north end of Figure Eight Island. While some homes may be subject to damage during severe storm events, the level of damage would not necessarily result in the property owners moving or demolishing their homes. Thus, the existing tax base would be maintained.

Alternative 3 would preserve the existing tax value. However, since the width of the beach along the north end of Figure Eight Island would vary from a maximum immediately following beach nourishment to a minimum at the end of the 5-year nourishment cycle, some of the threatened 40 structures north of 302 Bridge Road North could still be subjected to some storm damage. This could lead to the eventual abandonment and/or demolition of some of the structures which would in turn reduce the tax value on Figure Eight Island. Since abandonment and/or demolition of these homes would be determined by the affected property owners, they were assumed to remain in place throughout the 30-year analysis period with no impact on the existing tax base.

Implementation of Alternative 3 will positively impact the local economy of New Hanover County. If the current erosion rates were to continue, the damage or destruction of imminently threatened homes would decrease the local tax revenue on Figure Eight Island. Therefore, the protection of these homes from erosion provided by the implementation of Alternative 3 will provide a positive direct, indirect, and cumulative economic benefit. Table 5.13depicts the average annual economic impact associated with Alternative 3. Over the 30-year planning period, the total implementation cost for Alternative 3, excluding environmental and physical monitoring costs, would be about $61.7 million in current dollars.

Table 5.13- Summary of Average Annual Economic Impact of Alternative 3

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$0	$0	$2,484,00	$2,484,000

NOISE POLLUTION

Direct Impacts: The relocation of Rich Inlet, dredging of the connector channels, construction of the closure dike, and the placement of beach compatible material on the oceanfront and backbarrier shoreline would temporarily raise the noise level in the areas due to the use of heavy machinery. This would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the low frequency of beach nourishment events and the time of year.

D. IMPACTS ASSOCIATED WITH ALTERNATIVE 4: BEACH NOURISHMENT WITHOUT INLET MANAGEMENT

Alternative 4 would include a beach fill along the ocean shoreline between Rich Inlet and Bridge Road and a fill along the Nixon Channel shoreline immediately behind the north end of Figure Eight Island and periodic nourishment to maintain the fills. The size of the beach fill along the ocean shoreline associated with Alternative 3 was dictated by the volume of material that would be removed to move the inlet ocean bar channel to a preferred position and alignment and modify the channels leading into both Nixon and Green Channels. For Alternative 4, the size of the beach fill was based on the modeled performance of a fill between Rich Inlet and Bridge Road without any modifications to Rich Inlet. In this regard, the size of the beach fill modeled under Alternative 4 was the same as Alternative 3, however, analysis of the model results found this beach fill to be over designed for the area between stations F90+00 and 80+00 and under designed for the area north of station 80+00. As a result, the beach fill under Alternative 4 was modified to address shoreline erosion issues resulting in a smaller initial beach fill between F90+00 and 80+00 and a larger fill between 80+00 and 100+00. The re-design of the beach fill for Alternative 4 is discussed below. Since Alternative 4 does not include any modification to the Rich Inlet ocean bar channel, material to construct and maintain the beach fills would be obtained from Nixon Channel, three upland disposal islands, and the offshore borrow site.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: Like Alternative 1, Dr. Cleary's shoreline analysis suggests that portions of shoreline behind Rich Inlet which contain salt marsh habitat have experienced erosion in response to the development of this large flood tide delta. While the erosion rates in this area are significantly greater than the pre-1993 rates, this increase cannot be directly attributable to dredging in Nixon Channel due to the influence of the migrating sand lobes into Nixon Channel associated with the morphological changes that have occurred to Rich Inlet since 1993. Regardless, this erosion of the salt marsh shoreline would be expected to continue so long as the flood tide delta directs the majority of the flow close to the eroding shoreline (Cleary, pers. comm.). Additional erosion of salt marshes has been occurring along the Nixon Channel shoreline. This erosion is related to movement of the Nixon Channel thalweg toward the island. Recent photographs have shown exposure of high marsh peat and shrub stumps along the estuarine shoreline in this location which have helped validate this process (Cleary, pers. comm.). Due to the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct or indirect impacts to salt marshes are expected to continue. Furthermore, direct impacts to the salt marsh resources in proximity to the dredged material disposal sites which may be utilized as a source of beach fill material for Alternative 4 during the excavation and transfer of

this material. However, impacts are not likely as proper construction practices such as the use of silt fencing would be utilized to protect these resources.

Cumulative Impacts: Similar to as described for Alternative 1, beyond the existing natural processes of erosion and development, no cumulative impacts are anticipated with Alternative 4.

Submerged Aquatic Vegetation

Direct, Indirect, and Cumulative Impacts: Three confirmed and 17 probable SAV occurrences have been identified within the Permit Area (Figures 4.3a and 4.3b in Chapter 4). The three confirmed occurrences are specifically found within tidal creeks along the edge of salt marshes west of Green and Nixon Channel. SAV resources require light to penetrate the water column for healthy growth. A prolonged increase in turbidity and TSS would serve to decrease the amount of available light. Cleary and Knierim (2001) observed that dredging within Nixon Channel and the associated beach nourishment along the northern portion of Figure Eight Island resulted in a temporary increase of turbidity and TSS primarily at the discharge site located on the ocean shoreline. No measurements were taken in proximity to the dredge site within Nixon Channel. These temporarily increased values would not be anticipated to affect the natural long-term growth of SAV. The use of offshore borrow areas would not be expected to impact SAV as these resources are not found in proximity to these sites. Should the dredged material disposal sites be utilized, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. This would reduce the likelihood of impacts associated with the burial of SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Furthermore, negative cumulative impacts are not expected to be incurred as SAVs are expected to migrate to their preferred depth should sea levels rise over the next 30 years as currently predicted.

Shellfish Habitat

Direct and Indirect Impacts: The dredging of material from Nixon Channel is predicted to cause a short term increase in turbidity and TSS. Due to the low silt percentage and the well-sorted within Nixon Channel, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. Using proper construction practices, the removal of material from the three upland dredge disposal islands should not allow for direct or indirect impacts to shellfish resources within proximity of the islands or pipelines.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard, as shown by Cleary and Knierim (2001) following dredging within Nixon Channel. Salinity throughout the inlet complex will remain unchanged as the waterways within the inlet complex are expected to provide the similar tidal prism as existing

conditions. Therefore, cumulative impacts to shellfish habitat under Alternative 4 are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Effects to upland hammocks are expected to be the same as described for Alternative 1 on page 202.

INLET DUNES AND DRY BEACHES

Direct Indirect Impacts: Morphological changes to the Inlet Dunes and Dry Beaches indicated by the Delft3D model for Alternative 4, particularly to Rich Inlet, were essentially the same as Alternative 2. This was to be expected since Alternative 4 would not alter the inlet in any way. The sand spit projecting off the north end of Figure Eight Island into Rich Inlet reduced in elevation over the 5-year simulation, becoming subtidal by the end of the simulation. This will result in the reduction of habitat for nesting turtles and foraging/resting shorebirds on the Figure Eight Island side of the inlet. Past monitoring data has shown turtles nesting in this area and also the presence of piping plovers and other shorebirds. It is estimated that approximately 5-10 acres of inlet beaches will be directly impacted due to the placement of fill along the Nixon Channel shoreline. A number of homes in proximity to the inlet beach along the extreme north end of Figure Eight Island are protected by sandbag revetments. Although these bags are anticipated to be removed in the future, the existing condition of the inlet beach is not compatible to beach users. Delft3D model results suggest that shoreline erosion will result in indirect impacts of 0-5 acres of Inlet Dunes and Dry Beaches.

Along the southern tip of Hutaff Island, the Inlet Dunes and Dry Beaches are anticipated to expand by approximately 5-10 acres allowing for additional habitat for shorebirds and nesting sea turtles (Figure 4.19 in Chapter 4) on Hutaff Island. This is anticipated to result in positive indirect impacts to the Inlet Dunes and Dry Beaches along Hutaff Island.

Cumulative Impacts: As shown by Dr. Cleary's geomorphic analysis of Rich Inlet, the habitats associated with the inlet undergo significant changes in response to the reorientation of the ebb tide delta. Although the relative position of the inlet has been stable over the past century, fluctuations in orientation of the main ebb-channel have forced subsequent periods of erosion and accretion on the adjacent shorelines of Figure Eight and Hutaff Islands (Cleary, 2009). Therefore, both positive and negative cumulative impacts to the Inlet Dunes and Dry Beaches will be incurred as part of the natural reorientation of the ebb tide delta and inlet over time.

INTERTIDAL FLATS AND SHOALS

Direct, Indirect, and Cumulative Impacts: Because the permitted dredging area associated with Alternative 4 does not include intertidal areas, this alternative is not expected to have direct impacts on intertidal flats and shoals. However, due to

maintenance dredging at an interval of approximately every three years, increases in suspended sediment and turbidity (which could be transported to the interior of the inlet complex during flood stages of the tidal cycle) could introduce minor secondary, or indirect, impacts. It should be noted that the biotic communities within the intertidal flats naturally fluctuate in density and abundance over time, but overall remain persistent. During flood stages of the tidal cycle, dredged material that remains in suspension could be transported into the interior portions of the inlet complex and settle on the intertidal flats and shoals. However, the material shoaling the Nixon channel has a low silt content, and is fairly coarse. This will result in only minor and ephemeral increases in both suspended sediment and turbidity. Delft3D modeling suggests that intertidal flats or shoals will be minimally impacted indirectly or cumulatively by 0-5 acres with this alternative. Therefore, beyond existing natural processes and the effects of navigation channel maintenance activities, no additional impacts are anticipated with Alternatives 4.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities:

Direct and Indirect Impacts: Similar to the impacts described for Alternative 3, with the implementation of Alternative 4, Delft3D model results suggest short-term impacts to 0.3 acres of dune communities on Figure Eight Island due to temporary disturbances to the fauna which potentially utilizes this habitat for roosting, foraging, and nesting. This 0.3 acres of impact is considered to be negligible due to the compensation occurring with beach nourishment along Figure Eight Island to help stabilize the dune system and provide long term storm protection. These stabilization measures will allow for long term growth and development of dune vegetation and provide habitat for roosting, foraging and nesting shorebirds. The dune communities located on Hutaff Island are not expected to be directly or indirectly impacted by the implementation of Alternative 4. Although the physical location of the dune system may change as natural overwashing and other storm-induced events might occur, the dune communities at Hutaff Island are expected to remain intact with minimal direct and indirect impacts.

Cumulative Impacts: Alternative 4 includes renourishment approximately every three (3) years. Therefore, the project will serve to provide long-term protection of the dunes along Figure Eight Island resulting in the protection of the nesting, foraging, and resting habitat for wildlife utilization.

Oceanfront Dry Beach Communities:

Direct Impacts: The beach nourishment plan included in Alternative 4 would benefit the dry beach communities along 12,500 linear feet of the Figure Eight Island shoreline through the expansion of the dry beach habitat. Beach nourishment would restore the dry beach habitat along from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00, 12,500 feet), with a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). Direct impacts include

100-150 acres of existing dry beach habitat along the oceanfront shoreline and the Nixon Channel shoreline on Figure Eight Island. The width of the oceanfront dry beach will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 172 feet. The width in the remaining areas will vary from 17 feet between stations F90+00 and 20+00, 43 feet from 30+00 to 60+00, and 86 feet from 70+00 to 80+00, including the existing dry beach. This increased dry beach area will serve to benefit seabeach amaranth, nesting sea turtles as well as resting and nesting birds. Direct impacts will be incurred as renourishment is scheduled for approximately every three (3) years. This includes the mortality of macro invertebrates such as ghost crabs. However, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008).

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Street *et al*., 2005). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles.

Indirect and Cumulative Impacts: As discussed in the Shoreline Change section on page 181, volumetric losses from the beach fill for Alternative 4 between stations F90+00 and 105+00 averaged 209,600 cubic yards/year over the 5-year simulation period. Between 80+00 and 100+00 large rates of erosion were observed where the entire fill by year 3 of the simulation and progressed into the existing upland area. However, the beach fill between stations F90+00 and 30+00 performed very well and would not require periodic nourishment on a regular basis. North of baseline station 30+00, modeled losses from the fill over three years totaled 602,000 cubic yards with over 50% of the volume loss occurring north of station 80+00.

Changes indicated by Delft3D modeling along the southern 3,000 feet of Hutaff Island were similar to the changes computed for Alternative 2, the without project condition. The model results indicated a slight increase in the accretion rate on the south end of Hutaff compared to Alternative 2. This small increase in the accretion rate may have been due to higher rates of sediment transport into Rich Inlet associated with the erosion of the artificial fill on Figure Eight Island.

In general, the performance of the fill as indicated by the model results will enhance the dry beach area available to wildlife, including seabeach amaranth, sea turtles, shorebirds, as well as recreational space for residents and visitors on Figure Eight Island as described above for Alternative 3. According to Greene (2002), beach nourishment can benefit endangered and threatened sea turtles by restoring habitat along eroded beaches. Some studies have found no significant difference between nourished and non-nourished beaches in the number of eggs per nest, as well as, hatching and emergence success

(Nelson *et al*., 1985; Ryder, 1991). Other projects have shown increased numbers of nests, hatchlings, and survival rate of young turtles (Raymond, 1984). The increase in dry beach on Figure Eight Island and on Hutaff Island is also expected to positively affect the shorebirds, water birds and colonial birds that utilize this habitat. Therefore, Alternative 4 is expected to provide benefits to birds and turtles for foraging and nesting as well as recreational space for residents and visitors on Figure Eight Island.

WET BEACH COMMUNITIES

Direct Impacts: The addition of beach fill to Figure Eight Island will cause short-term impacts to approximately 60-70 acres of the wet beach community. These communities will be immediately buried with up to seven feet of dredged fill material along 12,500 linear feet of shoreline. Including the maintenance events, this is expected to occur at least once every three years. This will occur along all areas receiving beach fill including portions of the Nixon Channel shoreline. These impacts are considered to be short-term because studies have demonstrated rapid recovery times for organisms inhabiting wet beaches. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Also, as previously stated, with the use of beach compatible material, infaunal organisms are expected to respond as studies have shown (Van Dolah et al., 1994), and dredging would occur during winter months when infaunal community activity and its onshore populations are at their lowest.

Indirect Impacts: Indirect impacts of approximately 20-25 acres along the ocean shoreline of Figure Eight Island, as indicated by Delft3D modeling by the gradual shifting of the marine intertidal beach habitat. This may affect shorebirds, crustacean, and fish foraging, which could also impact recreational fishing. However, this shifting would occur over a 3-year period and would allow for the gradual adjustment of the infaunal organisms. The slow rate of transition is expected to minimally affect shorebirds, crustaceans, and fish foraging. Furthermore, impacts will be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing impacts to infaunal communities and sea turtle nesting. In addition, dredging will occur during the winter months while biological activity is reduced.

Cumulative Impacts: As a result of the renourishment activity approximately every three (3) years, negative cumulative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However, as researched, organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). Other studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As stated above, Nelson (1985) has demonstrated the adaptability and rapid recovery for organisms residing in the marine intertidal zone. With a minimum three (3) year period between any maintenance events, there is expected

to be ample time for any species to recover, thus cumulative impacts to these resources are not appreciable.

MARINE HABITATS

Softbottom Communities

Direct and Indirect Impacts: The activities associated with Alternative 4, would result in direct impacts of softbottom community every three years within the Permit Area. This includes the proposed borrow area within Nixon Channel and any offshore borrow area (location to be determined). Excavating these areas will cause an immediate removal of infaunal and non-motile epibenthic organisms from the softbottom community. Construction of the beach would result in the direct deposition of material from mean low water (MLW) to the construction toe-of-fill, which covers softbottom habitat. Over time, the slope of the fill would adjust and equilibrate seaward approximately 172 feet in the areas north of baseline station 82+50 and between 86 feet and 17 feet in areas south of station 80+00 to Bridge Road. The adjusted fill along the entire beach fill area will merge with the existing profile at a depth of -24 feet NAVD. Therefore, softbottom habitats located landward of the toe of fill would be directly and indirectly impacted by project activities. It should be reiterated that the material placed over the softbottom habitat meets the State's sediment criteria requirements and is therefore considered to be compatible to the native sediment. As previously described, the adaptive nature of the infaunal species will limit these impacts. Recolonization of these infaunal species typically tends to occur within the order of several months. Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). Both direct and indirect impacts are expected to be minimal.

Dredging from the offshore borrow area will result in a direct mortality of all organisms present within the dredged material (Posey and Alphin, 2002). Although the recruitment pattern is altered, the recovery of species after sediment removal is relatively quick, depending upon the opportunistic nature of the species (Street *et al*., 2005; Posey and Alphin, 2002). At dredge sites monitored off the coast of New Jersey, infaunal assemblages recovered within one year after disturbance, while biomass and taxonomic richness took 1.5 to 2.5 years to recover (Street *et al*., 2005).

Cumulative Impacts: Although many of the infaunal organisms found within the offshore borrow areas are considered to be resilient, the temporal spacing of approximately three (3) years between the periodic maintenance events within the proposed dredged areas may not allow for a full recovery of these infaunal communities within this softbottom habitat. Therefore, cumulative impacts may be anticipated if dredging occurred within the same location or footprint of a previous dredge event. Should alternate footprints be utilized within the previously permitted area within Nixon Channel, these impacts may not be incurred. The infill rate within the previously permitted area within Nixon Channel is much higher than what would be expected at an offshore borrow area,

therefore recovery of infaunal communities may occur within the 3-year cycle within that location.

WATER QUALITY

Turbidity and TSS

Direct and Indirect Impacts: The dredging within Nixon Channel, prospective offshore borrow areas, and the placement of material on the ocean and estuarine shoreline will result in the suspension of silt and fine fractions in the water column. However, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001and it was determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values (44.0 mg/l and 301.0 mg/l for turbidity and TSS, respectively) returned to ambient conditions rapidly (Clearly and Knierim, 2001). In addition, turbidity monitoring during the construction of the closure dike at Bogue Inlet in 2005 revealed that turbidity levels never exceeded the State standard of 25 NTUs with the highest observation of 16.4 NTU. The low sit/clay content of the material within the areas being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging and placement of material on the beaches. Therefore, temporary negative direct impacts related to turbidity are expected similar to those discussed for Alternative 1. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area.

Cumulative Impacts: Renourishment of the Figure Eight Island beach are anticipated to occur approximately every three (3) years and each maintenance event will take approximately eight (8) weeks to complete, pending weather and working conditions. With a minimum 3-year maintenance period and the factors stated above, no cumulative impacts regarding suspended particulates and turbidity are expected.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 4 is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The simulated change to the tidal prism within the permit area was not specifically modeled for Alternative 4; however it was simulated for Alternative 2 (Abandon and Retreat). Like Alternative 2, Alternative 4 does not

include any dredging within the inlet gorge or ocean bar. Although this alternative will dredge within the existing permitted footprint of Nixon Channel, it can best be compared to the model simulation performed for Alternative 2. Basing the anticipated changes to the tidal prism on the results from Alternative 2, over the next 5 years, the tidal prism of the inlet as a whole was shown to decrease by approximately 13% as the inlet channels naturally reconfigure themselves. Nixon Channel and Green Channel presently carry 49% and 39% of the flow through the inlet, respectively, with the balance of the flow moved through the marsh areas behind the inlet. It is known that the natural conditions within a tidal inlet are highly dynamic and that the tidal prism may become altered as conditions change. The estimated decrease of 13% in tidal prism is strictly based off the Delft3D modeling results which calculate these values based on data input and should be interpreted cautiously as natural conditions are highly variable. However, based off the modeling results, the hydrodynamics within the permit area is expected to be altered. Despite this alteration in tidal prism, due to the continued large volume of water moving in and out of the inlet, hydrodynamics and salinity are not expected to be impacted in response to Alternative 4.

Larval Transport

Direct Impacts: The sporadic dredging and beach fill operations associated with Alternative 4 are not anticipated to impact larval transport into Rich Inlet. Larvae is expected, however, to be entrained within the dredge while operating in Nixon Channel. Due to the time of the year when dredging will take place combined with the limited duration of dredging and the relative small volume of water pumped through the dredge, impacts to larvae are expected to be minimal.

Indirect and Cumulative Impacts: No indirect or cumulative impacts are anticipated.

PUBLIC SAFETY

Direct and Indirect Impacts: During the construction of Alternative 4, public safety will be temporarily impacted due to the usage of heavy machinery within Nixon Channel and along the oceanfront shoreline of Figure Eight Island. Pipelines would be extended from the upland dredge disposal sites located behind Figure Eight Island to the Nixon Channel shoreline and the ocean shoreline. The implementation of Alternative 4 will provide beach fill along of the northern 3.8 km (2.4 mi) of Figure Eight Island thereby adding protection to the current nineteen (19) homes that are imminently threatened on the island. Without the threat of these homes being damaged or demolished, public safety would increase due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline would be covered by the placement of fill material during nourishment or removed and replaced with a nourished beach tapered from a developed dune ridge. Construction will take place within the dredging window of November 16th through

March 31st when public use of Nixon Channel and Figure Eight Island is at its lowest peak. No public safety impacts would be incurred on Hutaff Island.

Cumulative Impacts: Public safety within Nixon Channel and along the oceanfront shoreline of Figure Eight Island will be temporarily impacted during each maintenance event scheduled approximately every three (3) years. These impacts will be similar in nature as those described above. No impacts are anticipated along Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary negative impacts to aesthetic resources will result from Alternative 4 due to the visual presence of heavy machinery within the natural settings of Nixon Channel and portions of its shoreline as well as the oceanfront shoreline of Figure Eight Island. Following completion of the construction phase of Alternative 4, the aesthetic resources will be as they were prior to construction. Currently 19 structures have sandbags present along the ocean and Nixon Channel shorelines. With the removal or burial of the sandbags along the northern portion of Figure Eight Island, the aesthetic quality of the island is expected to improve.

Indirect and Cumulative Impacts: Cumulative impacts to aesthetic resources will occur due to the anticipated dredging within Nixon Channel and usage of the material contained within the upland dredge disposal islands for renourishment events occurring every three (3) years on Figure Eight Island. Due to the time length in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Direct impacts to recreational resources are anticipated to be similar as those described under Alternative 3.

Indirect and Cumulative Impacts: Immediately following construction, recreational resources and opportunities are expected to benefit from the increased size and extent of the nourished beaches along the oceanfront shoreline and Nixon Channel shoreline. This will offer additional area for surf fishing, bird watching, and other recreational opportunities. However, recreational activities will be interrupted every three (3) years during maintenance dredging and beach fill operations. Impacts to recreation are expected to be minimal since scraping and filling activities are generally taking place during winter months when recreational activities are at their lowest levels.

NAVIGATION

Direct, Indirect, and Cumulative Impacts: The initial construction followed by periodic maintenance dredging in Nixon Channel benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will

be temporarily directly impacted due to the presence of pipelines within the waterway. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. Navigation will also be temporarily restricted within the areas between the offshore borrow area and the disposal areas along the oceanfront shoreline and Nixon Channel shoreline. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled for every three (3) years.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 4 is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 4 would include the use of approximately 0.86M cubic yards of material as beach fill along 12,500 linear feet of the Figure Eight Island shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00). The width of the oceanfront dry beach will vary along the length of the 12,500 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be 172 feet. The width in the remaining areas will vary from 17 feet between stations F90+00 and 20+00, 43 feet from 30+00 to 60+00, and 86 feet from 70+00 to 80+00, including the existing dry beach (Table 5.12). In addition, the alternative includes a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). These two locations will be renourished approximately every three (3) years.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 4 will result in similar positive affects to solid waste as those described under Alternative 3.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Construction of Alternative 4 would be accomplished by removing 400,000 cubic yards from the existing permit area in Nixon Channel and the balance; 529,300 cubic yards from the offshore borrow areas identified by Dr. Cleary. Initial construction would cost an estimated $12.3 million. Periodic nourishment every three years using a combination of offshore material, shoal material from Nixon Channel, and dredge disposal site material would cost approximately $9.0 million every 3 years.

Over the 30 year planning period, the total implementation cost of beach nourishment (in present dollars) would be about $102.5 million. The equivalent average annual costs for initial construction and future maintenance over a 30 year period would be $3,725,000/year. Table 5.14 depicts the average annual economic impact associated with Alternative 4.

Table 5.14- Summary of Average Annual Economic Impact of Alternative 4

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$0	$0	$3,725,000	$3,725,000

NOISE POLLUTION

Direct Impacts: Dredging within Nixon Channel and the offshore borrow areas along with the utilization of material from within the upland dredge disposal sites, which are included in Alternative 4, would temporarily raise the noise level in the areas of the dredge and the discharge point on the beach. This impact would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to air and noise pollution are anticipated.

E. IMPACTS ASSOCIATED WITH ALTERNATIVE 5A: TERMINAL GROIN WITH BEACH FILL FROM MAINTENANCE OF THE NIXON CHANNEL NAVIGATION CHANNEL AND CONNECTOR CHANNEL

A 1,600-foot long terminal groin, with 700 feet being seaward of the MHW line, 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 3.8 in Chapter 3). The 900 foot section landward of the MHW line would act as a shore anchor to protect against possible flanking of the landward end of the structure. Since the effective length of a terminal groin is that portion that would project seaward of the MHW line, the length of a terminal groin used in this document refers to that portion extending seaward of the MHW shoreline. The shore anchorage section would essentially follow the 1970 inlet shoreline and terminate near the Nixon Channel shoreline (Figure 3.8 in Chapter 3).

Alternative 5A would include beach fill in the same two areas as Alternative 3, 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. Material used for beach nourishment will be obtained from dredging the existing permit area in Nixon Channel to -11.4 ft NAVD (the depth currently permitted within that area) and a new connector channel, which would be dredged to -13.4 ft NAVD. The purpose of the new channel connector is to concentrate ebb flows away from the eroding portion of the Nixon Channel shoreline. Construction of the new channel connector and reestablishing the permitted dimensions in Nixon Channel would require the excavation of 994,400 cubic yards of material. A total of 200-265 acres of various habitat types is expected to be directly

impacted through the implementation of this alternative. It is anticipated that maintenance dredging would be conducted at a minimum of every five (5) years.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: The salt marsh resources within the Permit Area are located primarily along the sound sides of Figure Eight, Hutaff, and the marsh islands southeast east from the Atlantic Intracoastal Waterway (AIWW). During construction of the terminal groin at Figure Eight Island, 1.2 acres of low marsh habitat will be directly impacted due to the use of heavy machinery through the construction corridor and the placement of rubble over the terminal groin footprint. The bulldozers and construction equipment will be limited to operating within a defined construction corridor to limit the extent of direct impacts. Within the 1.2 acres of direct impacts expected, 0.4 acres of salt marsh habitat is within the footprint of the terminal groin with the remaining 0.8 acres of impact occurring within the construction corridor. The salt marsh habitat in this area is primarily comprised of *Salicornia virginica* (glasswort) unlike much of the *Spartina alterniflora* dominated salt marsh located behind the inlet complex.

Following the dredging within Nixon Channel and the connector channel, modeling results suggest that the primary flow will adjust from its current alignment along its southern bank to the middle of the channel, which should reduce the erosional stress along the salt marsh near the north end of Beach Road (see Chapter 3). This, along with the placement of 65,000 cubic yards of beach fill, will reduce the potential for the erosion of the salt marsh in this area. Along the salt marsh shoreline facing the entrance of Rich Inlet, currents are expected to be reduced slightly as flow is shifted from the back channel into the new dredge cuts thereby reducing potential salt marsh erosion at that location. The vast extent of the salt marsh resources located within the permit area is located at a considerable distance from the proposed project. With the exception of the construction corridor for the terminal groin along the northern portion of the island, no additional or indirect impacts to salt marsh are anticipated.

One terminal groin structure evaluated in the 2010 DENR report was the 1,525 foot-long terminal groin that was constructed in 2004 at the southern terminus of Amelia Island. The primary purpose of the groin at Amelia Island was to help stabilize the eroding shoreline and consequently protect the maritime forest and natural communities, including salt marsh habitats in proximity to the structure (DC&A 2003). Similar to the terminal groin design as described for Alternative 5A, this groin was constructed as a rubble mound structure. Downdrift erosion was prevented due to the low profile of the structure which allowed for material to wash over the groin, as the design calls for at Figure Eight Island. The terminal groin at Amelia Island, however, was also designed to be “leaky” and allow for material to pass through the structure as well. Based on a preliminary evaluation of aerial photographs pre- and post-construction of the terminal groin, no significant changes have been observed in the salt marsh communities in

response to the construction of the terminal groin (Olsen Associates, Inc. 2008), however these inferences have not be verified. Although the results from individual projects vary due to specific environmental and physical conditions, the salt marsh at this location doesn't appear to have been impacted by the terminal structure, as noted in the 2010 DENR terminal groin report. Due to these similarities, the results from the Amelia Island project can provide some assurances that the indirect impacts to the salt marsh communities in response to the construction of the terminal groin described for Alternative 5A are not likely to occur. However, the dynamic nature of the inlet system and the proximity of the salt marsh resources to the evolving shoreline, both positive and negative direct or indirect impacts to salt marshes are expected to continue.

Cumulative Impacts: Alternative 5A includes the maintenance of Nixon Channel and the connector channel at a minimum every five (5) years. No cumulative impact to the salt marshes are expected because the deepening of Nixon Channel and associated placement of material along the Nixon Channel shoreline which is expected to reduce erosion pressure in proximity to salt marsh resources.

Submerged Aquatic Vegetation

Direct and Indirect Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel and the connector channel are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs. The well-sorted sands with low silt content within these the majority of these dredged areas are expected keep turbidity and TSS levels below the state standard outside the immediate area of construction. However, a lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent salt marsh resources. Any placement of an outfall pipe within the disposal island would be oriented such that the effluent would not directly impact existing SAV beds as no known SAV resources have been identified in proximity to the disposal island.

Since dredging Nixon Channel and the connecting channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted (see Appendix B). Furthermore, dredging activity would occur during winter months when SAV resources are biologically less active. There are no anticipated SAV impacts due to changes in water quality.

Cumulative Effects: Turbidity and TSS levels are predicted to remain localized and below the state standard soon after all channel maintenance events, as observed following dredging in Nixon Channel in 2001. The highest weekly average of turbidity and TSS

recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively, during this monitoring (Cleary and Knierim, 2001). Maintenance events, scheduled for every five (5) years, will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Cumulative impacts to SAV under Alternative 5A are not expected.

Shellfish Habitat

Direct and Indirect Impacts: The dredging of material from Nixon Channel and the connector channel is predicted to cause a short term increase in turbidity and sedimentation levels. Due to the low silt percentage and the well-sorted sands in the majority of the areas to be dredged, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. However, a lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent shellfish resources. If deemed necessary, an outfall pipe would be placed within the disposal island and oriented such that the effluent would not directly impact existing shellfish resources. Therefore, these resources are not anticipated to be impacted by activities related to Alternative 5A.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard, as shown by Cleary and Knierim (2001) following dredging within Nixon Channel. Salinity throughout the inlet complex will remain unchanged as the waterways within the inlet complex are expected to provide the similar tidal prism as existing conditions. Therefore, cumulative impacts to shellfish habitat under Alternative 5A are not expected.

UPLAND HAMMOCK

Direct, Indirect, and Cumulative Impacts: Generally, the activities associated with Alternative 5A are not expected to cause any direct, indirect, or cumulative impacts to the upland hammock resources located within the Permit Area due to the distance and relative elevation of the resource from the proposed activities. However, lens of non-beach compatible material has been identified within a small portion of the proposed connector channel. This material would be pumped to an upland disposal area located in proximity to the AIWW where erosion control measures, including improvements to the dike surrounding the upland disposal area, will be implemented to control material from eroding into adjacent areas. Upland hammock habitat does exist along portions of the dredge disposal island, however, the disposal material is expected to remain confined within the settling pond and therefore impacts are not anticipated. No upland hammock habitat is located within the footprint of the terminal groin or associated construction corridor.

Changes to the tidal prism at the inlet due to construction of Alternative 5A will be minimal over the 5-year simulation. The relative amount of flow through Nixon Channel and Green Channel will proportionally remain similar as well (refer to Appendix B - Engineering Analysis). Sea level rise is forecasted to increase in rate and result in a rise as much of 1 meter by the year 2100 (Miller, pers. comm.). This rate is predicted to be considerably less (1 foot over the next 100 years) according to local monitoring stations. However, if validated, this increase in sea level rise could result in potential cumulative impacts to coastal upland hammocks. Outside of this natural effect, no impacts are anticipated.

INLET DUNES AND DRY BEACHES

Direct Impacts: Delft3D modeling results suggest that 5-10 acres of direct impact to the Inlet Dunes and Dry Beaches on Figure Eight Island with the implementation of Alternative 5A. Of this, 1.9 acres would be directly impacted as a result of the construction of the 900' landward portion of the terminal groin. The footprint of the terminal groin would account for 0.6 acres of impact while the construction corridor would account for 1.3 acres of direct impact. The corridor width will vary between 100 and 200 feet wide which will allow for equipment to transport material back and forth in a safe manner. This activity within the construction corridor will result in denuding the area of vegetation.

In addition, roughly 7.4 acres of beach fill would be placed along the Nixon Channel shoreline. Several biological resources, including shorebirds, which utilize the inlet beaches and dunes for resting will be negatively impacted during and immediately following the placement of sand upon the beach.

Sea turtle nesting habitat will not be directly impacted as activities associated with Alternative 5A will not coincide with sea turtle nesting season and only beach compatible material will be utilized. As shown in Chapter 4, turtle nests have been found at the north end of Figure Eight Island. The construction of the terminal groin and accompanying beach fill is expected to provide an additional and more stable habitat environment for nesting sea turtles.

No direct impacts are anticipated on Hutaff Island.

Indirect and Cumulative Impacts: The construction corridor will be kept open for an undetermined amount of time for any unseen maintenance or potential for structure removal. If the structure remains, then it is expected that the terminal groin will become covered in sand and possibly vegetated. Like Alternative 2, modeling results suggest that within five years of construction, portions of the inlet beach and dune system would be converted to a subtidal and intertidal sand flat (Figure 5.32). Essentially all of this loss is associated with the erosion of the sand spit extending off the north end of Figure Eight Island into Rich Inlet. The loss of the sand spit will result in negative indirect impacts to the birds and sea turtles which utilize this habitat for nesting and foraging. However, the

model shows that the placement of fill material on the south side of the structure will be maintained as dunes and dry beaches at the end of the 5-year period. Although the inlet dunes and beach habitats may be reduced on the Figure Eight Island side of Rich Inlet, the model results indicates the south end of Hutaff Island will accrete in response to Alternative 5A between year 0 and year 5 (Figures 3.23-3.28 in Chapter 3 and Figure 5.33 below). However, the amount of accretion on Hutaff Island for Alternative 5A was less than indicated under Alternative 2. Because Hutaff Island is unpopulated and access is restricted by boats only, the increased habitat in this location maybe considered more valuable for nesting and foraging wildlife. As shown by research, wintering plovers on the Atlantic coast prefer wide beaches in the vicinity of inlets (Nicholls and Baldassarre, 1990; Wilkinson and Spinks, 1994). Even though newly formed dry beach and dunes are shown on Hutaff Island, it doesn't appear to fully compensate for the loss on the northern portion of Figure Eight Island. Without the ability to predetermine the exact acreage amounts, the amount of potential deficit is not known at this time.

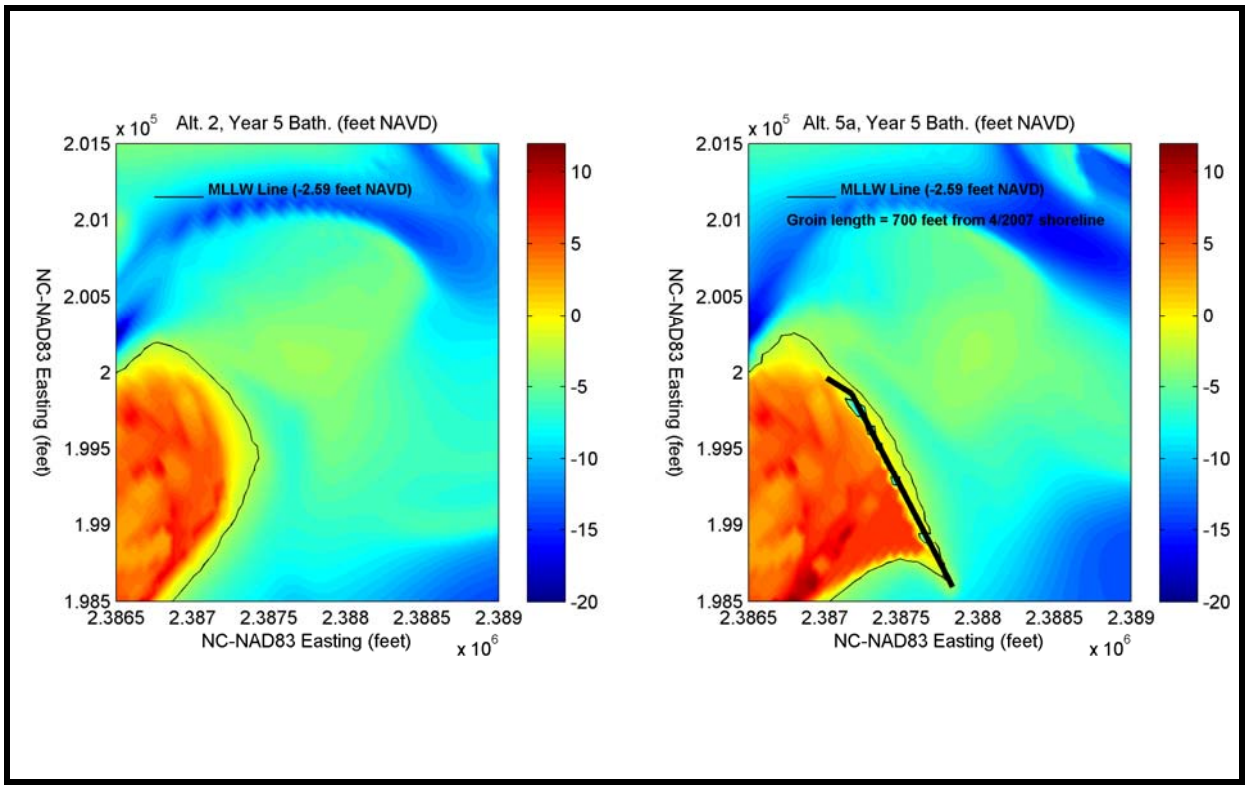


Figure 5.32. Year 5 Topography and Bathymetry of the northeastern portion of Figure Eight Island as depicted by Delft3D model results for Alternatives 2 and 5A.

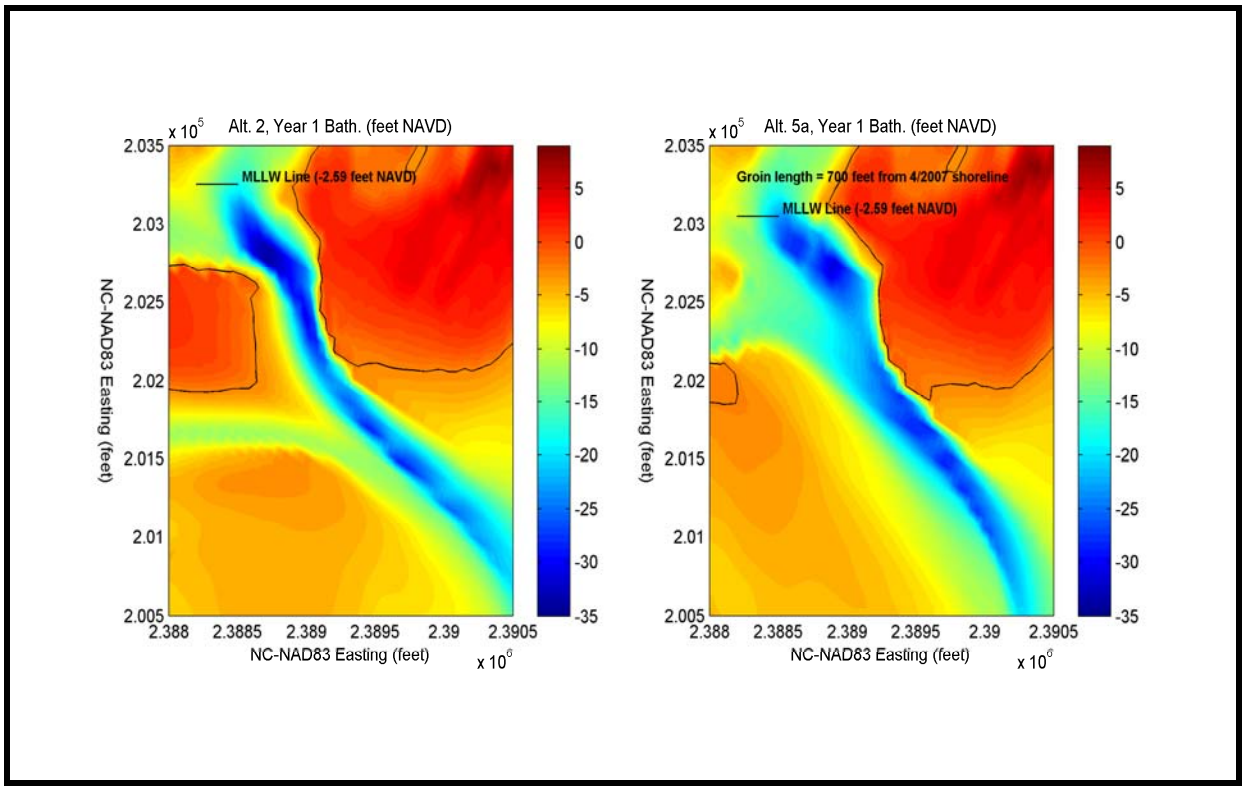


Figure 5.33. Year 5 Topography and Bathymetry of the southwestern portion of Hutaff Island as depicted by Delft3D model results for Alternatives 2 and 5A.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: The activities associated with Alternative 5A would directly impact approximately 26.8 acres of intertidal flats and shoals through direct excavation of these resources through dredging activities. This includes the direct removal of 994,400 cubic yards of material from the previously dredged area within Nixon Channel and the new connector channel. Infaunal species residing within intertidal flats and shoals would be directly impacted during the dredging events within these dredged areas. Specifically, the footprint of the area to be dredged for the connector channel is characterized by abundant intertidal habitat, which would effectively be removed and converted to the alternate habitat type of subtidal. The removal of this habitat may impact fish species which utilize flats and shoals as foraging grounds.

The presence of construction activity in association with the groin and beach nourishment placement may stress shorebirds, including the endangered piping plover, from foraging along the intertidal flats along the northern portion of Figure Eight Island. With construction taking place between November 16th and March 31st, direct impacts to birds utilizing these habitats should be minimal. Also, the use of mechanical equipment will be restricted within a specific construction corridor for the construction of the terminal groin which should help in reducing any potential stresses on the birds that may be foraging

and/or resting in the area. In addition, these birds would be expected to temporarily relocate to available nearby intertidal flats and shoals on the north side of the inlet.

Several different fish species inhabit the intertidal flats and shoals and the water column within these areas. As reported by USACE (1984), species that utilize these habitats include red drum, spotted seatrout, bluefish, Atlantic croaker, kingfish, and mullet. These species forage upon many of the benthic organisms that reside within intertidal flats and shoals. However, due to the winter time construction, many of these species will be located offshore and will not be utilizing the nearshore or inlet intertidal flats and shoal areas. For any fish species that may be present, it is expected, like the bird resources, that their mobility will provide them the opportunity to temporarily relocate to adjacent habitats while dredging and terminal groin construction is taking place.

Indirect Impacts: The direct removal of approximately 944,900 cubic yards of material from Nixon Channel and the connector channel will result in a sediment deficit within the inlet complex system. Because the accretion fillet will be artificially filled immediately following the construction of the terminal groin, material will continue to be transported beyond the structure into the inlet where the intertidal flats and shoals will continue to receive sediment input due to this sand bypassing allowing for the continued presence of intertidal flats and shoals. Delft3D modeling suggests that 5 years following construction, an additional 1,226 cubic yards of material may be lost from the system as a result of implementation of Alternative 5A resulting in a net loss of 946,126 cubic yards of material (Figure 5.34). Although the extent of the habitat is anticipated to be reduced initially, intertidal flats and shoals are expected to reform elsewhere. At the end of the 5 year period, the Delft3D model shows these habitats reforming in the area just northwest of the connector channel. Specifically, a net increase in shoaling is expected within the flood tide delta and along the western tip of Hutaff Island. This shoaling should help serve to maintain the integrity of the intertidal flats and shoals in this area, but at a reduced size. Approximately 0.7 acres of intertidal flats and shoals may be indirectly impacted based on the results of the Delft3D model. Most of the net volume loss occurred over the ebb tide delta (total net loss of 116,279 cubic yards) with some net loss persisting in the dredged area of Nixon Channel (net loss of 116,368 cubic yards). This appeared to be due to the material being naturally deposited in the new connector channel thus preventing it from being transported up into the Nixon Channel area. The macrobenthic community is anticipated to recolonize within these reformed intertidal flats and shoals. However, these reformed intertidal and shoals may be less in size and extent from the pre-construction acreage.

Because of the anticipated net reduction of the extent of intertidal flats and shoals relative to the without project condition, indirect negative impacts to the foraging and resting bird species utilizing the intertidal flats and shoals within the inlet complex are anticipated. Impacts to the intertidal flats and shoals within this area will cause the direct mortality of macroinfaunal species which is a prey source for foraging birds and fish populations. However, studies of dredging and disposal effects on nearshore and estuarine fish

populations have reported rapid recovery or minimal effects (Courtenay *et al.*, 1980; de Groot, 1979a; de Groot, 1979b; Posey and Alphin, 2000). These effects are anticipated in part due to the winter time construction when biological activity is lowest. Topographic changes in both inshore and offshore borrow areas have also shown to positively affect certain fish by creating refuge or forage areas (Lalancette, 1984). The unconsolidated and unvegetated communities that remain in the inlet complex would continue to redistribute as they lack structure and are dynamic in nature.

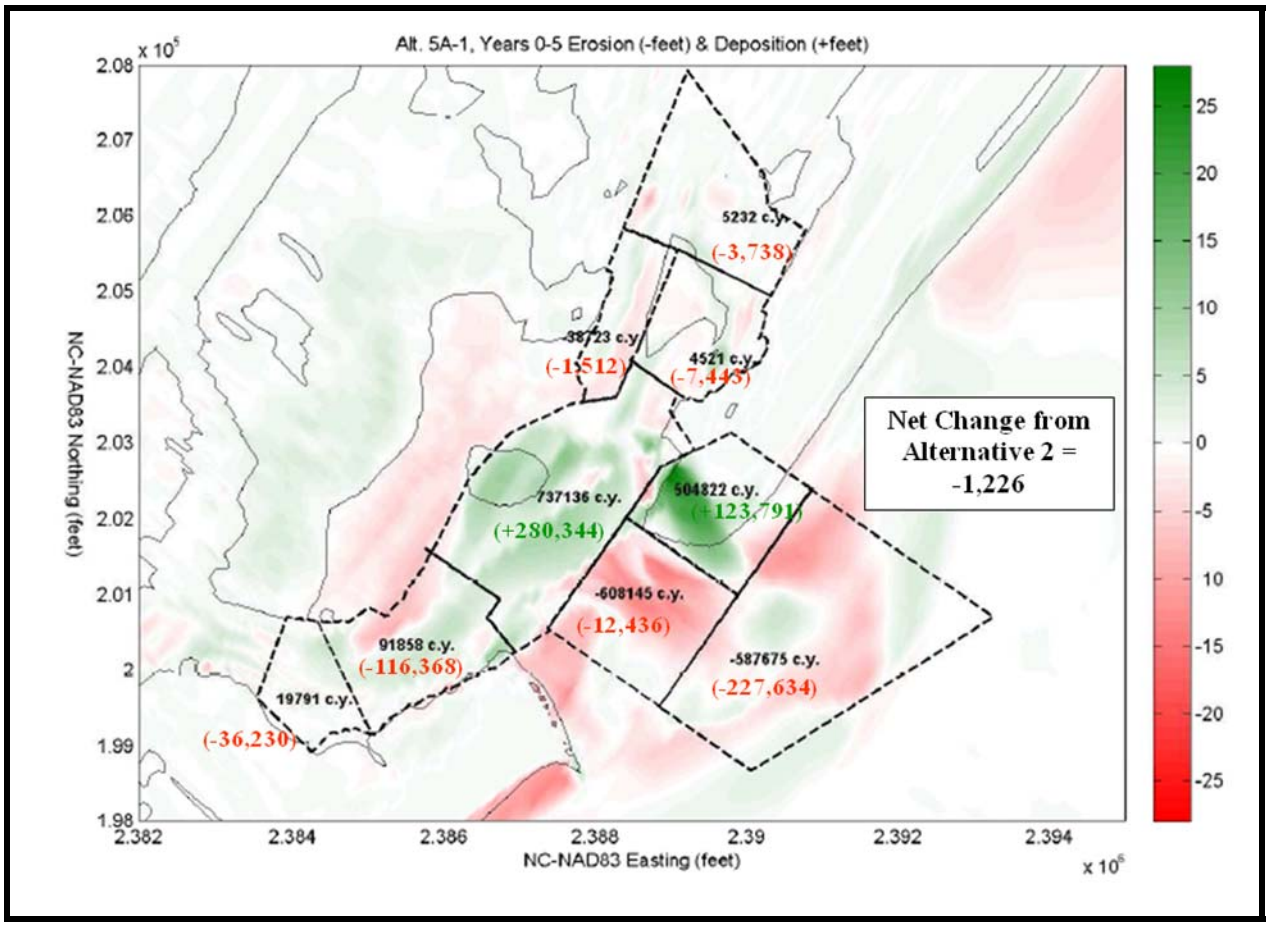


Figure 5.34. Alternative 5A modeled shoaling volumes within discrete areas within the Permit Area. Values in red indicate loss in material compared to existing conditions (Alternative 2). Values in green indicate increase of material compared to existing conditions.

The overall effects of the initial sediment deficit is not known; however, one can reference the 20-year old terminal groin in Oregon Inlet to obtain a general understanding of impacts to intertidal shoals and flats on both sides of the inlet. As described by USFWS (2008), habitat behind the terminal groin on Pea Island has undergone succession over the 20 years due to wind and water-borne sand, and it is no longer as suitable for piping plover nesting and foraging habitat than when the terminal groin

structure was initially constructed. Since the piping plover is primarily a winter resident at Oregon Inlet, the major threat to this species in the vicinity of the inlet is the degradation of intertidal beach foraging habitat (USACE 2001). The construction of the terminal groin resulted in the formation of about a 50-acre fillet; thus, restoring and stabilizing the tip of Pea Island (Dennis and Miller 1993). This provided valuable habitat for piping plovers and other shorebirds in the years following construction by the creation of a vernal pool or mud flat. However, in more recent years the presence of the terminal groin, as well as other actions such as dredging and nourishment, has modified habitat important to piping plovers by eliminating intertidal flats on the downshore side of the structure and allowing encroachment of vegetation in the stabilized areas. This stabilization of the northern tip of Pea Island has changed some of the inlet dynamics as it pertains to piping plover habitats.

Despite this, piping plovers have continued to utilize Pea Island. Although no data of piping populations are available prior to the construction of the terminal groin, post-construction data demonstrates the variability in annual counts. Populations of piping plovers on Pea Island have been relatively low prior to 2000 with an annual range of 0 to 8 individuals and an annual average of 2 individuals observed from1986 through 1999. In 2000, observations on Pea Island increased sharply to 87 individuals. Annual observations subsequently declined to 33 individuals in 2001, and increased sharply to 307 individuals in 2002. Pea Island observations declined steadily over the next three years, reaching a low of 4 individuals in 2005. Annual observations increased to 19 individuals in 2006; however, no piping plovers were reported from Pea Island during 2007 or 2008. In 2009, a total of 40 individuals were observed on Pea Island (NCDENR, 2010).

Cumulative Impacts: Although intertidal flats and shoals are expected to be reduced within the permit area, the habitat should persist because the intertidal flats and shoals are considered to be ephemeral and dynamic. The shoaling rate within the inlet complex is expected to increase following the implementation of Alternative 5A compared to existing conditions. Based on the results of the Delft3D model simulation for Alternative 5A, the rate of shoaling of the existing permit 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, the 5-year channel maintenance requirement would be 472,000 cubic yards. With a minimum of 5-years between dredging events, should allow for the recovery of infaunal organisms residing within the intertidal flats and shoals. In turn, the foraging fish and shorebirds are not expected to be cumulatively impacted.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct and Indirect Impacts:

The existing dune system along much of Figure Eight Island has been maintained through the deployment of sandbags. An artificial dune, similar to Alternatives 3, would be provided in the existing sandbag area between stations 77+50 and 95+00 under Alternative 5A. However, beach nourishment along Figure Eight Island is expected to help stabilize the dune system and provide long term storm protection. These stabilization measures will provide positive direct and indirect impacts to the coastal dune communities as it allows for growth and development of dune vegetation thereby providing habitat for roosting, foraging and nesting shorebirds. On Hutaff Island, approximately 0.3 acres of coastal dune communities are expected to be directly affected by the implementation of Alternative 5A within the first year following construction.

Cumulative Impacts: Alternative 5A includes renourishment at a minimum of every five (5) years. Therefore, the project will serve to provide protection of the dunes. Cumulative impacts are anticipated to be beneficial on Figure Eight Island as the renourishment cycles are expected to maintain the coastal dune system over a long period of time. This should allow the establishment of a vegetated community which provides habitat for resting birds and other wildlife. Although overwashing of dunes can result in the formation of important habitat for a variety of shorebirds on the backside of barrier islands, the dunes along Figure Eight Island are located in front of residential development and therefore overwashing are not expected. The dune communities located on Hutaff Island would be expected to migrate westward as natural processes including transgression will influence the environment. Although the physical location of the dune system may change as overwashing and other storm-induced events influence the environment, impacts to the dune communities at Hutaff Island in response to Alternative 5A are expected to be minimal.

Oceanfront Dry Beach Communities

Direct Impacts: Beach nourishment would affect approximately 100-150 acres the dry beach habitat along from the intersection of Beach Road and Beachbay Lane to the terminal groin located along the northern portion of the ocean shoreline of Figure Eight Island. Direct impacts will be incurred during the initial fill placement and the construction of the terminal groin. The construction of the terminal groin will directly impact 0.29 acres of dry beach due to the construction corridor and the footprint of the structure. These impacts will include the mortality of crustaceans including ghost crabs, however, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008). This reduction in dry beach habitat will initially reduce available nesting habitat for seabeach amaranth, sea turtles, and shorebirds, including the piping plover, however the increased beach

width as a result of nourishment will compensate for this loss. The width of the oceanfront dry beach immediately following construction will vary along the length of the 12,000 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will vary between 133 and 274 feet. The remaining areas will vary between 32 to 86 feet. This area will become beneficial habitat for resting colonial waterbirds.

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Street *et al*., 2005). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. Because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat with native compatible material. The proposed project would be conducted during the winter and, therefore, would not impact potential nesting activity by birds or turtles.

Indirect Impacts: Like Alternative 2, the Delft3D 5-year model simulation indicated erosion is expected to occur on the north side of the terminal groin. Along the ocean shoreline south of the terminal groin, the shoreline could become more stable which should assist in maintaining wildlife habitat for seabeach amaranth, nesting sea turtles, and shorebirds and reduce the frequency for beach nourishment. For the most part, the volume loss identified from the northern 2,000 feet of shoreline on Figure Eight Island occurred offshore as a relatively wide dry sand beach remained south of the terminal groin through the 5-year model simulation. The sand spit on the northern end of Figure Eight Island experienced less erosion compared to Delft3D model results for Alternative 2. The dry beach along the southern 3,000 feet of Hutaff Island accreted over the 5-year modeling period with the rate of accretion being about 43% less than determined for Alternative 2. This will provide additional habitat for nesting sea turtles and resting shorebirds.

Cumulative Impacts: Habitat for resting colonial waterbirds, nesting shorebirds, and nesting sea turtles along the ocean dry beach is expected to be maintained at the location of the terminal groin fillet for approximately 2,000 linear feet. The remaining 10,000 linear feet should be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel and the connector channel. These renourishment events are expected to occur within a minimum of every five (5) years. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist.

The continued negative shoreline impacts on the north end of Figure eight Island will depend on how the inlet bar channel behaves. While the present orientation of the bar

channel toward Hutaff Island has persisted since the mid-1990's, how long the channel will remain in this condition is impossible to predict. Based on past behavior, the bar channel is likely to naturally shift to the south and assume an alignment toward the north end of Figure Eight Island. Should this occur, the high rates of erosion on the north end of the island and the destruction of homes and infrastructure in this area could be abated for an unknown time period and the negative aesthetic impacts associated with the erosion reduced. In addition, the frequency of dredge and fill operations would be required at a less frequent rate.

WET BEACH COMMUNITIES

Direct Impacts: The addition of beach fill to Figure Eight Island will impact 50-60 acres of the wet beach community along the oceanfront shoreline, immediately burying the infaunal community. The construction of the terminal groin will impact approximately 1.6 acres of wet beach due to 1.1 acres within the construction corridor and 0.5 acres within the footprint of the structure causing the mortality of the infaunal community within this area.

Areas where fill will exceed 40 cm are expected to experience higher rates of infaunal mortality. As mentioned in Chapter 4, Nelson (1985) indicates that organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels. Furthermore, dredging will occur during the winter months while biological activity is reduced and the population of infaunal organisms are more likely to have migrated, in part, offshore. Although the wet beach infauna can adapt to fluctuations in the natural environment, the addition of sediment to the wet beach would have immediate yet minimal negative impacts to foraging fish and birds.

Indirect Impacts: Delft3D model results suggest that secondary impacts of 5-10 acres of marine intertidal habitat will occur along the ocean shoreline of Figure Eight Island while the fill placement equilibrates. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing to the recovery period for infaunal communities.

The ability for infaunal species to repopulate disturbed wet beach habitat in proximity to a shoreline stabilizing structure was demonstrated following the construction of the rubble weir jetty structures at Murrells Inlet, South Carolina. These structures, constructed in the late 1970's, includes a 3,347 foot jetty extending into the ocean with a 1,348 foot weir section on the north side of the inlet. The southern jetty includes a 3,317 foot structure that extends into the ocean without a weir system. The macrobenthic communities of the intertidal and nearshore subtidal environments were sampled during the construction of the jetties and once again five (5) years later. Comparison of species

abundance between years and among localities (updrift and downdrift) suggested no widespread impacts to macrobenthic fauna were attributable to jetty construction (Knott et al, 1984). Although the physical conditions are not identical at both locations, a similar response would be anticipated following the construction of the terminal groin on Figure Eight Island.

Cumulative Impacts: As a result of the dredging and renourishment activity at a minimum every five (5) years, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). With the adaptability of benthic communities, sufficient period between maintenance events, and the use of compatible material, Alternative 5A is not expected to result in long-term cumulative impacts.

MARINE HABITATS

Softbottom Communities

Direct and Indirect Impacts: The activities associated with Alternative 5A, would result in direct impacts to approximately 80-90 acres of softbottom community within the dredging footprint in Nixon Channel and the connector channel as well as the fill footprint of construction associated with the terminal groin. It should be acknowledged that some of the acreage amount or footprint e overlaps with the amount stated in the intertidal shoals discussion. Excavating the channels will cause an immediate negative impact by removing infaunal and non-motile epibenthic organisms from the softbottom community. Construction of the beach would result in the direct deposition of material from the dune or berm crest seaward to the construction toe-of-fill. Over time, the slope of the fill would adjust and equilibrate seaward. Softbottom habitats located seaward of the toe of fill would be indirectly impacted during equilibration time frame, which is expected to occur over a 12 month time frame. Burial depths during the adjustment period will vary. Studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As described above, the resilient nature of the infaunal species will limit the indirect impacts. Recolonization of these infaunal species typically tends to occur within the order of several months. Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). It should be reiterated that the material placed over the softbottom habitat meets the State's sediment criteria language and is therefore considered to be compatible to the native sediment.

Negative indirect impacts include the temporary loss of prey for foraging fish and invertebrates from the dredged softbottom habitat within Nixon Channel and the connector channel. For softbottom habitat outside the terminal groin, the infaunal communities are expected to fully recover based on the factors stated above. Within the

700 foot long footprint of the terminal groin, approximately 0.55 acres of near and offshore softbottom will be permanently removed. It is not known to what the full effects of this will be on the fishery resource, but with the softbottom habitat surrounding the footprint of the structure, the fishery resource should be capable of locating food sources and foraging within nearby areas.

Fish, including mullet that migrate over the nearshore softbottom habitat, may be impeded when they encounter the terminal groin. A study conducted at Murrells Inlet examined the movement of fish and plankton across the weir jetty. These data suggest that few swimming organisms were moving across the weir during the study. Further evidence supporting the hypothesis that the weir is a barrier to free swimming species came from visual observations. Visible schools of fishes, including menhaden and mullet, were never observed passing directly over the weir. The crest of the weir remained visible at the surface of the water even at high tide, and its location was marked by the turbulence from passing waves (USACE, 1981). Although the jetty at Murrells Inlet acted as a barrier for fish migration, the physical nature of the proposed structure at Figure Eight Island is much shorter in length. Furthermore, the accretion fillet is expected to fill seaward reducing the exposed area of the groin further. Therefore, migrating fish may be only minimally impacted by the presence of the terminal groin.

Cumulative Impacts: After the initial construction of the terminal groin, cumulative impacts are expected to be the same as Alternatives 1 and 3.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: Although no natural hardbottom communities have been observed within the Permit Area, it is anticipated that the construction of the terminal groin may provide an artificial hardbottom habitat. The physical structure of the proposed groin is expected to create habitat which may provide a foraging site and shelter for fishes, including bluefish, in the surf zone (Hay and Sutherland, 1988). Juvenile black sea bass, for example, use a variety of man-made habitats including artificial reefs, shipwrecks, bridge abutments, piers, pilings, jetties, groins, submerged pipes and culverts, navigation aids, anchorages, rip-rap barriers, fish and lobster traps, and rough bottom along the sides of navigation channels (NOAA, 2007b). Although this may be beneficial to some species, Chapman and Bulleri (2003) have concluded that creating rocky habitat has led to the introduction of non-native invasive species within the vicinity of a hard structure. These structures are often associated with higher fish abundances and species richness than in other surf zone communities (Peters and Nelson 1987; Clark et al. 1996). Some benefits to hardbottom communities are anticipated with the construction of the terminal groin.

WATER QUALITY

Turbidity and TSS

Direct Impacts: The dredging within Nixon Channel and the connector channel will result in the suspension of silt and fine fractions in the water column. However, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001and it was determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values (44.0 mg/l and 301.0 mg/l for turbidity and TSS, respectively) returned to ambient conditions rapidly (Clearly and Knierim, 2001). In addition, turbidity monitoring during the construction of the closure dike at Bogue Inlet in 2005 revealed that turbidity levels never exceeded the State standard of 25 NTUs with the highest observation of 16.4 NTU. The low sit/clay content of the material within the areas being dredged should result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging and placement of material on the beaches. Therefore, temporary and minimal impacts related to turbidity are expected similar to those discussed for Alternative 1. Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area.

Indirect and Cumulative Impacts: Although dredging and renouishment are anticipated to occur approximately at a minimum of every five (5) years. Due to factors described above, no indirect or cumulative impacts regarding turbidity are expected.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 5A is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: It is known that the natural conditions within a tidal inlet are highly dynamic and that the tidal prism may become altered as conditions change. Following the dredging of Nixon Channel and the connector channel into the inlet gorge, the hydrology within the inlet complex will also be altered from its current state, however by year 5 of the simulated model run, the flow through Nixon Channel for Alternative 5A was 5% greater than what is indicated for Alternative 2. Furthermore, the minor changes to the tidal prism in Nixon Channel due to construction of Alternative 5A are generally smaller than those of Alternative 3 due to the smaller dredge cuts. These relatively small changes in tidal prism will allow for the tidal exchange to continue

within Rich Inlet, Nixon Channel, and Green Channel thereby maintaining the existing state of hydrodynamic and salinity (see Chapter 3 for more detail).

Larval Transport

Direct, Indirect, and Cumulative Impacts: Perpendicular coastal structures, particularly long jetties, can potentially interfere with the passage of larvae and early juvenile fish, such as bluefish, from offshore spawning grounds into estuarine nursery areas. Successful transport of larvae from fish spawning on the continental shelf through the inlet is dependent on along-shore transport processes which occur within a narrow zone parallel to the shoreline (Blanton et al. 1999; Churchill et al. 1999; Hare et al. 1999). Obstacles such as jetties adjacent to inlets may block the natural passage for larvae into inlets and reduce recruitment success (Kapolnai, et al. 1996; Churchill et al. 1997; Blanton et al. 1999). Miller (1992) and Settle (NMFS, unpub. data), estimated that successful passage of winter-spawned, estuarine-dependent larvae through Oregon Inlet could be reduced 60-100% while reviewing the potential impacts of a previously proposed dual jetty system at Oregon Inlet.

The Fish and Wildlife Coordination Act Report concluded that the Oregon Inlet project should not be constructed because of, among other concerns, the impact of jetties on larval fish passage (USACE, 1999). Although there are conflicting opinions on the magnitude of fisheries impacts of a dual jetty system at Oregon Inlet, it was postulated that the construction of the Oregon Inlet structures could prevent some portion of ocean-spawned larvae from reaching estuarine nursery areas (USACE, 1999). Construction or lengthening of jetties, particularly where inlets occur infrequently along the coast (such as Oregon Inlet), could lower successful fish recruitment and fishery productivity (Kapolnai et al. 1996; Churchhill et al. 1997; Blanton et al. 1999).

While concerns regarding larval transport into estuarine habitats through inlets due to interference by jetties may have merit, the proposed terminal groin along Rich Inlet is not expected to impact larval fish transport. As described in Section 2.0, the fillet of the terminal groin will be artificially filled with beach compatible material immediately following construction which will effectively extend the dry beach shoreline seaward approaching the end of the terminal groin. Therefore, unlike the proposed duel jetties at Oregon Inlet which were planned to extend approximately 2,500 from the shoreline, the single terminal groin would not act as a direct impediment to longshore transport of larvae into the inlet. Once the beach protrudes to near the end of the structure, either by natural longshore transport or through beach nourishment, wave processes transport sand around and over the groins into the tidal inlet. The same sand by-passing action would also affect the by-pass of estuarine dependent larval forms thereby reducing any impacts to bluefish and other species.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: During the construction of Alternative 5A, construction hazards will increase due to the usage of heavy machinery within Nixon Channel and along the oceanfront shoreline of Figure Eight Island during beach nourishment activities and the construction of the terminal groin. Safety precautions, such as access restriction and use of USCG navigation rules will be undertaken to reduce this risk. Also, construction will be conducted during a period when boat traffic and beach use is at its lowest. For Figure Eight Island, the implementation of Alternative 5A will alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of Figure Eight Island thereby protecting the twenty (20) imminently threatened homes on the island. Without the threat of these homes being damaged or demolished, public safety should increase due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, would be removed and/or covered up and replaced with a nourished beach tapered from a developed dune ridge.

The proposed crest elevation of the groin is intended to follow the existing topography along the landward half of the structure. Along the seaward half of the structure, the crest elevation will follow the construction cross-section, except near its seaward end. At this location, the groin crest elevation will be +3.5' NAVD to ensure its visibility at all phases of the tide. In addition, a U.S. Coast Guard approved navigation aid consisting of a three-pile dolphin and light, will be installed at the seaward end of the terminal groin. These features will reduce the chance of the structure becoming a navigational hazard to vessels. No public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Temporary impacts to aesthetic resources will result from the implementation of Alternative 5A due to the usage of heavy machinery within Rich Inlet and on the oceanfront shoreline of Figure Eight Island due to the construction of the terminal groin and the dredge and beach fill operation. Following completion of the construction phase of Alternative 5A, the aesthetic resources will be as they were prior to construction with the exception of the terminal groin at the northern portion of Figure Eight Island. The landward portion of the terminal groin, which will be constructed with steel or concrete sheet piles, will have a crest elevation of +4 feet NAVD which is close to the existing ground elevation. Any material removed to construct the foundation of the terminal groin will be back filled with some of the material used to cover the structure. Also, the area disturbed by the construction activities will be restored to near pre-construction conditions by grading and planting of native plants. As a result, most of the landward portion of the groin will not be visible. The terminal groin and the dredge and fill operation will occur during the winter month when the number of residents on the island are at their lowest. Therefore, while the aesthetic resources may be temporarily

impacted, less people will notice the disruption. The removal of the sandbags along the northern portion of Figure Eight Island will improve the aesthetic quality of the island.

No impacts to the aesthetic resources are anticipated within proximity to Hutaff Island.

Indirect and Cumulative Impacts: Indirect and cumulative impacts will occur due to the anticipated on-going maintenance of Nixon Channel along with the placement of dredged material on Figure Eight Island. These events will occur at a minimal five (5) year cycle. Due to the length of time in between maintenance events, cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct Impacts: Figure Eight Island is a private island with limited public access. General public access is restricted to boat access only. However, the shorelines and shoals of Nixon Channel, Green Channel, Rich Inlet, and the northern spit of Figure Eight Island are heavily used by the general public, especially during the summer months. The recreational opportunities along the ocean shoreline are primarily utilized by the private homeowners and guests to the island. Recreational opportunities such as beachcombing, sunbathing, surfing, fishing, and walking along the beach will be temporarily impacted during the construction activities associated with Alternative 5A. However, all construction activities will be limited to working within a window when recreational use is at its lowest during the year. Even during construction, complete access will not be restricted in these areas.

Indirect and Cumulative Impacts: Following construction, recreational resources are expected to benefit from Alternative 5Adue to the increased size and extent of the nourished beach. Along the terminal groin, fin fish will likely be attracted to rubble structures due to their increased structural complexity which provides shelter from predators (Hay and Sutherland, 1988). The presence of fish along the terminal groin may increase recreational fishing opportunities resulting in beneficial uses. Macroalgae and sessile invertebrates including sponges and tunicates will also utilize the structure as habitat. The flora and fauna will provide snorkeling opportunities along the length of the structure as well.

NAVIGATION

Direct and Indirect Impacts: The initial construction followed by periodic maintenance dredging in Nixon Channel will benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within Nixon Channel and the connector channel. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. There will be some minor negative impacts to navigation in Nixon Channel due to the presence of barges used to transport the stone for

construction of the terminal groin. The barges would be moored in relatively deep water next to an offloading pier. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled approximately every five (5) years.

Cumulative Impacts: Following the dredging of Nixon Channel and the connector channel, Delft3D modeling results suggest that the entrance of Rich Inlet will behave in a similar manner to natural conditions over the next 5 years. The dredged area will be expected to shoal, however they will remain navigable in between maintenance events. The flood channel adjacent to the north end of Figure Eight Island will largely maintain its present dimensions. The terminal groin will be clearly marked; therefore it should not pose a threat to boats. Therefore, following construction of Alternative 5A, boaters should find navigation within the back side of Figure Eight Island and the newly constructed connector channel easier to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a minimum every five (5) years. Therefore, navigation is expected to be positive over the long-term.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 5A is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 5A would include the use of approximately 913,000 cubic yards of material as beach fill along 12,000 linear feet of the Figure Eight Island shoreline. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to the location of the terminal groin. The width of the oceanfront dry beach will vary along the length of the 12,000 foot fill area. Furthermore, the installation of the terminal groin will result in a wider beach within the accretion fillet which will protect the infrastructure as well. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will vary between 133 and 274 feet. The remaining areas will vary between 32 to 86 feet. In addition, the alternative includes a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). These two locations will be renourished at a minimum every five (5) years.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts: This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition. Implementation of Alternative 5A is expected to benefit the pubic by not contributing to additional solid waste.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 5A is expected to benefit the local economy of New Hanover County. If the current erosion rates were to continue, the damage or destruction of imminently threatened homes would decrease the local tax revenue on Figure Eight Island. As depicted in Table 5.15, the average annual equivalent cost for constructing and maintaining Alternative 5A would be $1,863,000. Over the 30-year planning period, the total cost for Alternative 5A in current dollars would be about $39.5 million.

Table 5.15 Summary of Average Annual Economic Impact of Alternative 5A

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$0	$0	$1,863,000	$1,863,000

No structures or buildable lots are expected to be lost under Alternative 5A, but again, repetitive storm damage could eventually lead to the demolition of some of the threatened structures. The protection of the homes and infrastructure is expected to provide a short and long-term benefit on the economy.

NOISE POLLUTION

Direct Impacts: The dredging of the Nixon Channel and the connector channel into, the placement of beach compatible material on the oceanfront and estuarine shoreline, and construction of the terminal groin would temporarily raise the noise level in the areas due to the use of heavy machinery. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. The noise pollution would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the low frequency of beach nourishment events and the time of year.

E. IMPACTS ASSOCIATED WITH ALTERNATIVE 5B (APPLICANT'S PREFERRED ALTERNATIVE): TERMINAL GROIN WITH BEACH FILL FROM NIXON CHANNEL AND DREDGE DISPOSAL ISLANDS

The design and location of the terminal groin for Alternative 5B would be identical to that described for Alternative 5A as would the beach fill along the Nixon Channel shoreline, however, as discussed below, the beach fill along the ocean shoreline would be smaller than the beach fill under Alternative 5A. The material to construct the beach fills

for Alternative 5B would be derived from maintenance of the existing permit area in Nixon Channel. The three northern disposal areas situated adjacent to the AIWW would provide a supplemental source of beach nourishment material. These disposal islands would be used in the event that shoaling of the Nixon Channel permit area does not provide enough material to maintain the beach south of the terminal groin or if it is needed to respond to damages associated with coastal storms. Alternative 5B would not include a new channel connecting Nixon Channel to the inlet gorge.

Based on these Delft3D model results the initial beach fill for Alternative 5B, which would be constructed to a crest elevation of 1.8 m (6.0 ft) NAVD, would be limited to the area between stations 60+00 and 100+00 (terminal groin). In this regard, the area between the terminal groin and station 80+00, which lies within the estimated limits of the accretion fillet that would form next to the terminal groin, would be pre-filled by placing material at a rate of 80 cubic yards/linear foot. This would widen the entire fillet area by an average of approximately 70 feet. South of station 80+00, the placement rate would be reduce to 20 cubic yards/linear foot to station 70+00 and then transition to 0 cubic yards/linear foot at station 60+00. Table 5.18 provides a summary of the placement rates and design berm widths for Alternative 5B.

The total volume of initial beach fill along the ocean shoreline, including the dune fill, would be 224,800 cubic yards. The Nixon Channel beach fill would require 65,000 cubic yards bringing the total beach fill volume to 289,800 cubic yards.

ESTUARINE HABITATS

Salt Marsh Communities

Direct and Indirect Impacts: Because this alternative does not involve dredging the connector channel from Nixon Channel to the inlet gorge, flow within Nixon Channel will not be adjusted from its current alignment along its southern bank to the middle of the channel. Therefore, the erosional stress along the salt marsh near the north end of Beach Road (see Chapter 3) will be expected to continue along with the development of salt marsh just further east. However, the placement of 65,000 cubic yards of beach fill will be expected to reduce the potential for the erosion of the salt marsh in this area. The vast extent of the salt marsh resources located within the permit area are located at a considerable distance from the proposed project, however salt marsh resources are located within the footprint of the construction corridor for the terminal groin and direct impacts are anticipated within this area. Direct impacts to the salt marsh resources in proximity to the dredged material disposal sites are not likely as proper construction practices such as the use of silt fencing would be utilized to protect these resources.

As discussed above, based on a preliminary evaluation of aerial photographs pre- and post-construction of the terminal groin, no significant changes have been observed in the salt marsh communities in response to the construction of the terminal groin (Olsen

Associates, Inc. 2008), however these inferences have not be verified. Although the results from individual projects vary due to specific environmental and physical conditions, the salt marsh at this location does not appear to have been impacted by the terminal structure, as noted in the 2010 DENR terminal groin report. Due to these similarities, the results from the Amelia Island project can provide some assurances that the indirect impacts to the salt marsh communities in response to the construction of the terminal groin described for Alternative 5B are not likely to occur. However, direct impacts are expected to be incurred during the construction of the groin. There will be 1.2 acres of low marsh habitat directly impacted due to the use of heavy machinery through the construction corridor and the placement of rubble over the terminal groin footprint. The bulldozers and construction equipment will be limited to operating within a defined construction corridor to limit the extent of direct impacts. Within the 1.2 acres of direct impacts expected, 0.4 acres of salt marsh habitat is expected to be impacted within the footprint of the terminal groin with the remaining 0.8 acres of impact occurring within the construction corridor. The salt marsh habitat in this area is primarily comprised of *Salicornia virginica* (glasswort) unlike much of the *Spartina alterniflora* dominated salt marsh located behind the inlet complex.

Cumulative Impacts: Alternative 5B includes the maintenance of the existing permit area in Nixon Channel minimally every five (5) years with this material, along with material obtained from the dredge disposal islands, used to nourish the beach fills along the Nixon Channel and ocean shorelines of Figure Eight Island. Structural maintenance of the terminal groin is not anticipated. Therefore, no cumulative impacts to the salt marshes in proximity to the footprint of the terminal groin or other locations within the Permit Area are expected.

Submerged Aquatic Vegetation

Direct and Indirect Impacts: As discussed previously, SAV resources are found away from the throat of Rich Inlet in areas that are protected from naturally induced changes in water quality such as turbidity and TSS. Dredging within Nixon Channel are predicted to cause a short term increase in turbidity and TSS levels during construction operations; however it is expected that the levels will remain within the State standard of 25 NTUs as shown in Cleary and Knierim's 2001 report. The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Turbidity values at control sites located approximately 10,000 feet from the location of the fill operation averages 7.7 NTU while TSS values averaged 47.7. The well-sorted sands with low silt content within these dredged areas are expected keep turbidity and TSS levels below the state standard outside the immediate area of construction. Since dredging within Nixon Channel is not expected to significantly alter the tidal flow through the inlet, the salinity within the permit area is expected to maintain its existing condition and therefore SAVs are not anticipated to be impacted (see Appendix B). Should the dredged material disposal sites be utilized, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. This would reduce the likelihood of impacts associated with the burial of

SAV resources. In addition, dredging will occur during the dredging window between November 16th and March 31st, which is when biological activity is low and SAV resources are less abundant within the Permit Area. Therefore, there are no anticipated SAV impacts due to changes in water quality.

Cumulative Effects: As discussed above under Alternative 5A, turbidity and TSS levels are predicted to remain localized and below the state standard soon after all channel maintenance events, as observed following dredging in Nixon Channel in 2001 (Cleary and Knierim, 2001). The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Maintenance events, scheduled for every five (5) years, will be restricted to within the original dredge footprint and will occur during the winter months when SAV resources are biologically inactive. Should the dredged material disposal sites be utilized, SAVs would not be expected to be impacted due to the utilization of proper construction methods, including silt fencing. Cumulative impacts to SAV under Alternative 5B are not expected.

Shellfish Habitat

Direct and Indirect Impacts: The dredging of material from Nixon Channel is predicted to cause a short term increase in turbidity and TSS. Due to the low silt percentage and the well-sorted within Nixon Channel, the turbidity levels are expected to remain below the state standard outside the immediate area of dredging. Using proper construction practices, the removal of material from the three upland dredge disposal islands should not cause direct or indirect impacts to shellfish resources within proximity of the islands or pipelines.

Cumulative Effects: Turbidity levels are predicted to remain localized and below the state standard, as shown by Cleary and Knierim (2001) following dredging within Nixon Channel. Salinity throughout the inlet complex will remain unchanged as the waterways within the inlet complex are expected to provide the similar tidal prism as existing conditions. Therefore, cumulative impacts to shellfish habitat under Alternative 5B are not expected.

UPLAND HAMMOCK

Direct and Indirect Impacts: The activities associated with Alternative 5B is not anticipated to cause direct or indirect impacts to the upland hammock resources located within the Permit Area due to the distance of the resource from the oceanfront shoreline. The closest upland hammock is located on Figure Eight Island approximately 305 m (1,000 ft.) from Rich Inlet as shown in Figure 4.1 in Chapter 4. Furthermore, due to the utilization of proper construction practices, upland hammocks are not anticipated to be impacts in association with the removal of material from the three upland dredge disposal islands.

Cumulative Impacts: The elevation of the upland hammock communities relative to sea level will minimize direct and/or indirect impacts to occur. However, if sea level rise predictions are validated and increase at a rate of close to or less than 1 foot over the next hundred years, this community may become more vulnerable to salt water inundation leading to cumulative impacts.

INLET DUNES AND DRY BEACHES

Direct, Indirect, and Cumulative Impacts: Impacts to Inlet Dunes and Dry Beaches are expected to be the same as described for Alternative 5A.

INTERTIDAL FLATS AND SHOALS

Direct Impacts: Because the permitted dredging area associated with Alternative 5B does not include intertidal areas, this alternative is not expected to have direct impacts on intertidal flats and shoals. The presence of construction activity in association with the groin and beach nourishment placement may stress shorebirds, including the endangered piping plover, from foraging along the intertidal flats along the northern portion of Figure Eight Island. With construction taking place between November 16th and March 31st, direct impacts to birds utilizing these habitats should be minimal. Also, the use of mechanical equipment will be restricted within a specific construction corridor for the construction of the terminal groin which should help in reducing any potential stresses on the birds that may be foraging and/or resting in the area. In addition, these birds would be expected to temporarily relocate to available nearby intertidal flats and shoals on the north side of the inlet.

Several different fish species inhabit the intertidal flats and shoals and the water column within these areas. As reported by USACE (1984), species that utilize these habitats include red drum, spotted sea trout, bluefish, Atlantic croaker, kingfish, and mullet. These species forage upon many of the benthic organisms that reside within intertidal flats and shoals. However, due to the winter time construction, many of these species will be located offshore and will not be utilizing the nearshore or inlet intertidal flats and shoal areas. For any fish species that may be present, it is expected, like the bird resources, that their mobility will provide them the opportunity to temporarily relocate to adjacent habitats while Nixon Channel dredging and terminal groin construction is taking place.

Indirect Impacts: Because the accretion fillet will be artificially filled immediately following the construction of the terminal groin, material will continue to be transported via alongshore transport beyond the structure into the inlet. This transport is expected to continue providing sediment input for intertidal flats and shoals development and their continued presence for bird and fish resource use. However, the initial removal of material from Nixon Channel will result in a sediment deficit of 289,800 cubic yards within the inlet complex system immediately following the first dredging event. Subsequent dredging events scheduled every 5 year and will remove 175,800 cubic yards

per event. This sediment deficit is expected to reduce the amount of material used for intertidal shoal redevelopment within the inlet complex and thereby potentially affecting piping plover, and other shorebirds, as well as fishery resources. However, due to the continuation of sediment transport, these intertidal shoals are expected to reform. Although the Delft3D model was not performed specifically for Alternative 5B, utilizing the results from other modeled alternatives, it is assumed that only minimal changes will occur. For example, model results from Alternative 2, which does not include the dredging within Nixon Channel or a terminal groin, suggests that the tidal prism decreased by approximately 13% at the end of the 5-year model simulation. The model results from Alternative 5A, which includes the terminal groin along with dredging within Nixon Channel and the connector channel, indicates that the flow through Nixon Channel for Alternative 5A was 5% greater than what is indicated for Alternative 2 over that same 5-year period. With the tidal prism remaining relatively unchanged after dredging and the installation of the groin structure, sediment movement and distribution will be minimally affected within the inlet which should result in the continuation of intertidal flats and shoals development and redevelopment.

The overall effects of the initial sediment deficit is not known; however, one can reference the 20-year old terminal groin in Oregon Inlet to obtain a general understanding of impacts to intertidal shoals and flats on both sides of the inlet. As described by USFWS (2008), habitat behind the terminal groin on Pea Island has undergone succession over the 20 years due to wind and water-borne sand, and it is no longer as suitable for piping plover nesting and foraging habitat as when the terminal groin structure was initially constructed. Since the piping plover is primarily a winter resident at Oregon Inlet, the major threat to this species in the vicinity of the inlet is the degradation of intertidal beach foraging habitat (USACE 2001). The construction of the terminal groin resulted in the formation of about a 50-acre fillet; thus, restoring and stabilizing the tip of Pea Island (Dennis and Miller 1993). This provided valuable habitat for piping plovers and other shorebirds in the years following construction by the creation of a vernal pool or mud flat. However, in more recent years the presence of the terminal groin, as well as other actions such as dredging and nourishment, has modified habitat important to piping plovers by eliminating intertidal flats on the downshore side of the structure and allowing encroachment of vegetation in the stabilized areas. This stabilization of the northern tip of Pea Island has changed some of the inlet dynamics as it pertains to piping plover habitats.

Despite this, piping plovers have continued to utilize Pea Island. Although no data of piping populations are available prior to the construction of the terminal groin, post-construction data demonstrates the variability in annual counts. Populations of piping plovers on Pea Island have been relatively low prior to 2000 with an annual range of 0 to 8 individuals and an annual average of 2 individuals observed from1986 through 1999. In 2000, observations on Pea Island increased sharply to 87 individuals. Annual observations subsequently declined to 33 individuals in 2001, and increased sharply to 307 individuals in 2002. Pea Island observations declined steadily over the next three years, reaching a low of 4 individuals in 2005. Annual observations increased to 19

individuals in 2006; however, no piping plovers were reported from Pea Island during 2007 or 2008. In 2009, a total of 40 individuals were observed on Pea Island (NCDENR, 2010).

The presence of intertidal flats and shoals within the inlet complex are expected to continue to persist with the implementation of Alternative 5B. As shown in Figure 5.34, which depicts the anticipated shoaling rates within the inlet complex for Alternative 5A, shoaling is expected to increase in some locations and decrease in others. Specifically, it is expected that the intertidal shoals in proximity to the area dredged within Nixon Channel and along the ebb tide delta may be reduced. The reduction in proximity to Nixon Channel is would be attributed to material in-filling the newly dredged area. Model results also suggest that the intertidal habitat located within the flood tide delta as well as the area extending to the west of Hutaff Island are anticipated to increase. Despite the dredging and construction of the terminal groin, the tidal prism and sediment transport is anticipated to continue similar to existing conditions allowing for the continued formation of intertidal flats and shoal habitat. Any reduction of this habitat is expected to be ephemeral; and long-term effects on shorebird or fishery resources using the areas for foraging and resting are not anticipated.

Cumulative Impacts: As discussed above, most of the intertidal flats and shoals located within the Rich Inlet and nearshore complex are considered to be ephemeral and dynamic. The implementation of Alternative 5B is not expected to change that, with the exception of the down shore area, or fillet, of the terminal groin. As demonstrated on the northern tip of Pea Island over a 20-year period, the fillet area on Figure Eight side should become more stabilized resulting in the increase of vegetative cover. Also, as shown on Pea Island, the terminal groin fillet area should continue to provide some long-term use for piping plover, and other shorebirds. With the terminal groin expected to be in place over a long period of time, cumulative effects to bird and fishery resources utilizing intertidal flats and shoals are expected to be similar to that described in the indirect impacts above. The additional dredging of ~175,800 cubic yards of sediment in Nixon Channel every 5 years, if needed, is expected to result in a minor deficit, but it is unknown to what extent that would cumulatively have on the development and redevelopment of intertidal flats and/or shoals.

OCEANFRONT DRY BEACH AND DUNE HABITATS

Oceanfront Dune Communities

Direct and Indirect Impacts: The direct and indirect impacts to the oceanfront dune communities are expected to be the same as described for Alternative 5A. Beach nourishment along Figure Eight Island is expected to help stabilize the dune system and provide long term storm protection. These stabilization measures will provide positive direct and indirect impacts to the coastal dune communities as it allows for growth and development of dune vegetation thereby providing habitat for roosting, foraging and nesting shorebirds. On Hutaff Island, approximately 0.3 acres of coastal dune

communities are expected to be directly or indirectly affected by the implementation of Alternative 5B within the first year following construction

Cumulative Impacts: Alternative 5B includes renourishment every five (5) years. Therefore, the project will serve to provide protection of the dunes. No cumulative impacts are anticipated as the direct impacts as described above are expected to be temporary in nature. Although overwashing of dunes can result in the formation of important habitat for a variety of shorebirds, the dunes along Figure Eight Island are located in front of residential development and therefore overwashing events would not provide this effect. The dune communities located on Hutaff Island would be expected to migrate westward as natural processes influence the environment, but the dune communities are expected to remain intact. However, if the predicted increase in rates of sea level rise (Miller, pers. comm.; IPCC, 2007) is validated, the long term viability of dunes within the permit could be impacted as the potential of storm surge could increase.

Oceanfront Dry Beach Communities

Direct Impacts: Beach nourishment would impact approximately 25-50 acres the dry beach habitat along from the intersection of Beach Road and Beachbay Lane to the terminal groin located along the northern portion of the ocean shoreline of Figure Eight Island. Direct impacts will be incurred during the initial placement the construction of the terminal groin. The construction of the terminal groin will directly impact 0.29 acres of dry beach due to the construction corridor and the footprint of the structure. These impacts will include the mortality of crustaceans including ghost crabs, however, these communities are expected to recover within the order of months to more than one year (National Research Council, 1995; Carter and Floyd, 2008). This reduction in dry beach habitat will initially reduce available nesting habitat for seabeach amaranth, sea turtles, and shorebirds, including the piping plover, however the increased beach width as a result of nourishment will compensate for this loss.

The composition, color, and grain size of the beach sand can affect the incubation time, sex, and hatching success of turtle hatchlings (Street *et al*., 2005). Physical characteristics such as density, compaction, shear resistance, moisture content, slope, sand color, grain size, grain shape, sand mineral content, and gas exchange may affect the success of sea turtle nests (Nelson and Dickerson 1988, Crain et al. 1995). The fill placed upon Figure Eight Island will conform to the State sediment criteria rules and therefore is not expected to impact the nesting success of sea turtles. Because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat with native compatible material. The proposed project would be conducted during the winter and, therefore, would not impact potential nesting activity by birds or turtles.

Indirect Impacts: The increased area of dry beach as a result of nourishment will result in positive indirect impacts including the increased habitat for nesting sea turtles, resting and nesting shorebirds, and seabeach amaranth. The width of the oceanfront dry beach

immediately following construction will vary along the length of the 4,000 foot fill area. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be increased by 70 feet. The width dry sand beach south of station 80+00 will be increased by 17 feet. This area will become beneficial habitat for resting colonial waterbirds. Also, because the material utilized for the nourishment will meet State Sediment Criteria, the widened dry beach is expected to increase sea turtles nesting habitat. The proposed project would be conducted during the winter and, therefore, would not impact potential nesting activity by birds or turtles.

Volumetric changes along the southern 3,000 feet of Hutaff Island and the five (5) beach segments on Figure Eight Island interpreted from the results of the Delft3D model simulations used for Alternative 5B are summarized in Table 5.17. Two volume change rates are listed for Alternative 5B, one without beach fill and the other with beach fill. Since the beach fill for Alternative 5B is smaller than the Alternative 5A fill, volume changes for the Alternative 5B beach fill along Figure Eight Island were estimated based on the percent of fill remaining in each beach segment determined from the model results for Alternative 5A. The model results for Alternatives 2, 3, and 5A are included in this table for comparison purposes.

Hutaff Island

The southern 3,000 feet of Hutaff Island accreted under Alternative 5B (terminal groin without beach fill) with the rate of accretion about 42% of that estimated for Alternative 2 (without project condition). As was the case under Alternative 2, the accretion on the south end of Hutaff Island was due to bar channel of Rich Inlet assuming an alignment toward Hutaff Island which resulted in a significant buildup of material off the north end of the island. However, the northward orientation of the bar channel under Alternative 5B did not develop to the same extent as Alternative 2 which had lowered the rate of accretion.

Figure Eight Island.

The simulation of the terminal groin without any beach fill indicated that the shoreline erosion along Figure Eight Island between Rich Inlet and Bridge Road would be reduced in each of the four beach segments south of the terminal groin.

The projected performance of the beach fill for Alternative 5B was based on the volume of initial beach fill retained within the area between station 60+00 and 100+00 indicated by the results of the Delft3D simulation for Alternative 5A. In this regard, 65.3% of the initial beach fill volume should still be in place between station 60+00 and 80+00 at the end of 5-years with 17.0% remaining in the area between station 80+00 and 100+00. This net increase in dry beach habitat will benefit nesting sea turtles, seabeach amaranth, and shorebirds.

Cumulative Impacts: With reduced erosion rates, habitat for resting colonial waterbirds, nesting shorebirds, seabeach amaranth, and nesting sea turtles along the ocean dry beach is expected to be maintained at the location of the terminal groin fillet for approximately 2,000 linear feet. The remaining 10,000 linear feet should be maintained with supplemental beach renourishment cycles via maintenance dredging within Nixon Channel utilization of material from the upland dredge disposal islands. These renourishment events are expected to occur within a minimum of every five (5) years. Maintaining the dry beach along the oceanfront shoreline will help ensure that bird and sea turtle habitat will persist.

The continued negative shoreline change on the north end of Figure eight Island will depend on how the inlet bar channel behaves. While the present orientation of the bar channel toward Hutaff Island has persisted since the mid-1990's, how long the channel will remain in this condition is impossible to predict. Based on past behavior, the bar channel is likely to naturally shift to the south and assume an alignment toward the north end of Figure Eight Island. Should this occur, the high rates of erosion on the north end of the island and the destruction of homes and infrastructure in this area could be abated for an unknown time period and the negative aesthetic impacts associated with the erosion reduced. In addition, the frequency of dredge and fill operations would be required at a less frequent rate.

WET BEACH COMMUNITIES

Direct Impacts: The addition of beach fill to Figure Eight Island will impact 30-40 acres of the wet beach community along the oceanfront shoreline, immediately burying the infaunal community. The construction of the terminal groin will impact approximately 1.6 acres of wet beach due to 1.1 acres within the construction corridor and 0.5 acres within the footprint of the structure causing the mortality of the infaunal community within this area. Impacts to the wet beach communities are expected to be similar to those described for Alternative 5A.

Indirect Impacts: Delft3D model results suggest that secondary impacts of approximately 5 acres of marine intertidal habitat will occur along the ocean shoreline of Figure Eight Island while the fill placement equilibrates. This may affect shorebird, crustacean and fish foraging, and recreational fishing through a temporary reduction in bait species during and immediately after construction. Impacts should be reduced due to the fact that the material utilized for beach fill will be compatible with native material, thereby reducing to the recovery period for infaunal communities.

Cumulative Impacts: As a result of the dredging and renourishment activity at a minimum every five (5) years, negative effects could occur if the diversity and abundance of infaunal populations do not recover between nourishment events. However organisms that reside in intertidal zones are more adaptable to fluctuations in their environment, including high sediment transport and turbidity levels (Nelson, 1985). With the

adaptability of benthic communities, sufficient period between maintenance events, and the use of compatible material, Alternative 5B is not expected to result in long-term cumulative impacts.

MARINE HABITATS

Softbottom Communities

Direct Impacts: The activities associated with Alternative 5B would result in a direct impact to approximately 40-50 acres of softbottom community within the dredging footprint in Nixon Channel. In addition, the construction of the terminal groin will directly impact 1.6 acres of softbottom community within the construction corridor. Excavating the channels will cause an immediate negative impact by removing infaunal and non-motile epibenthic organisms from the softbottom community. Studies reported by Maurer (National Research Council, 1995) supported the burial capabilities of nearshore species, which found that these species were capable of burrowing through sand up to 40 cm. As described above, the resilient nature of the infaunal species will limit the direct impacts. Recolonization of these infaunal species typically tends to occur within the order of several months, especially with the use of material that is compatible with native sediment and meets the State's sediment criteria rules.

Indirect Impacts: Construction of the beach would result in the direct deposition of material from the dune or berm crest seaward to the construction toe-of-fill. Over time, the slope of the fill would adjust and equilibrate seaward. Therefore, softbottom habitats located seaward of the toe of fill would be indirectly impacted by project activities as they could become covered by material. Studies have shown that many infaunal organisms that utilize this softbottom habitat are capable of burrowing through sand up to 40 cm, and thus can survive being covered by limited amounts of material (National Research Council, 1995). Softbottom communities may also change with natural shifting patterns of sediment erosion or deposition (Street *et al*., 2005). Negative indirect impacts include the temporary loss of prey for foraging fish and invertebrates from the dredged softbottom habitat within Nixon Channel.

Cumulative Impacts: Cumulative impacts are expected to be the similar in nature as Alternatives 1 and 3, and 5A, however because the footprint of the fill area is considerably smaller, the magnitude of impacts is anticipated to be less.

Hardbottom Communities

Direct, Indirect, and Cumulative Impacts: Although no natural hardbottom communities have been observed within the Permit Area, it is anticipated that the construction of the terminal groin may provide an artificial hardbottom habitat. The physical structure of the proposed groin is expected to create habitat which may provide a foraging site and shelter for fishes, including bluefish, in the surf zone (Hay and Sutherland, 1988). Juvenile black sea bass, for example, use a variety of man-made habitats including

artificial reefs, shipwrecks, bridge abutments, piers, pilings, jetties, groins, submerged pipes and culverts, navigation aids, anchorages, rip-rap barriers, fish and lobster traps, and rough bottom along the sides of navigation channels (NOAA, 2007b). Although this may be beneficial to some species, Chapman and Bulleri (2003) have concluded that creating rocky habitat has led to the introduction of non-native invasive species within the vicinity of a hard structure. These structures are often associated with higher fish abundances and species richness than in other surf zone communities (Peters and Nelson 1987; Clark et al. 1996). Some benefits to hardbottom communities are anticipated with the construction of the terminal groin.

WATER QUALITY

Turbidity and TSS

Direct Impacts: The dredging of Nixon Channel and the transport of material from the dredge disposal sites along with the placement of this material on the ocean and estuarine shoreline as well as the construction of the terminal groin could result in the suspension of silt and fine fractions in the water column. The low sit/clay content of the material within the areas being dredged would result in relatively low concentrations of suspended sediment outside the immediate area of deposition. The low concentration of suspended sediment indicates that turbidities are likely to remain low during dredging and placement of material on the beaches. As stated previously, measurements for turbidity and TSS were taken before, during, and after the dredging within Nixon Channel and the associated placement of beach fill along the oceanfront shoreline of Figure Eight Island in 2001and it was determined that both parameters increased at the point of discharge on the oceanfront shoreline, however, these values returned to ambient conditions rapidly (Clearly and Knierim, 2001). The highest weekly average of turbidity and TSS recorded at the discharge site was 44.0 mg/l and 301.0 mg/l, respectively (Cleary and Knierim, 2001). Natural conditions support fluctuating turbidity levels in the nearshore and offshore water column of the Permit Area. Therefore, although minimal, temporary negative direct impacts related to turbidity are expected.

Indirect and Cumulative Impacts: Although dredging and renourishment are anticipated to occur approximately every five (5) years, due to factors described above, no indirect or cumulative impacts regarding turbidity are expected.

Nutrients

Direct, Indirect, and Cumulative Impacts: The implementation of Alternative 5b is not anticipated to impact the nutrients within the waters located in the Permit Area.

WATER COLUMN

Hydrodynamics and Salinity

Direct, Indirect, and Cumulative Impacts: The dredging of the existing permit area in Nixon Channel would be comparable to the dredging that presently occurs. While this dredging activity may have some impact on flows in Nixon Channel, dredging of the area under Alternative 5B would not significantly alter the hydrology of the inlet complex. Furthermore, the tidal flow through Nixon and Green Channels are anticipated to maintain their relative proportional amounts just as indicated by the model results for Alternatives 2 and 5A. The relatively small changes in tidal prism will allow for the tidal exchange to continue within Rich Inlet, Nixon Channel, and Green Channel thereby maintaining baseline hydrodynamics and salinity levels.

Larval Transport

Direct, Indirect, and Cumulative Impacts: The impacts to larval transport would be the same as described under Alternative 5A on page 269.

PUBLIC SAFETY

Direct, Indirect, and Cumulative Impacts: Impacts to public safety are anticipated to be similar to those discussed for Alternative 5A. These include negatively direct impacts due to the usage of heavy machinery within Nixon Channel and along the oceanfront shoreline of Figure Eight Island during beach nourishment activities and the construction of the terminal groin. The implementation of Alternative 5B will cause positive indirect impacts as it should alleviate the erosional pressure along of the northern 3.8 km (2.4 mi) of Figure Eight Island thereby protecting the nineteen (19) imminently threatened homes on the island. Without the threat of these homes being damaged or demolished, public safety will be positively indirectly impacted due to the avoidance of hazardous conditions caused by continued erosion including the exposure of utilities and leaking septic tanks. Furthermore, the sandbags, which could pose a public safety hazard due to their size and orientation to the eroded shoreline, would be removed and replaced with a nourished beach tapered from a developed dune ridge.

The proposed crest elevation of the groin is intended to follow the existing topography along the landward half of the structure. Along the seaward half of the structure, the crest elevation will follow the construction cross-section, except near its seaward end. At this location, the groin crest elevation will be +3.5’ NAVD to ensure its visibility at all phases of the tide which will reduce the chance of the structure becoming a navigational hazard to vessels. In addition, a U.S. Coast Guard approved navigation aid in the form of a three-pile dolphin with a light would be installed at the seaward end of the terminal groin. Construction of the terminal groin as well as the dredge and fill operation will be conducted during a period when boat traffic and beach use is at its lowest. The duration of construction would be less than what is necessary for Alternative 5A due to the smaller

volume to be dredged. No public safety hazards are anticipated in proximity to Hutaff Island.

AESTHETIC RESOURCES

Direct Impacts: Direct impacts to aesthetic resources are anticipated to be similar as those described under Alternative 5A on page 271.

Indirect and Cumulative Impacts: Indirect and cumulative impacts will occur due to the anticipated on-going maintenance of Nixon Channel and transport of material from the dredge disposal islands along with the placement of dredged material on Figure Eight Island. These events will occur at a minimal five (5) year cycle. Due to the length of time in between maintenance events, indirect and cumulative effects are expected to be minimal.

RECREATIONAL RESOURCES

Direct, Indirect, and Cumulative Impacts: Impacts to recreational resources are anticipated to be similar to those described under Alternative 5A on page 271.

NAVIGATION

Direct and Indirect Impacts: The initial construction followed by periodic maintenance dredging in Nixon Channel will benefit navigation due to a maintained depth created by on-going dredging activities. During the dredging, however, navigation will be temporarily directly impacted due to the presence of pipelines within Nixon Channel. In addition, navigation will be restricted during the transportation of material from the upland dredge disposal sites to the beach. At no time will complete restriction of navigation occur in Nixon Channel during dredge operations. There will be some minor negative impacts to navigation in Nixon Channel due to the presence of barges used to transport the stone for construction of the terminal groin. The barges would be moored in relatively deep water next to an offloading pier. Restrictions will be determined by the USCG and will be limited to the areas where the dredge and the pipelines are located. These restrictions will be imposed during every maintenance event, which is scheduled for at a minimum every five (5) years.

Cumulative Impacts: Utilizing the Delft3D model results for Alternative 5A as a proxy for Alternative 5B, it is anticipated that the entrance of Rich Inlet will behave in a similar manner to the existing conditions (as depicted for Alternative 2) over the next 5 years. The dredged area will be expected to shoal, however they will remain navigable in between maintenance events. Therefore, following construction of Alternative 5B, boaters should find navigation within the back side of Figure Eight Island easy to navigate after initial dredging and after each maintenance event, which is anticipated to occur at a minimum every five (5) years. In addition, the terminal groin will be clearly

marked; therefore it should not pose a threat to boats. Therefore, following construction of Alternative 5B, navigation will be positively impacted due the maintenance of the Nixon Channel navigation feature.

INFRASTRUCTURE

Direct, Indirect, and Cumulative Impacts: Alternative 5B is expected to benefit the infrastructure on Figure Eight Island due to the long-term protection from erosion. The beach nourishment plan included in Alternative 5B would include the use of approximately 224,800 cubic yards of material as beach fill along 4,000 linear feet of the Figure Eight Island shoreline. The remaining sections of the shoreline south of the beach fill area are expected to experience substantial reductions in shoreline erosion rates or actually experience some accretion. This would serve to protect the homes and infrastructure along the oceanfront shoreline of the island from the intersection of Beach Road and Beachbay Lane to the location of the terminal groin. The width of the oceanfront dry beach will vary along the length of the 4,000 foot fill area. Furthermore, the installation of the terminal groin will result in a wider beach within the accretion fillet which will protect the infrastructure as well. Within the area where the sandbags are present and erosion rates are highest, the width of the dry beach will be increased by 70 feet. The remaining areas will increase by about 17 feet. In addition, the alternative includes a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). These two locations will be renourished approximately every five (5) years.

SOLID WASTE

Direct, Indirect, and Cumulative Impacts:
This alternative will provide protection along portions of Figure Eight Island thereby decreasing the risk of damage to residential buildings and infrastructure. This would alleviate the potential of increased amount of solid waste through demolition. Implementation of Alternative 5B is expected to benefit the pubic by not contributing to additional solid waste.

ECONOMICS

Direct, Indirect, and Cumulative Impacts: Implementation of Alternative 5B is expected to positively impact the local economy of New Hanover County. Initial construction costs for the terminal groin would be the same as Alternative 5A. No structures or land would be lost under Alternative 5B, but again, repetitive storm damage could eventually lead to the demolition of some of the threatened structures.

Over the 30-year planning period, the total cost for Alternative 5B in current dollars would be about $16.9 million. As depicted in Table 5.16, the average annual equivalent cost for constructing and maintaining Alternative 5B would be $754,000.

Table 5.16- Summary of Average Annual Economic Impact of Alternative 5B

Long-Term Erosion Damages	Loss of Tax Revenues	Response/Construction Cost	Total Economic Cost
$0	$0	$754,000	$754,000

NOISE POLLUTION

Direct Impacts: The dredging of the Nixon Channel, the transport of material from the upland dredge disposal sites, the placement of beach compatible material on the oceanfront and estuarine shoreline, and the construction of the terminal groin would temporarily raise the noise level in the areas due to the use of heavy machinery. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. The noise pollution would be short-term since the equipment would be constantly relocating as work moves down the beach. Construction equipment would be properly maintained to minimize these effects in compliance with local laws. Also, dredging and beach placement would occur during times when residents and visitors are less likely to be present.

Indirect and Cumulative Impacts: No indirect or cumulative impacts pertaining to noise pollution are anticipated due to the low frequency of beach nourishment events and the time of year.

Chapter 6 AVOIDANCE AND MINIMIZATION

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

1. How will construction practices avoid and minimize environmental impacts?

Construction Schedule

Dredging within Nixon Channel and the connector channel along with the nourishment of the estuarine and oceanfront shoreline of Figure Eight Island are scheduled to occur between November 16th and March 31st. 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, and the seabeach amaranth flowering period and to avoid periods of peak biological activity including fish and larval passageway. Also, the construction 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.

Terminal Groin Structure

Two design lengths of the terminal groin were evaluated through the use of the Delft3D model. One design included a seaward portion of the groin protruding 1200 feet while the other design included a 700 foot long seaward component. The applicant's preferred alternative includes the construction of the 700 foot long seaward portion as the protection afforded will be similar to the 1200 foot design. However, due to the shorter length, fewer impacts associated with larval transport are expected.

The type of material used to construct the terminal groin was also evaluated. Options included steel or concrete sheet pile and the use of rock rubble mound design. The applicant's preferred alternative includes the rubble mound design. This use of this material is expected to provide habitat for sessile benthic organisms as well as crustaceans and fin fish. Therefore, environmental benefits are anticipated due to the use of the rubble material opposed to sheet pile.

During the construction of the groin, a construction corridor varying in width from 100 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. Furthermore, the barge access location for the unloading of the rubble mound material will be situated along the Nixon Channel shoreline containing minimal vegetation.

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

As noted below, the Sediment Criteria Rule, contained in the Technical Standards for Beach Fill Projects (15A NCAC 07H .0312), provides beneficial guidelines for both grain size and percent weigh of calcium carbonate (NCDCM, 2007). However, other important characteristics such as organic content, heavy mineral content, and color are not addressed. These aspects of the beach fill will be considered. The monitoring program for sediment as it is placed on the beach will provide a benefit to the beach invertebrate community and would also benefit sea turtle nest construction and incubation of the eggs.

The North Carolina Coastal Resources Commission adopted new 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). The new rule limits the amount of material in the borrow area with a diameter equal to or greater than 4.76 mm and less than 76.00 mm (gravel) to no more than 5% above that which exists on the native beach (Table 6.1). Also, the percent of the borrow material by weight between 4.76 mm and 2.0 mm (granular) cannot exceed the native by more than 5% (Table 6.1). 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). The rule also limits the amount of silt (sediment size equal to or less than 0.0625 mm) to 5% above the native beach material (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). Finally, the State Sediment Criteria Rule Language limits calcium carbonate to no more than 15% above that of the native beach. 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 new 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 E –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 a result of sediment compliance efforts, compaction of fill material on the beach is less likely to occur due to the lower silt content or hardening of the beach due to high shell and/or carbonates. Compaction of fill could impact the ability of sea turtles to dig and nest along the nourished beach, resulting in an increase in false crawls. Also, macroinfauna indicative of a

healthy benthic community depend upon variable particle sizes and available interstitial pore space in the substrate for aeration properties. Compaction of the fill material could impact resident macroinfaunal populations thereby affecting the migratory and resident shorebirds, waterbirds, as well as the commercially and recreationally important fish that depend upon them.

Although the State rules do not make any reference to compatibility with regards to color, native and borrow area color values were recorded and compiled during field investigations. Native beach composite colors referenced to the Munsell Soil Color Chart (1994) for the beach on Figure Eight Island were determined to be gray to grayish brown with a value of 5Y X/1 for wet sand. The 5Y refers to the colors relation to Red, Yellow, Green, Blue, and Purple. In this case the "Y" refers to Yellow. The denominator in the fraction is the Chroma value, which indicates the colors strength (or departure from a neutral of the same lightness). The dry sand value for Figure Eight Island was determined to be 6. The native beach material on Hutaff Island contained an average wet and dry Munsell value for the beach is 5 and 6, respectively.

Composite characteristics from samples acquired from the Nixon Channel borrow area and the connector channel as proposed in Alternative 5B includes the average wet and dry Munsell color value is 6 and 7, respectively. This close resemblance in color between native and fill material will minimize the risk of changing the natural incubation temperature of sea turtle nests in the nourished area. Although no published data appears to be available, it is commonly observed that material placed on a beach undergoes bleaching within the first several months which results in a lighter color sand than what was documented to exist in the borrow area.

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 F8 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 F8 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 F8 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 F8 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 F8 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 F8 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 for 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 North Carolina Wildlife Resource Commission and North Carolina Audubon Society (NCAS) have performed breeding surveys for colonial nesting waterbirds within proximity of the Permit Area on a regular basis since 1977. Specifically, surveys have been conducted within the north side of Mason's Inlet and the Southside of Rich Inlet, flanking Figure Eight Island (Mangiameli, pers. comm.). Surveys have also been conducted along Hutaff Island (including the north side of Rich Inlet) as well as the south side of New Topsail Inlet, and Old Topsail Inlet. Surveys for breeding piping plovers have been conducted since 1989 at the same locations. Opportunistic surveys for non-breeding piping plovers have been conducted in more recent years. These ongoing surveys include observations from breeding and non-breeding seasons for several listed bird species as well as other shorebirds and waterbirds.

Along with the effort described above, 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. This monitoring is 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 Eight Island Homeowners Association, 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.). NCAS 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 Eight Island Homeowners Association, begins on approximately May 1 and continues through the last hatch date each year. NCAS 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.).

West Indian Manatee (*Trichechus manatus*)

The West Indian manatee can be found in shallow waters (1.5 to 6.1 m [5 to 20 ft]) of varying salinity levels including coastal bays, lagoons, estuaries and inland river systems. *T. manatus* have been recorded in North Carolina and are most likely to occur from June through October when water temperatures are warmest (temperatures above 23.9ºC [75ºF]) (Schwartz, 1995; USFWS, 2006f; USFWS, 2001b). Although the manatee is not expected to be present during dredge and fill operations, the contractor will adhere to the precautionary guidelines established by the USFWS – Raleigh Office for construction activities in North Carolina waters. Refer to the *Guidelines for Avoiding Impacts to the West Indian Manatee*. West Indian manatees rely on submerged aquatic vegetation (SAV) as a food source.

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 submerged aquatic vegetation (SAV), shellfish habitat, salt marsh, and intertidal communities found within the area to be investigated. Determining the baseline conditions of these resources prior to construction is a fundamental step in quantifying changes in response to the implementation of Alternative 5B. 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 activities provided the baseline conditions of a number of biological resources as reported in Chapter 4 of this document. The purpose of the baseline habitat mapping effort was to identify the current extent of the biological resources within the area prior to the construction of the terminal groin and subsequent beach fill and will serve as the baseline assessment of the subject resources within the identified Rich Inlet Habitat Mapping boundary, as designated in Figure 6.1. Subsequent habitat mapping efforts will be utilized to assess the extent of change to these habitats within the designated boundary following construction activities.

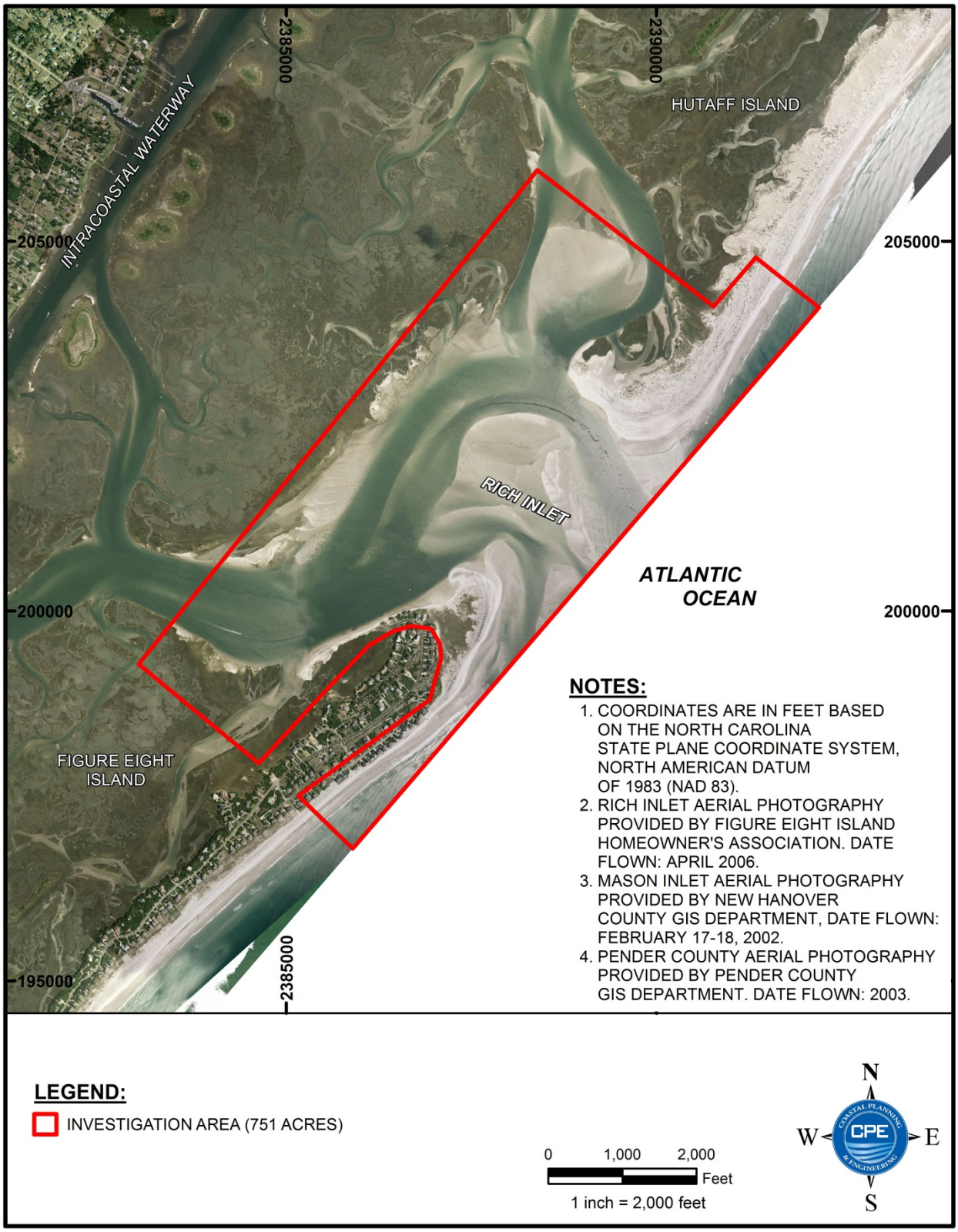


Figure 6.1- Rich Inlet Habitat Mapping Boundary

Monitoring Schedule
Pre-construction 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.

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 pre-construction conditions observed from the 2008 aerial photography.

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 F8 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 recourses.

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

Introduction
The legislation passed by the NC General Assembly in June 2011 authorizing the permitting of terminal groins at 4 inlets in North Carolina carried with it the requirement to provide a plan for managing inlet and the estuarine and ocean shorelines likely to be under the influence of the inlet. The 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 is 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 6.2. 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 station100+00, as shown in Figures 3.13a and 3.13b in Chapter 3. It should be noted that the current sandbags are located approximately from transect 16 to 20. 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.

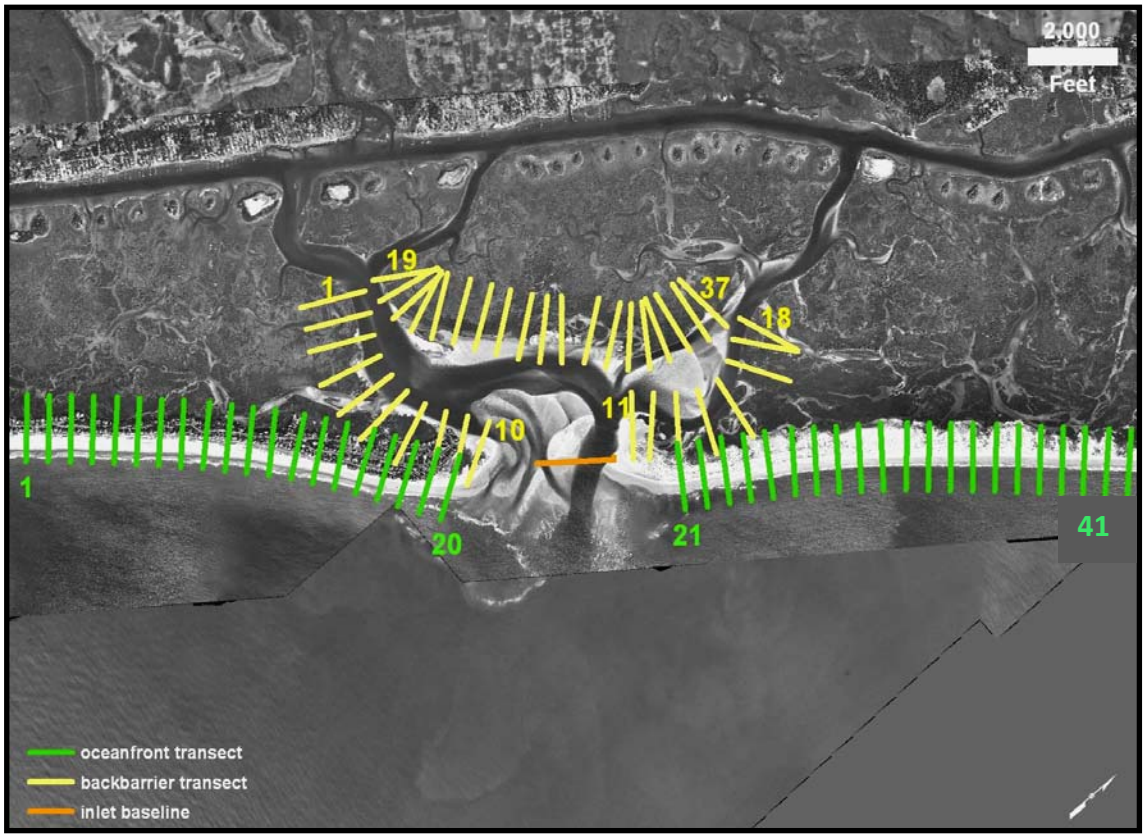


Figure 6.2. Shoreline transects.

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 6.3 and 6.4 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 6.2) 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.

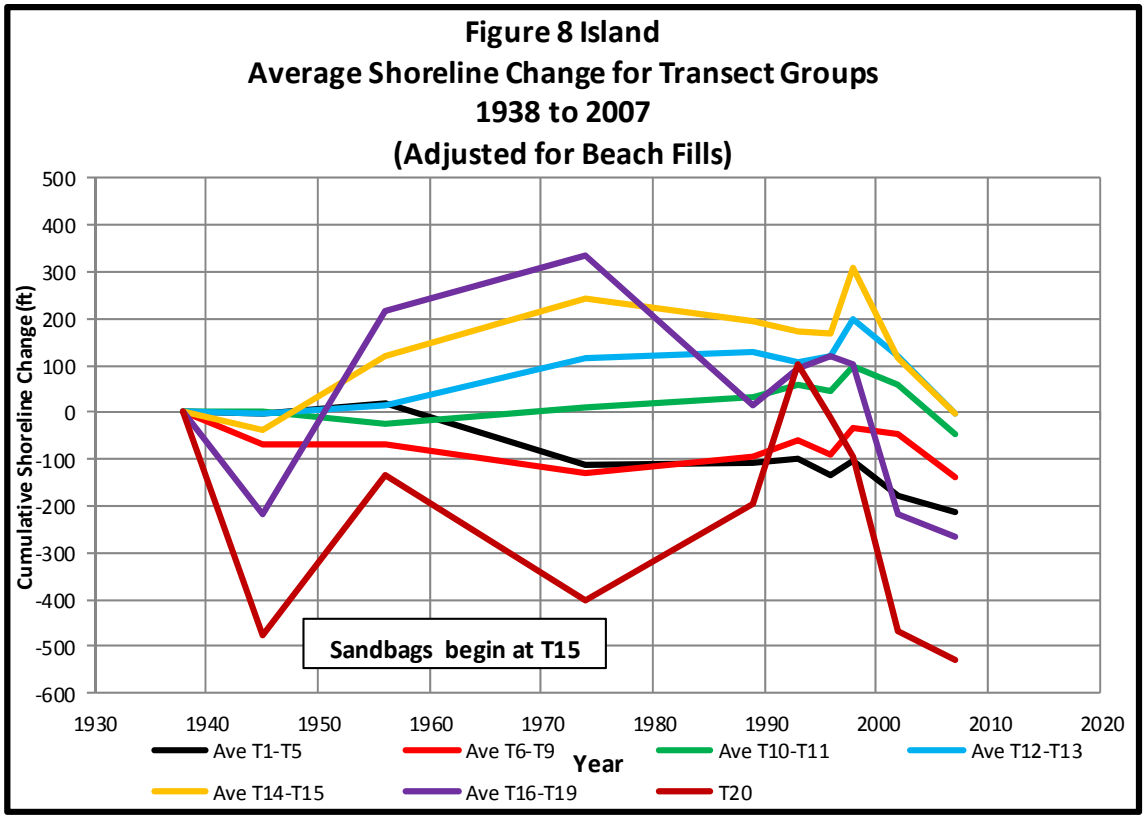


Figure 6.3. Cumulative shoreline changes between 1938 and 2007 for transect groups on Figure Eight Island.

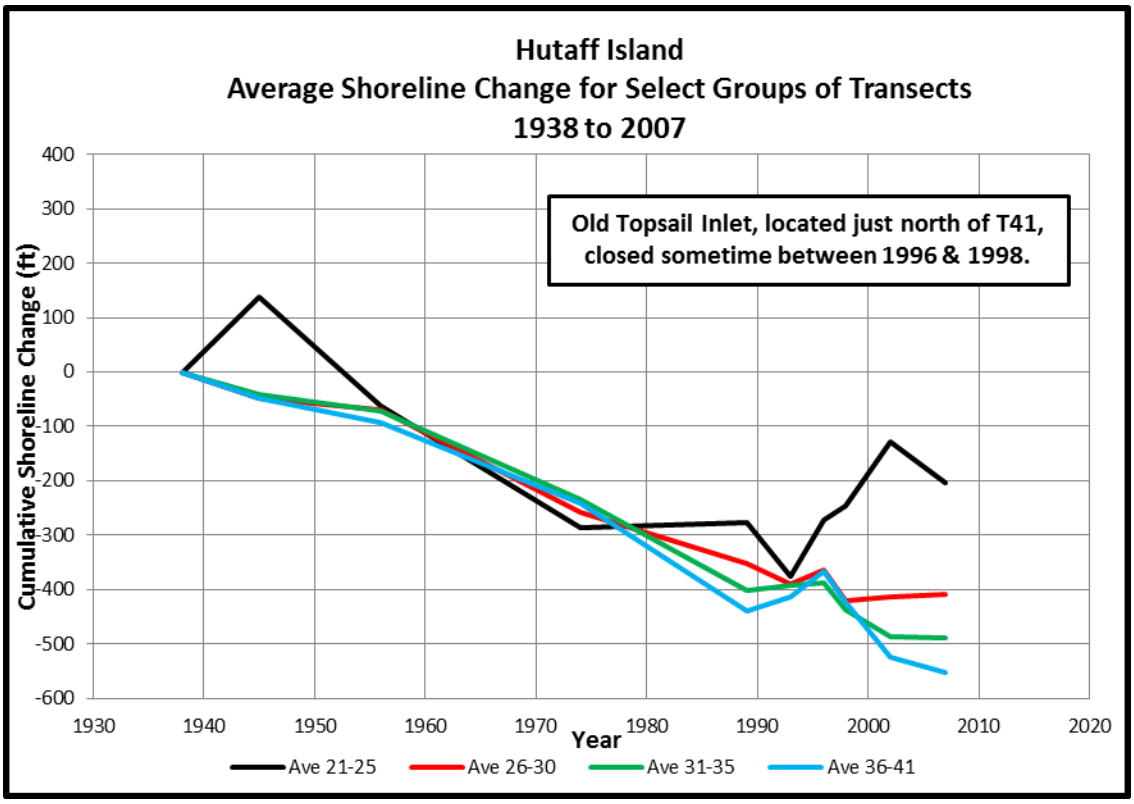


Figure 6.4. Cumulative shoreline changes between 1938 and 2007 for transect groups on Hutaff Island.

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 6.5 to 6.14) 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.

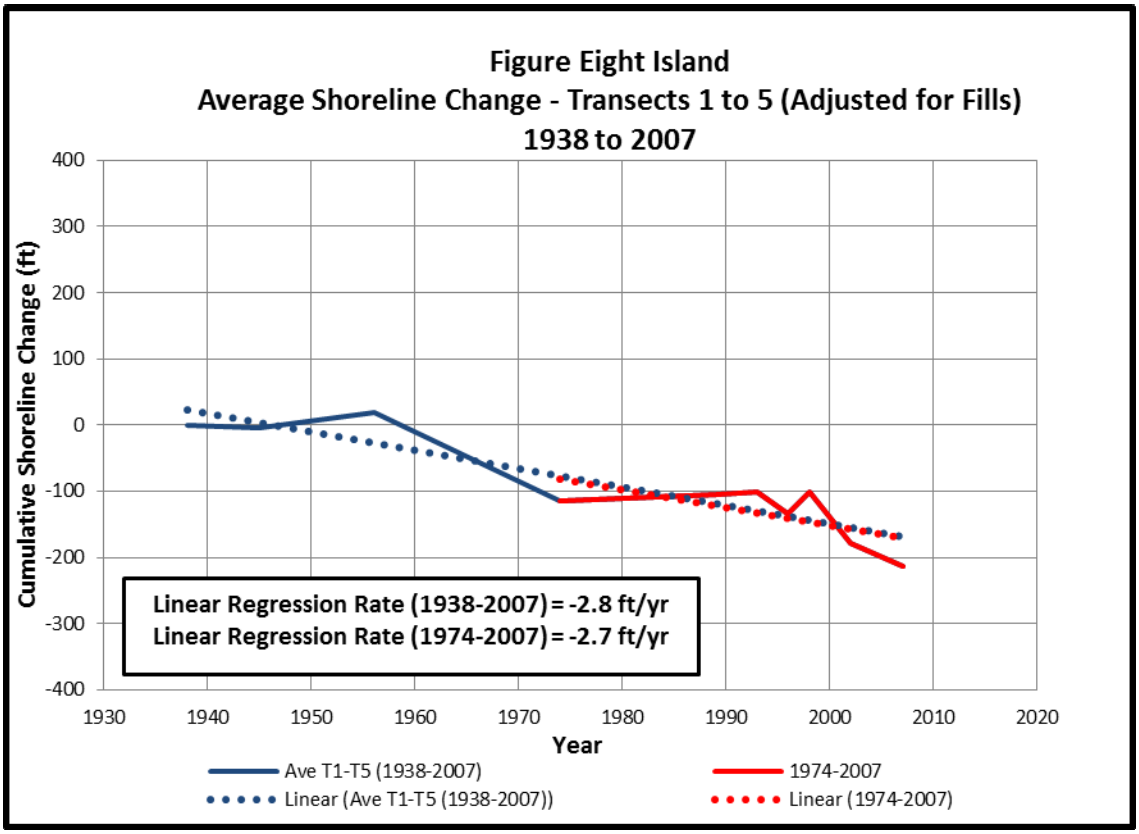


Figure 6.5. Figure Eight Island 1938-2007 average shoreline change for transects 1-5.

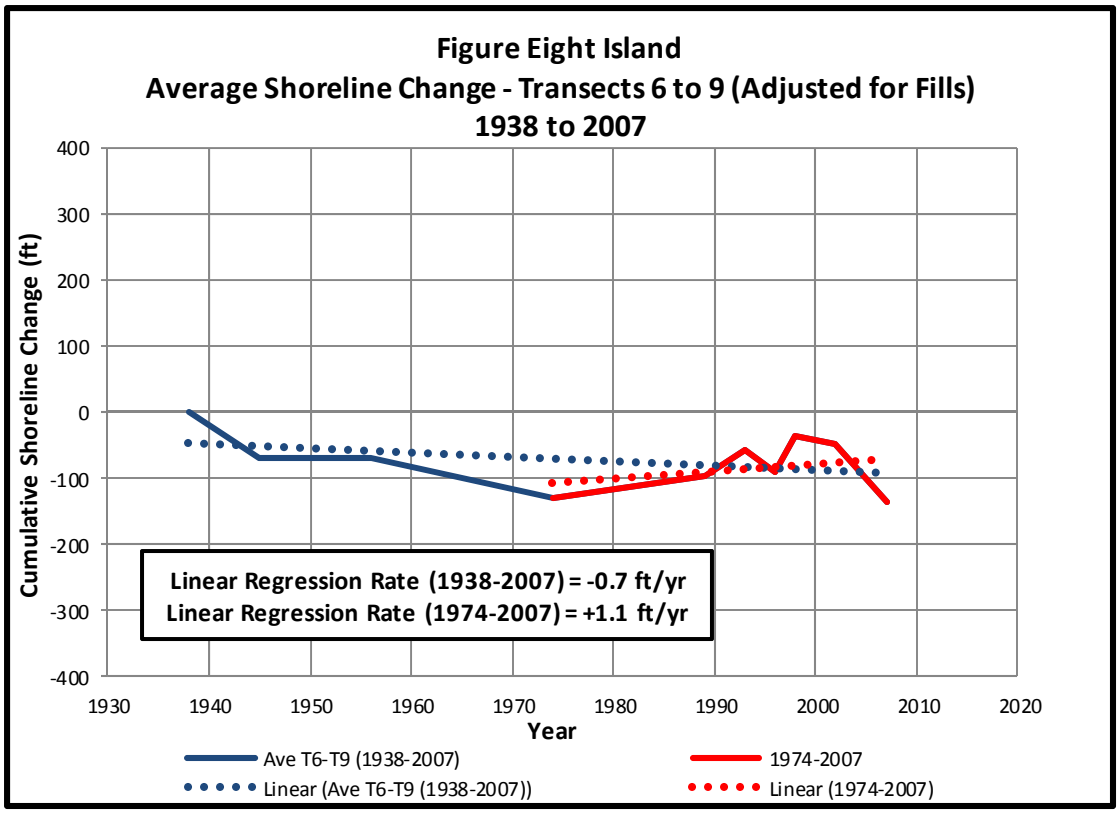


Figure 6.6. Figure Eight Island average shoreline change for transects 6-9.

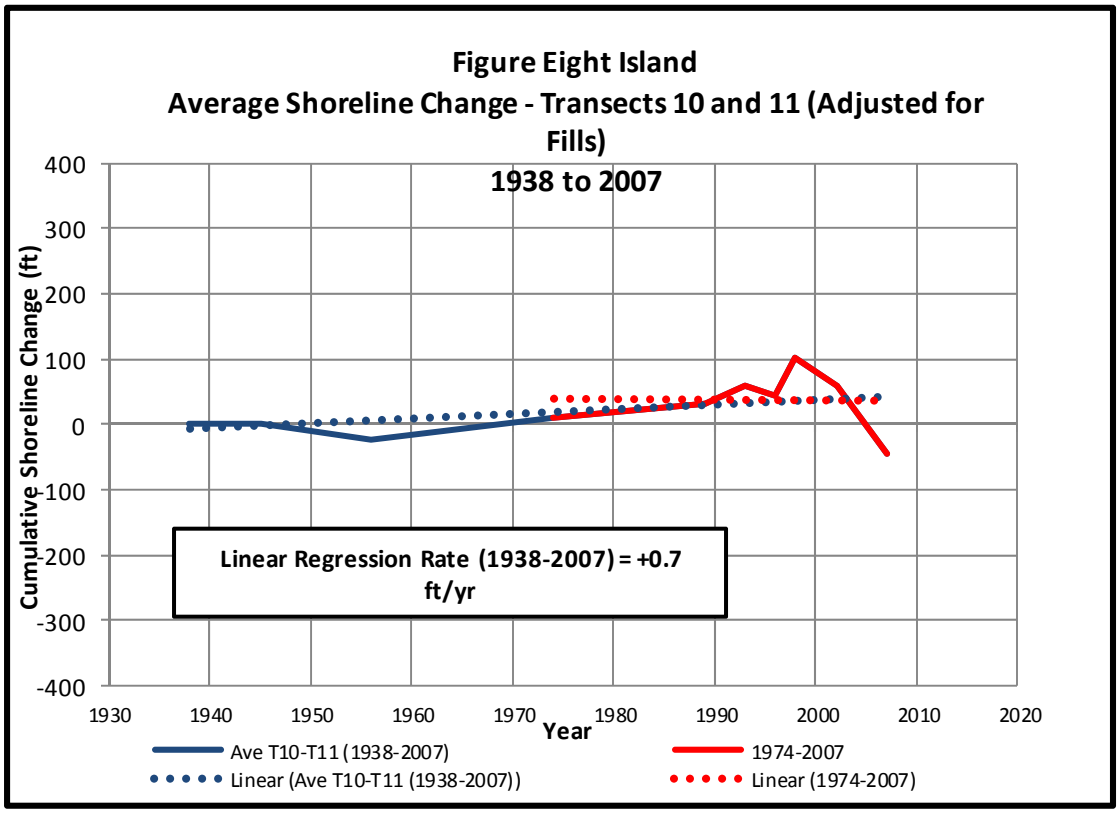


Figure 6.7. Figure Eight Island average shoreline change for transects 10-11.

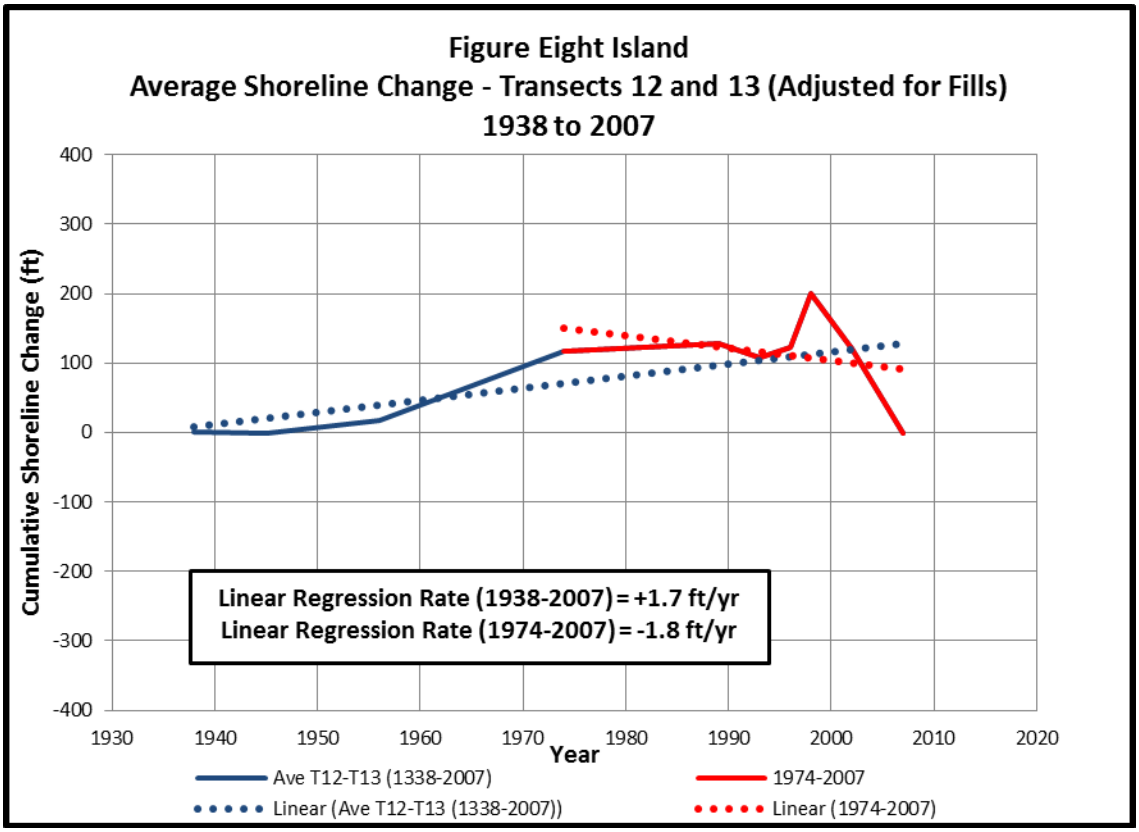


Figure 6.8. Figure Eight Island average shoreline change for transects 12-13.

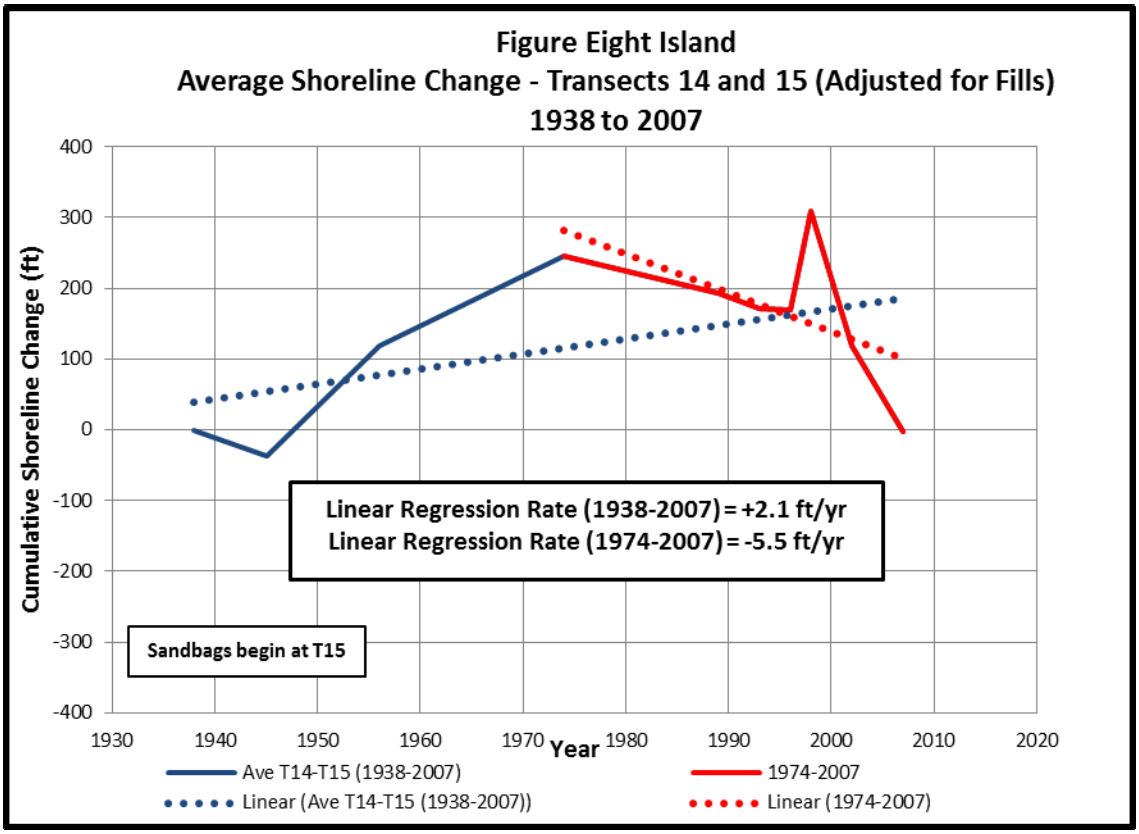


Figure 6.9. Figure Eight Island average shoreline change for transects 14-15.

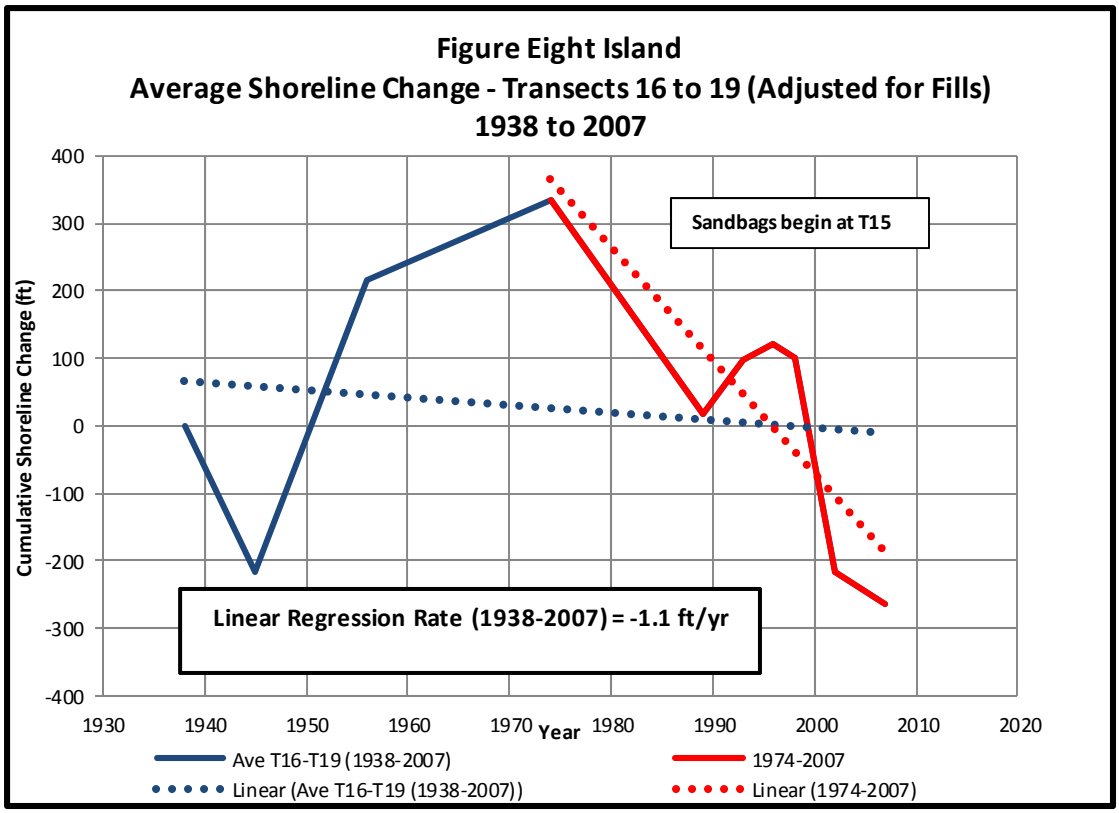


Figure 6.10. Figure Eight Island shoreline change for transects 16-19.

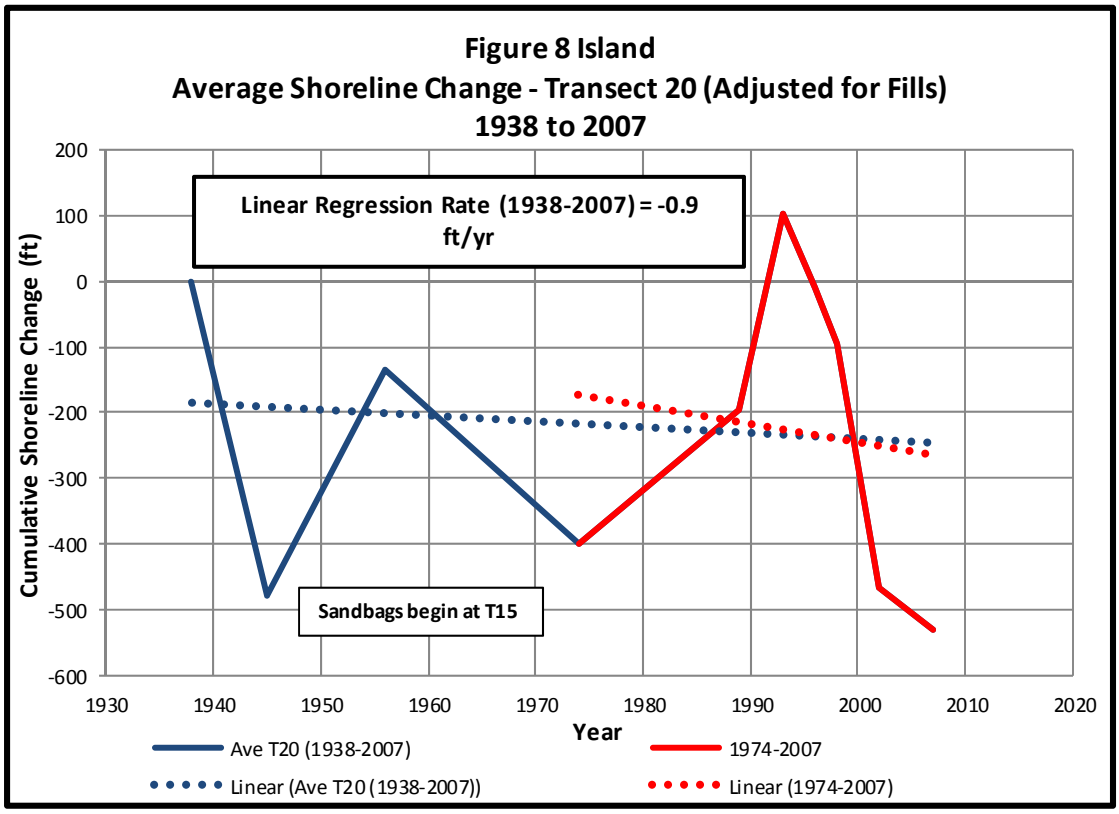


Figure 6.11. Figure Eight Island shoreline change for transect 20.

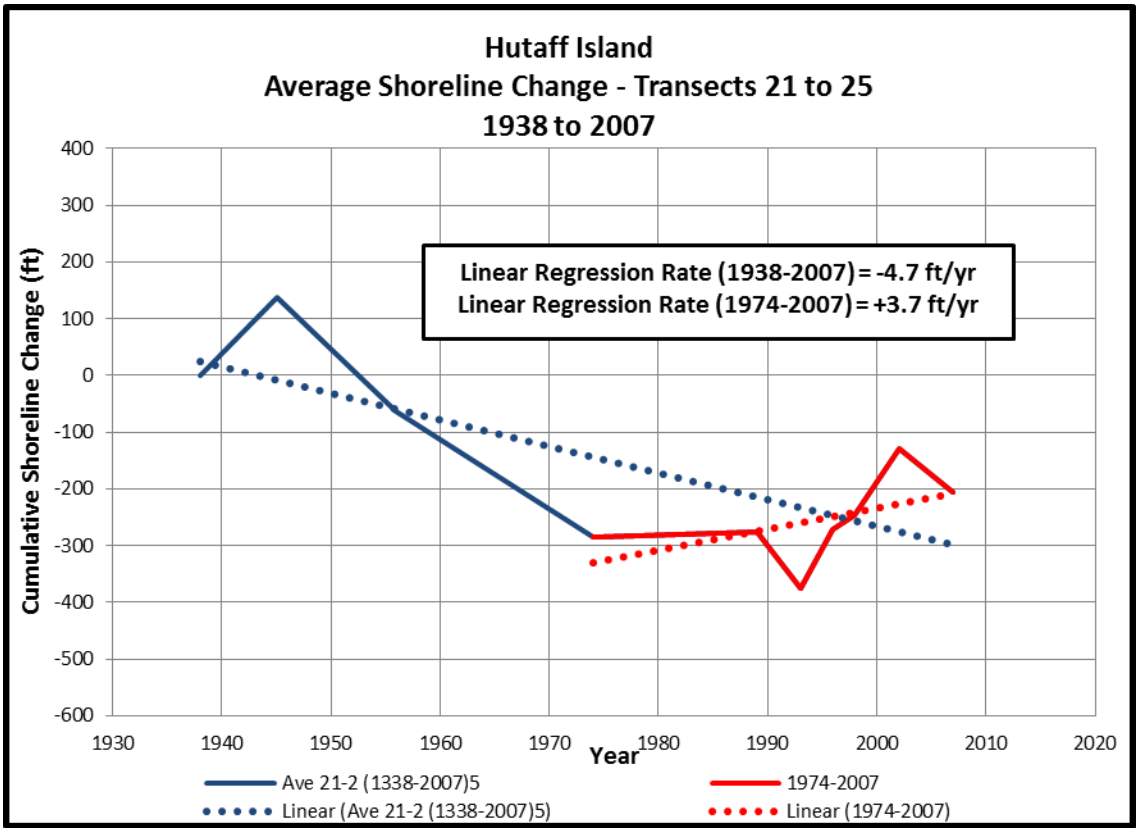


Figure 6.12. Hutaff Island average shoreline change for transects 21 to 25.

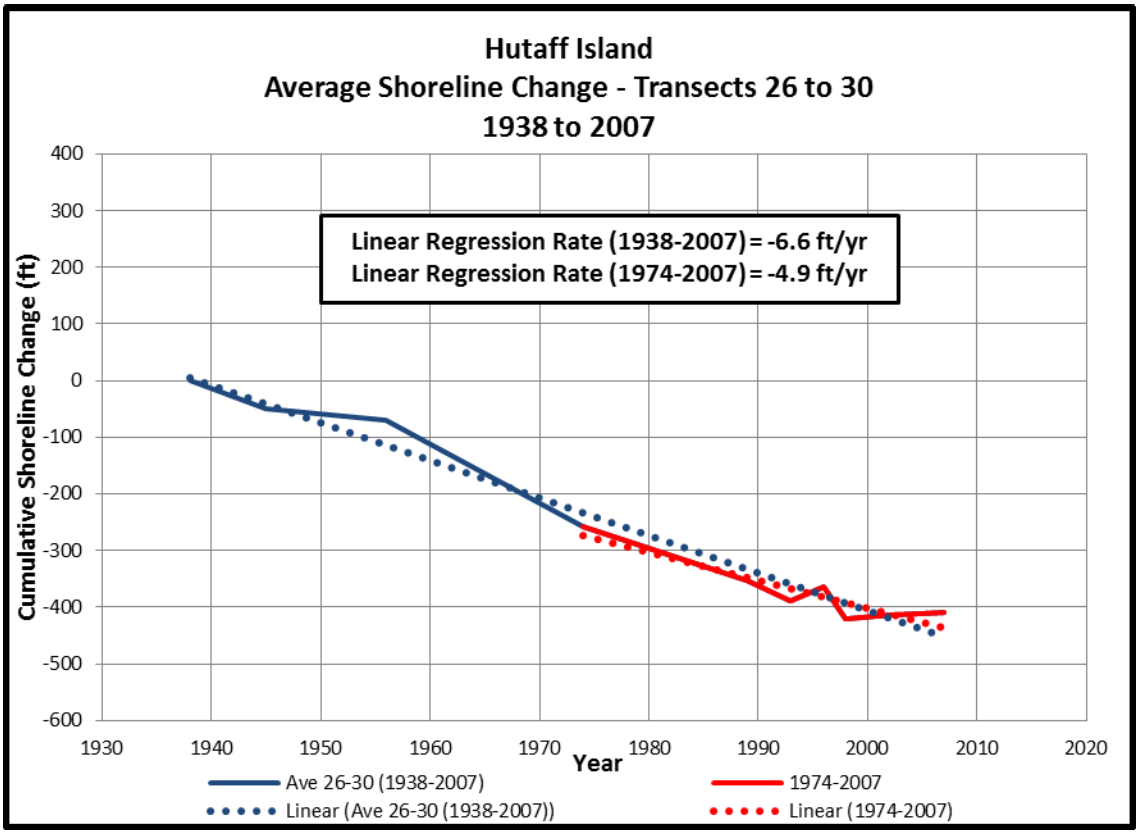


Figure 6.13. Hutaff Island average shoreline change for transects 26 to 30.

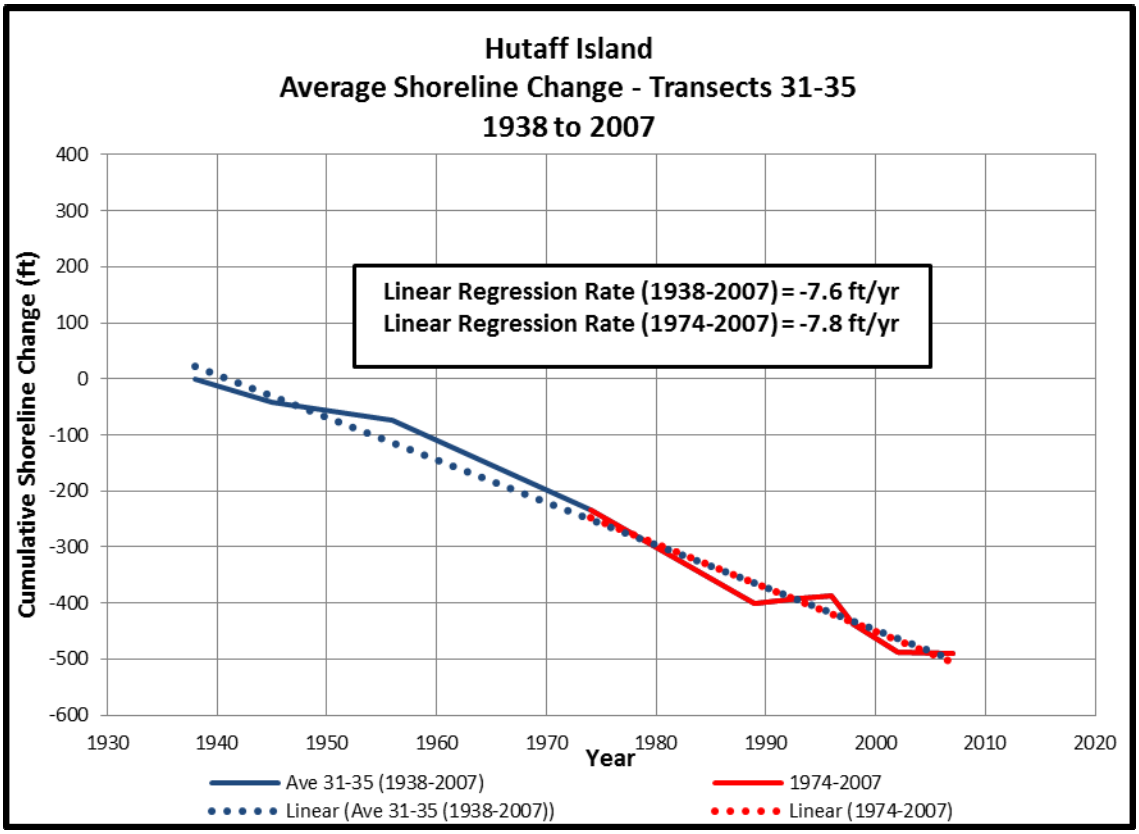


Figure 6.14. Hutaff Island average shoreline change for transects 31 to 35.

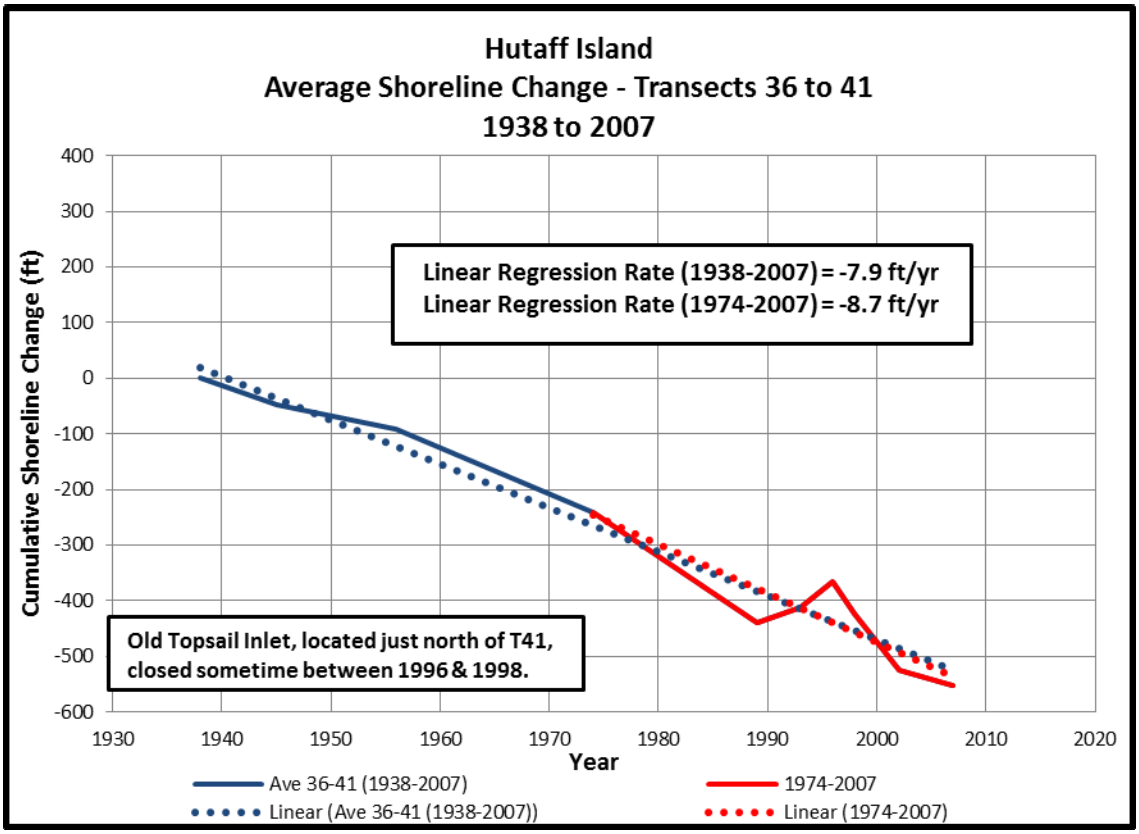


Figure 6.15. Hutaff Island shoreline change for transects 36 to 41.

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” 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 Figure 6.16 to 6.26. 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 Figure 6.16 to 6.26. 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 6.16 to 6.26.

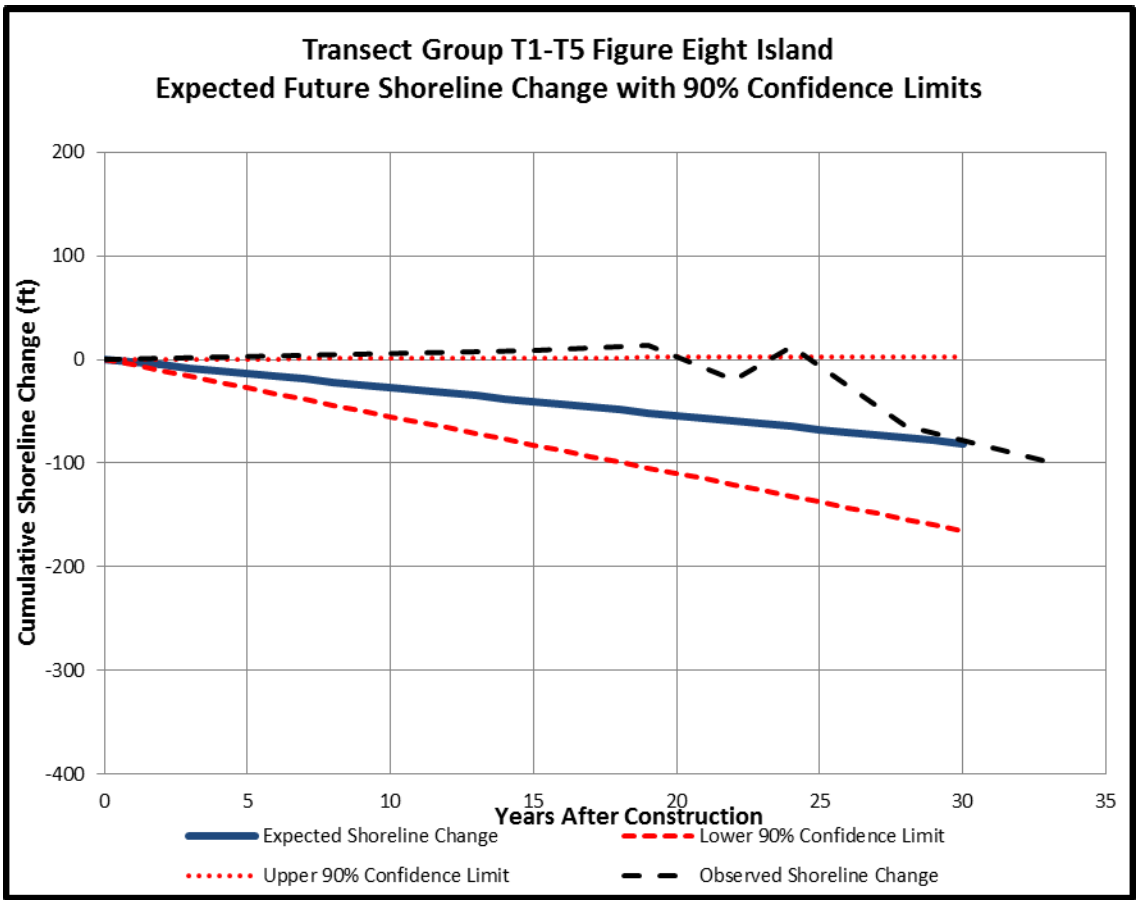


Figure 6.16. Transect Group T1-T5, Figure Eight Island – Expected future shoreline change.

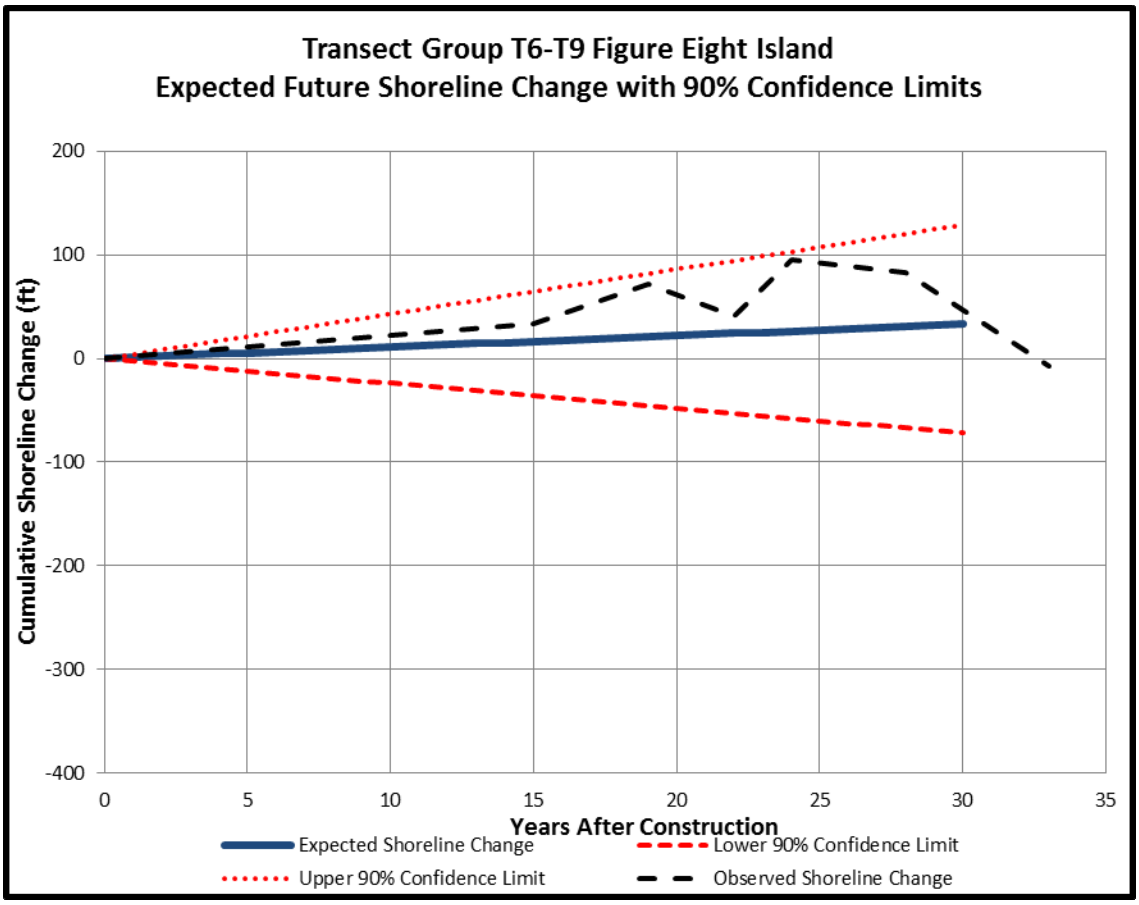


Figure 6.17. Transect Group T6-T9, Figure Eight Island – Expected future shoreline change.

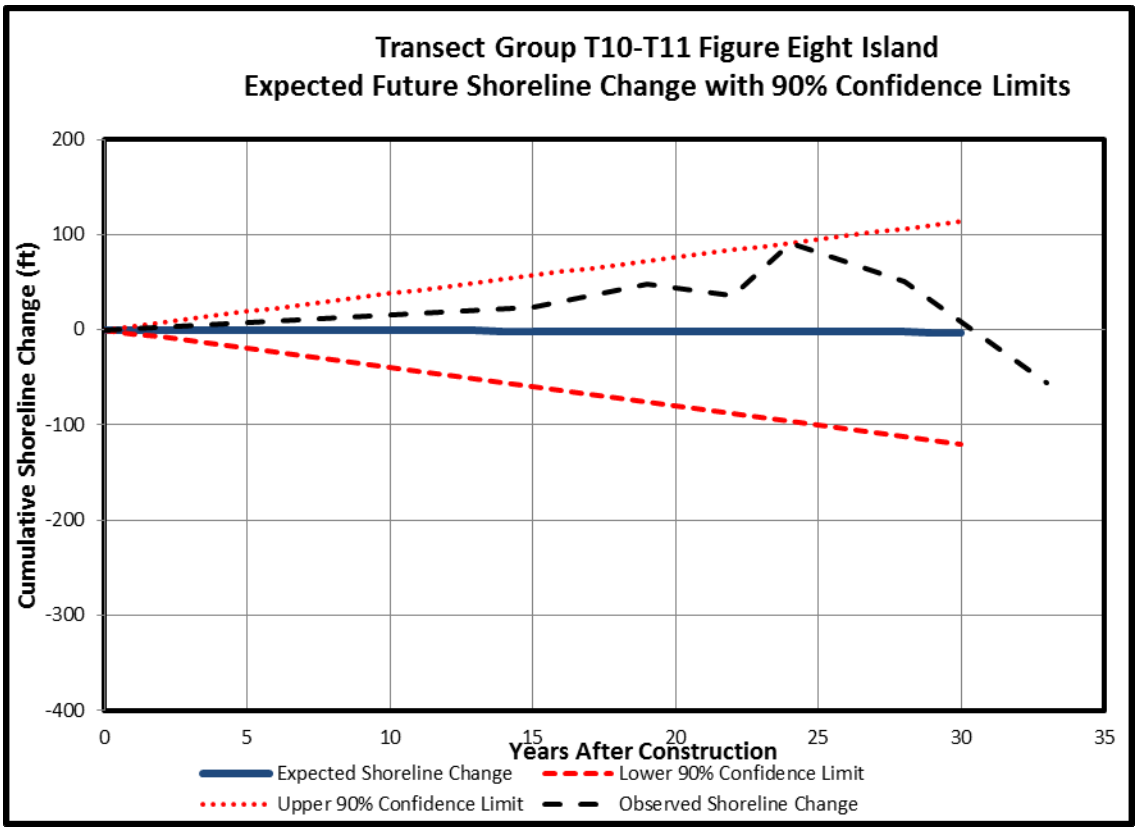


Figure 6.18. Transect Group T10-T11, Figure Eight Island – Expected future shoreline change.

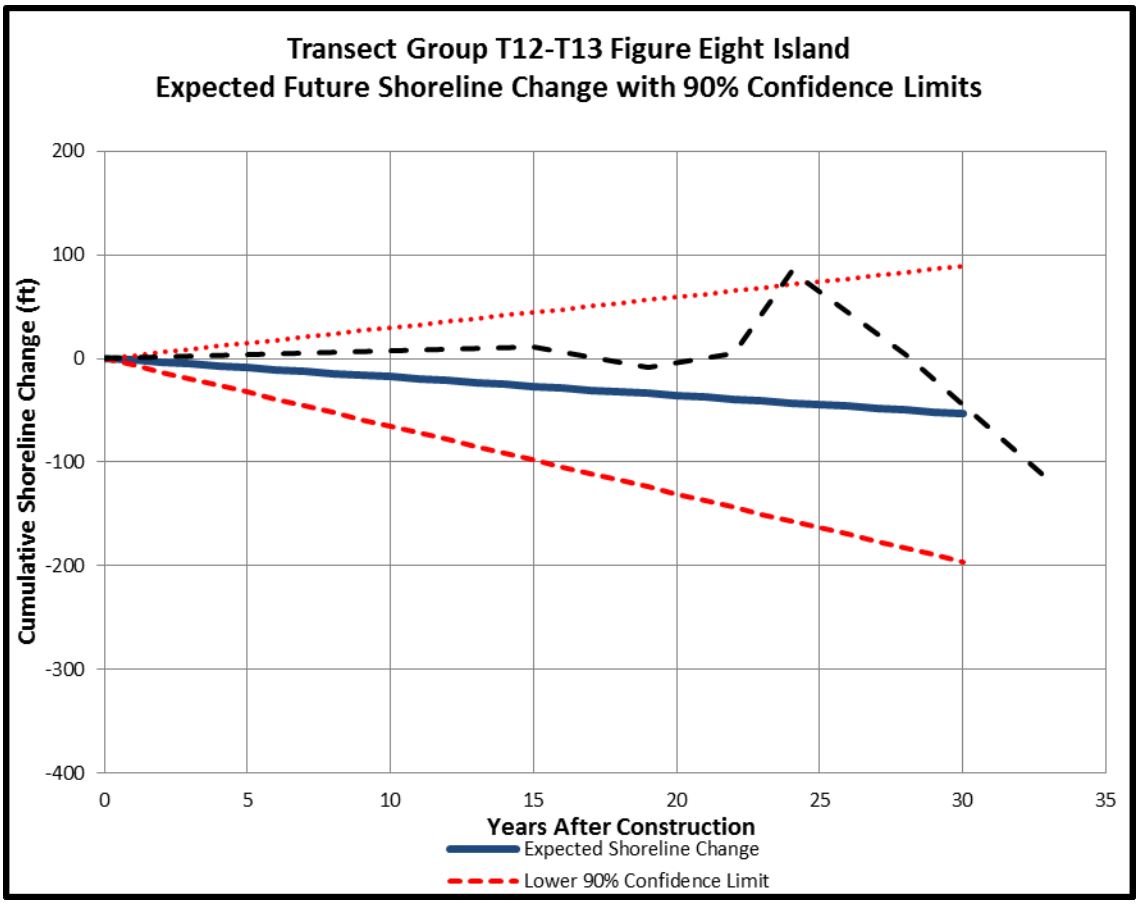


Figure 6.19. Transect Group T12-T13, Figure Eight Island – Expected future shoreline change.

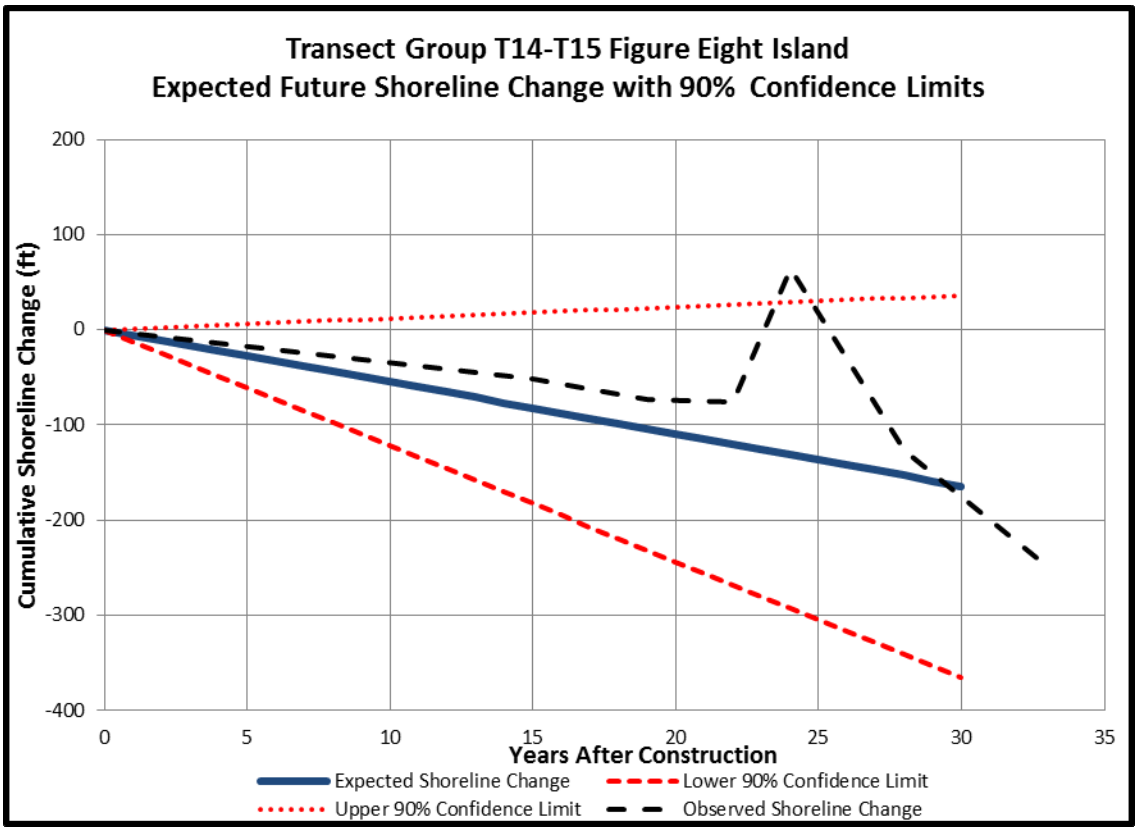


Figure 6.20. Transect Group T14-T15, Figure Eight Island – Expected future shoreline change.

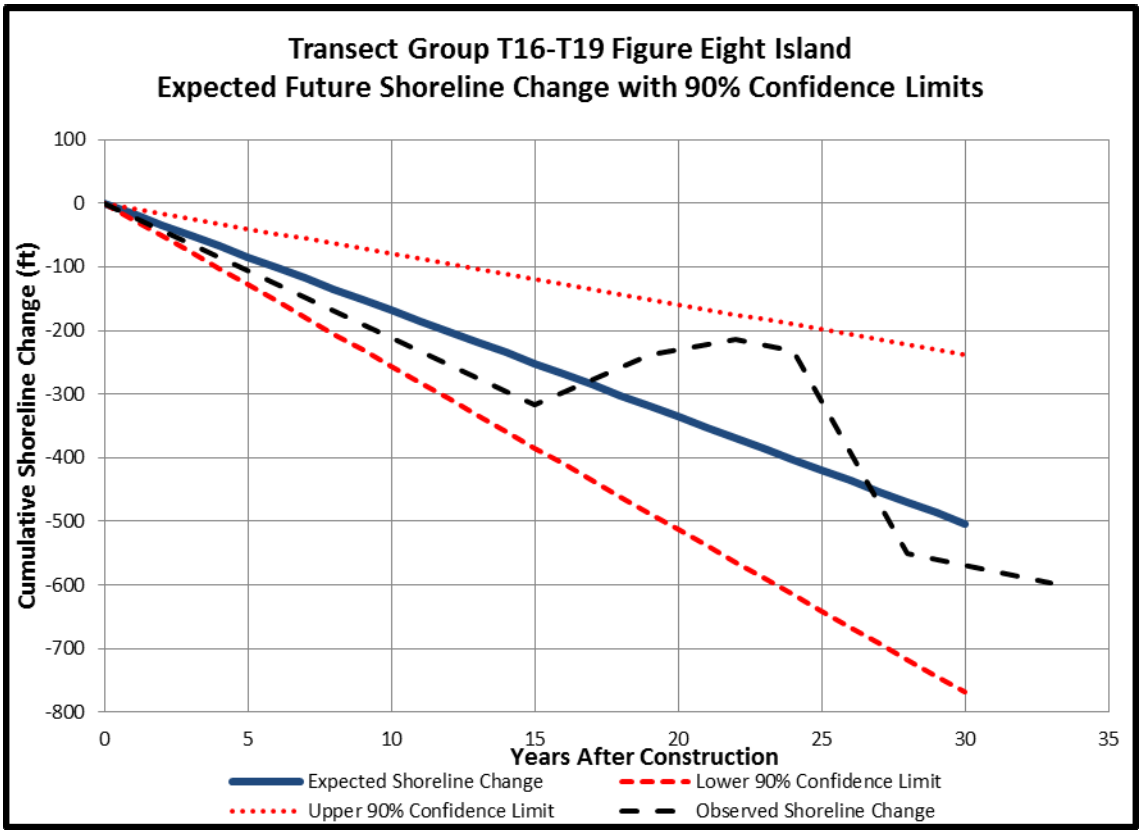


Figure 6.21. Transect Group T16-T19, Figure Eight Island – Expected future shoreline change.

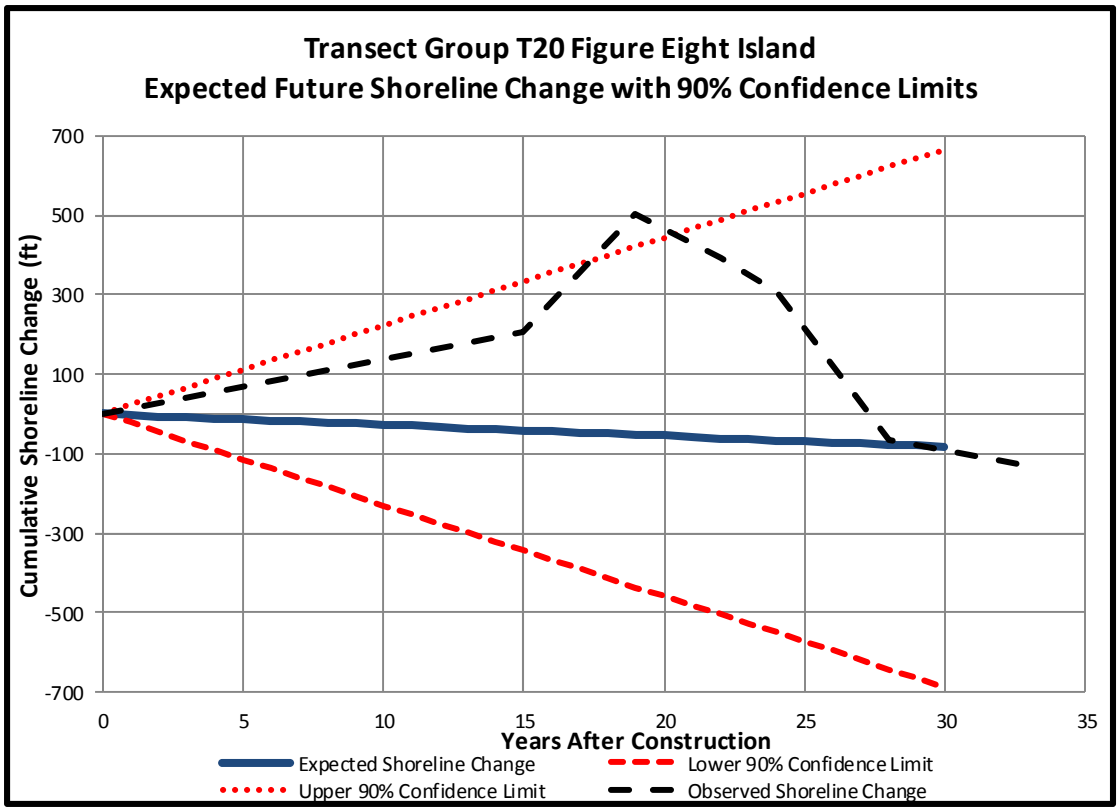


Figure 6.22. Transect Group T20, Figure Eight Island – Expected future shoreline change.

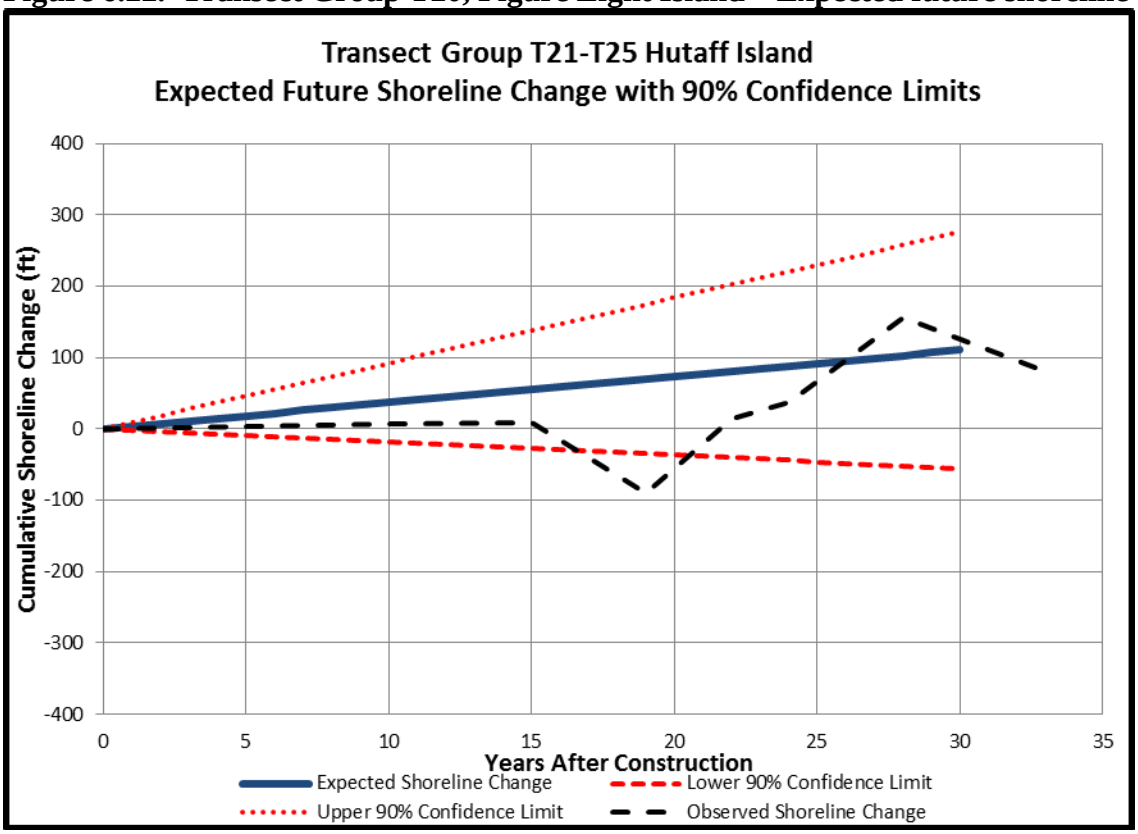


Figure 6.23. Transect Group T21-T25, Hutaff Island – Expected future shoreline change.

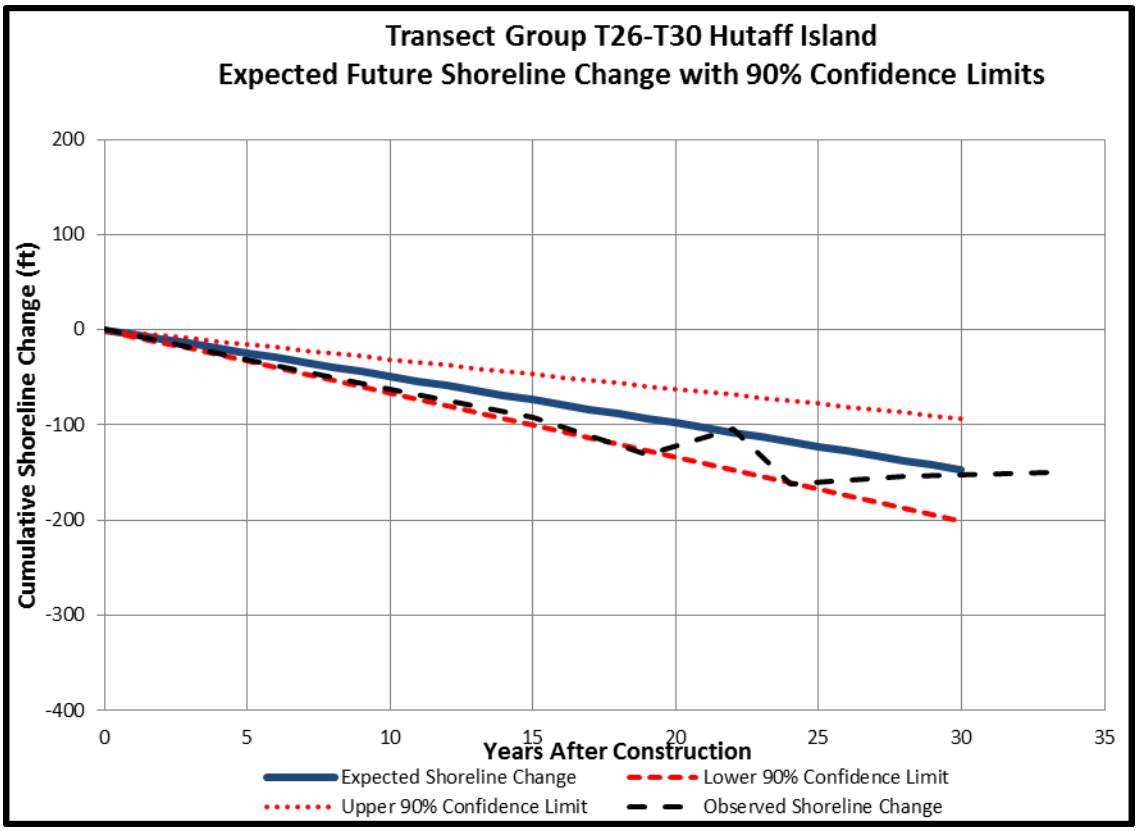


Figure 6.24. Transect Group T26-T30, Hutaff Island – Expected future shoreline change.

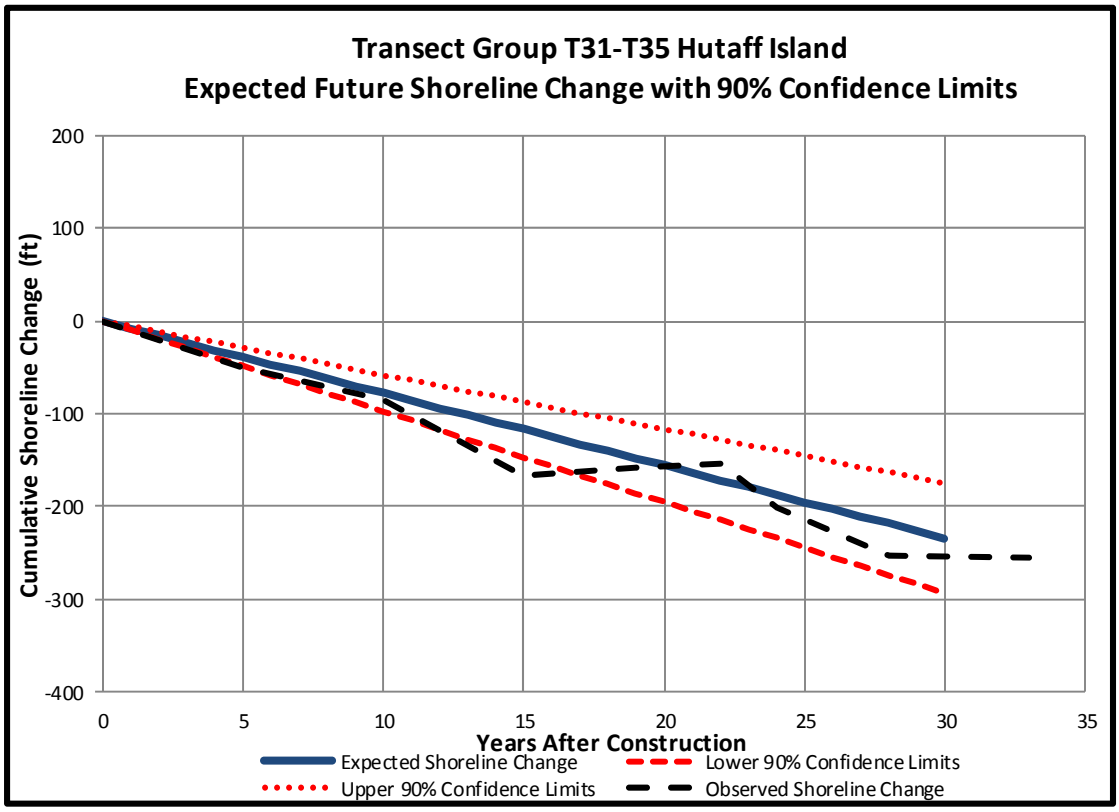


Figure 6.25. Transect Group T31-T35, Hutaff Island – Expected future shoreline change.

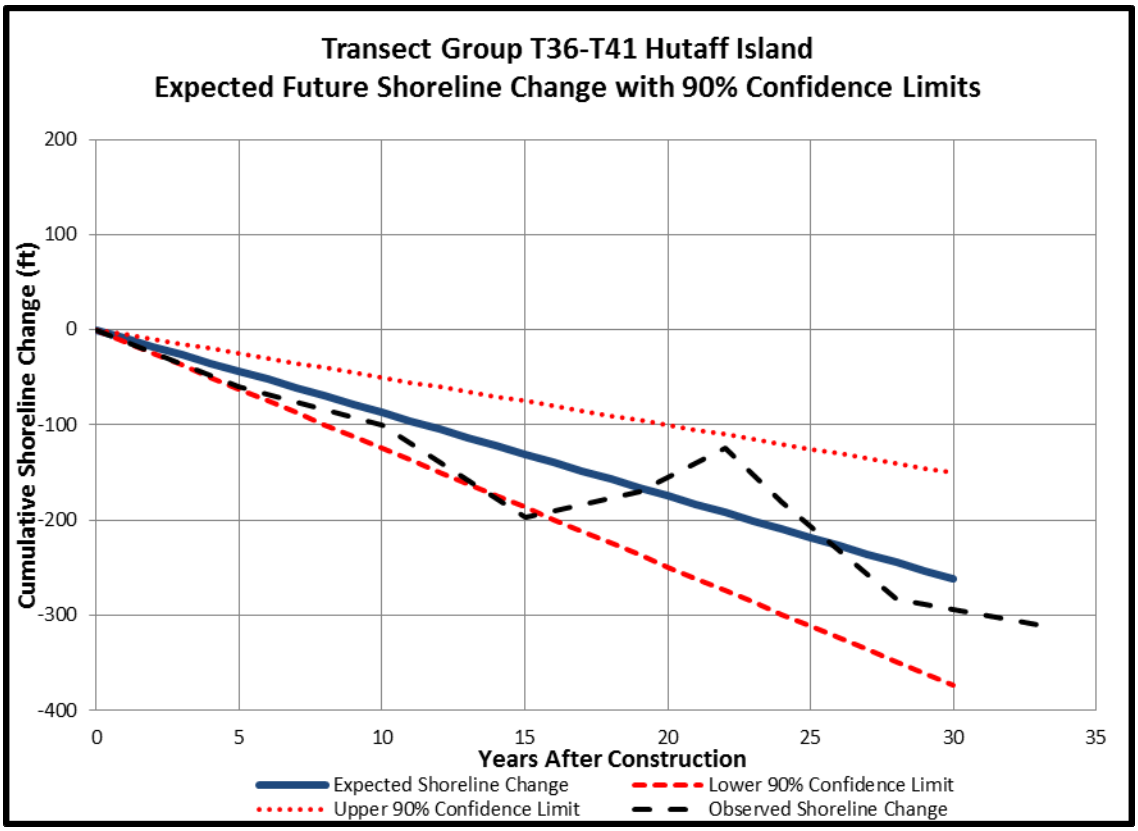


Figure 6.26. Transect Group T36-T41, Hutaff Island – Expected future shoreline change.

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 6.16 to 6.26, 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" 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**

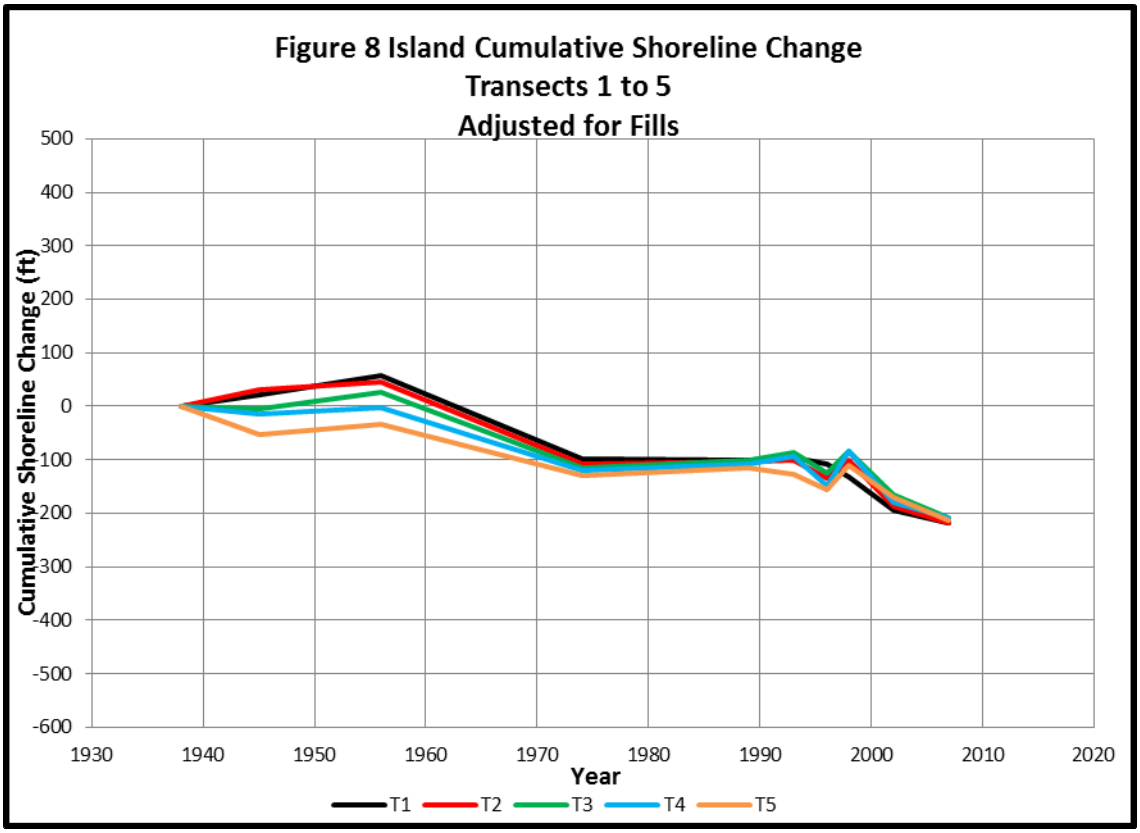


Figure A-1. Cumulative shoreline change Transects 1 to 5.

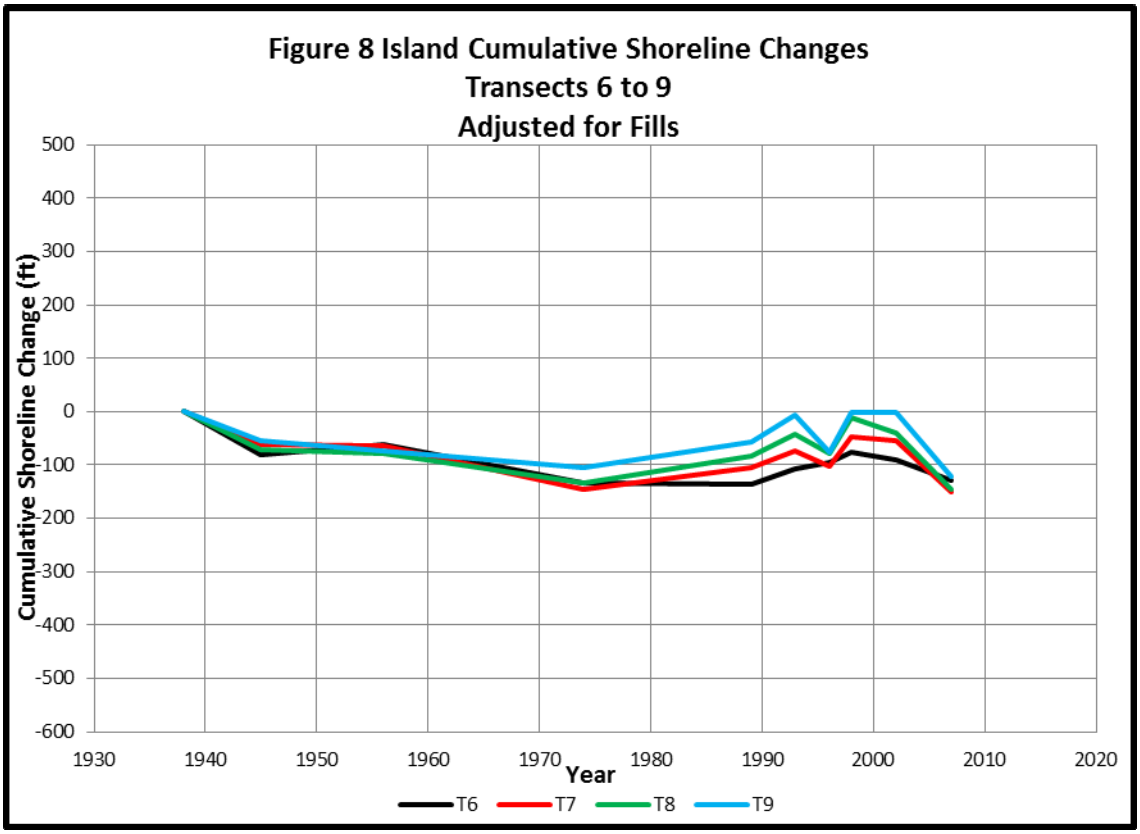


Figure A-2. Cumulative shoreline changes Transects 6 to 9.

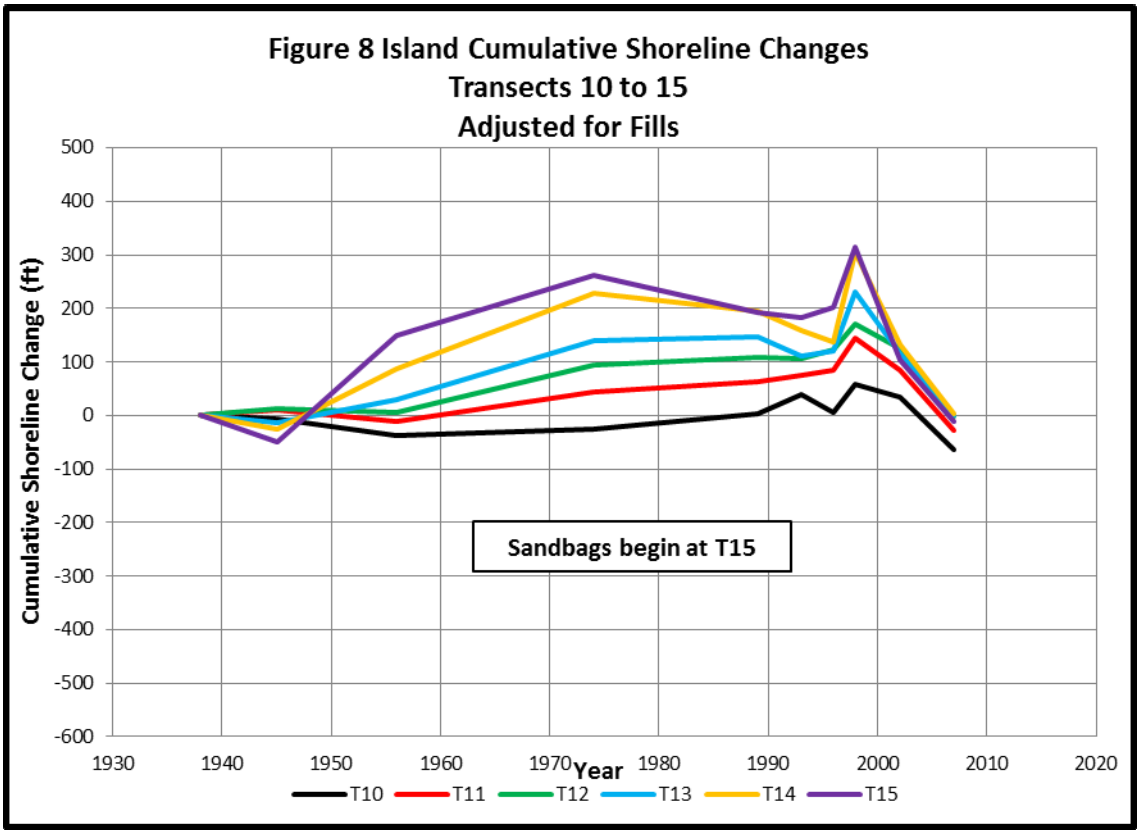


Figure A-3. Cumulative shoreline changes Transects 10 to 15.

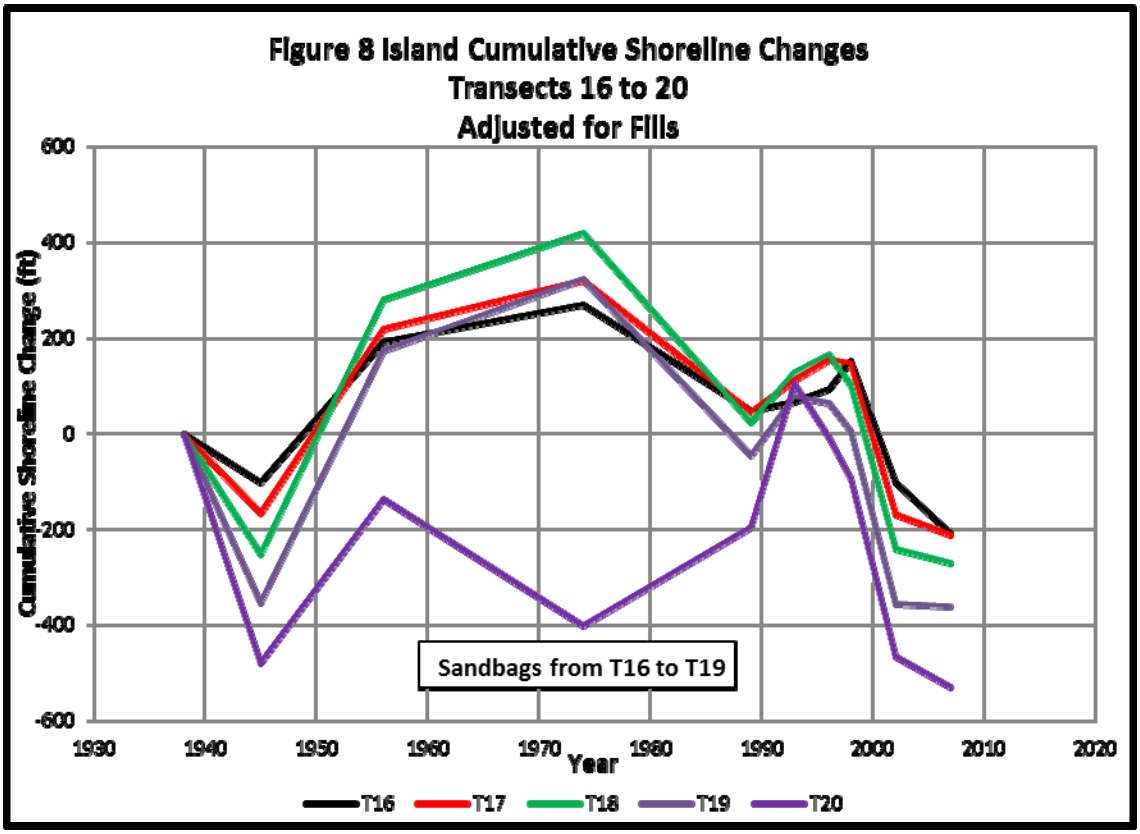


Figure A-4. Cumulative shoreline changes Transects 16 to 20.

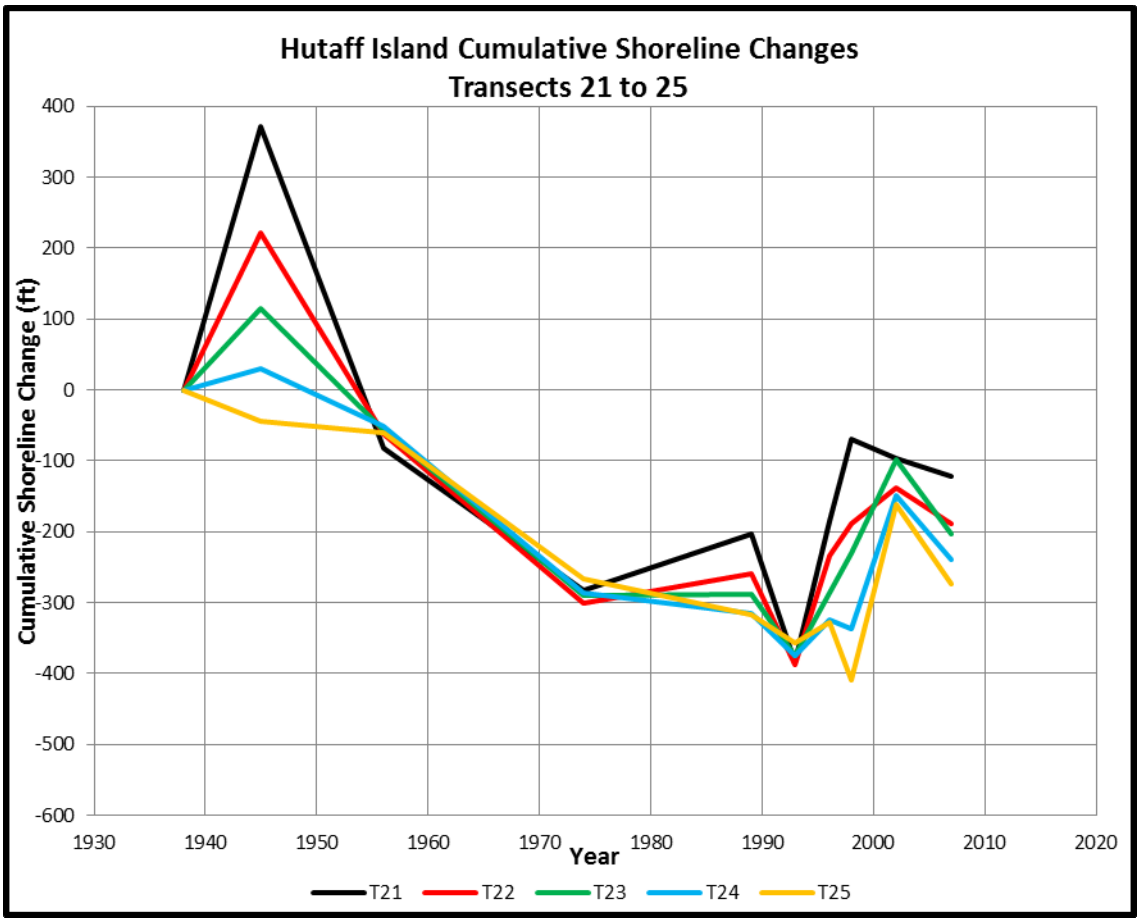


Figure A-5. Cumulative shoreline changes Transects 21 to 25.

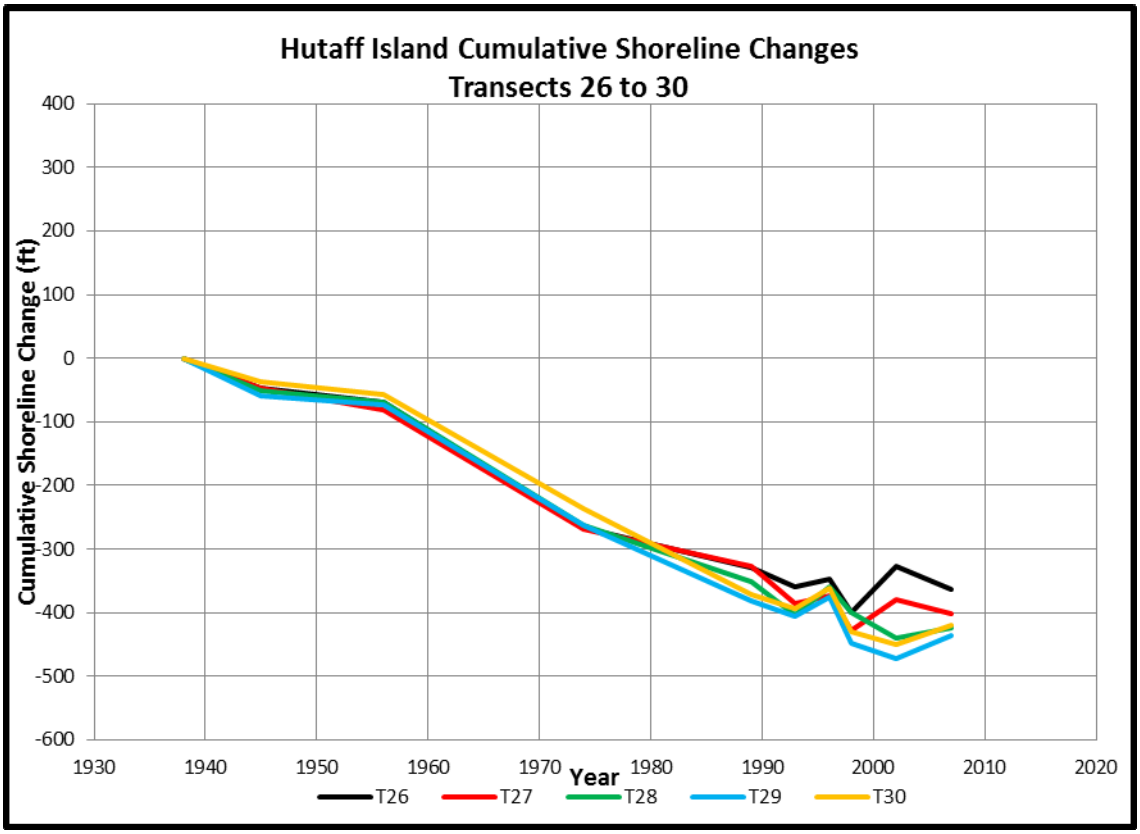


Figure A-6. Cumulative shoreline changes Transects 26 to 30.

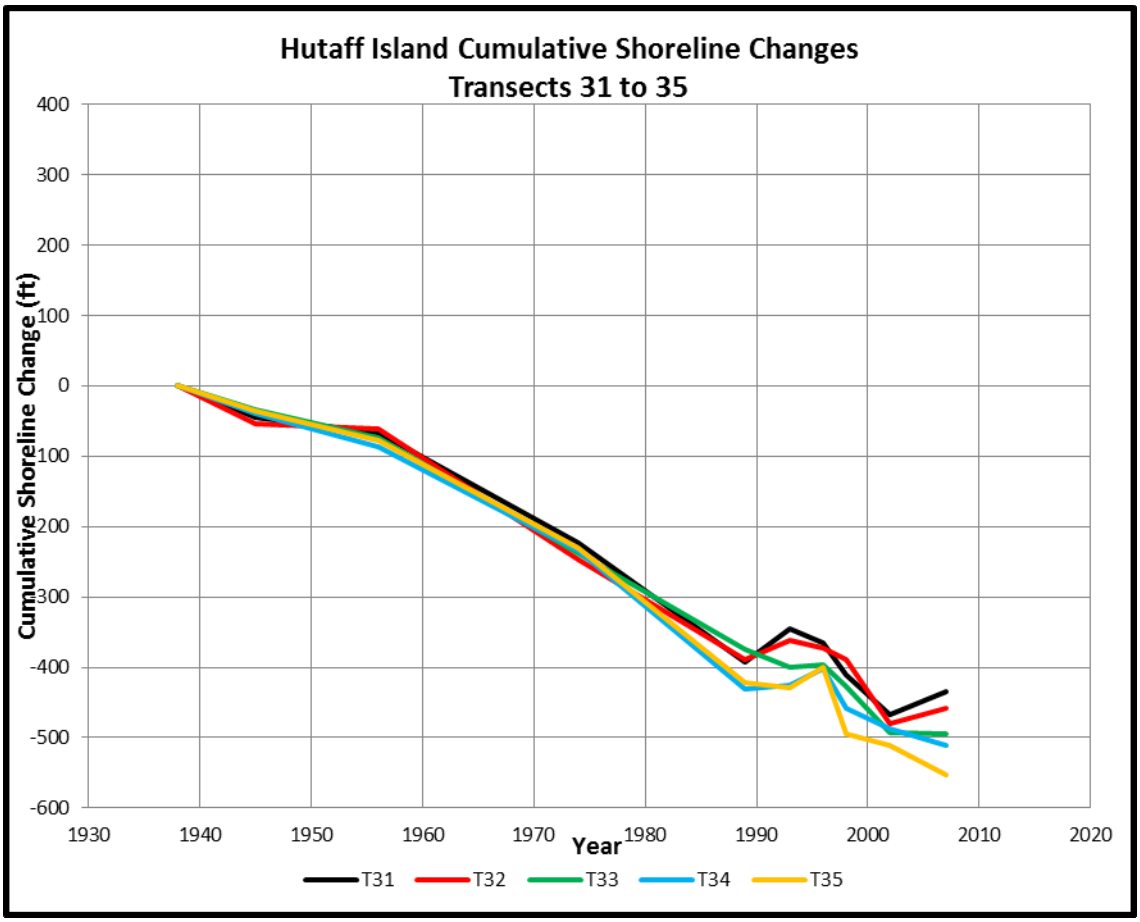


Figure A-7. Cumulative shoreline changes Transects 31to 35.

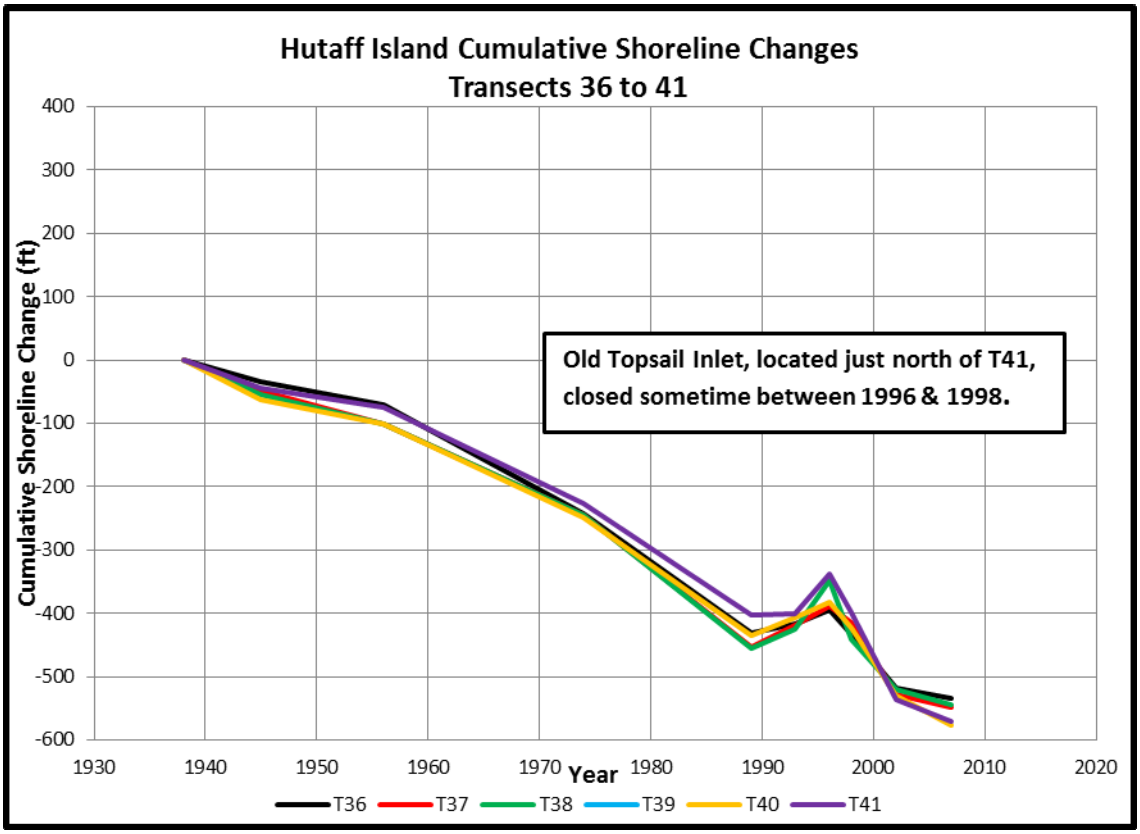


Figure A-8. Cumulative shoreline changes Transects 36 to 41.

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

Senate Bill 110 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, 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 three years following construction of the groin and 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 $1,821,000 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 $1.0 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 which would amount to approximately $1.0 million.

In summary, the financial assurances will be based upon:

- $480,000 for shoreline monitoring
- $0 for maintenance
- $1,821,000 for beach nourishment on Figure Eight Island
- $1,000,000 for the removal of the terminal groin

Based on these costs, the total amount of financial assurances provided by the Figure Eight Island Homeowners Association will be $3,301,000. The instrument type or form of financial assurance has yet to be determined.

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EXECUTIVE SUMMARY

This Environmental Impact Statement (EIS) meets requirements under the Federal Environmental Assessment and Review Process in determining how to best meet the needs of the people and the environment. This EIS includes an evaluation of resources and considerations involved in responding to the chronic erosion on the northern portion of Figure Eight Island so as to preserve the integrity of its infrastructure, provide protection to existing development, and ensure the continued use of the oceanfront beach along the northernmost three miles of its oceanfront shoreline. Significant resources which occur in the study area include socioeconomic resources, marine resources, terrestrial resources, threatened and endangered species, recreation and aesthetic resources, and cultural resources.

Chronic erosion problems along the northern sections of Figure Eight Island's ocean shoreline have been persistent since the early 1990's when the orientation and position of the main ebb channel through Rich Inlet moved northward. The northward movement of the main ebb channel was accompanied by the northward shift of the south side of the ebb tide delta away from the north end of Figure Eight Island, thus removing the protection it provided to the northern portion of the island. In addition to erosion issues along the ocean shoreline south of Rich Inlet, erosion is also prevalent along portions of the Nixon Channel shoreline extending from Rich Inlet southwest to the entrance to Nixon Creek. This erosion along the estuarine shoreline is associated with the proximity of the main flow channel to the shoreline.

As a result of this chronic erosion, Figure Eight Island is threatened with economic losses resulting from damages to structures and their contents due to hurricane and storm activity and the loss of beachfront land due to progressive shoreline erosion. The total assessed tax value of property within the limits of Figure Eight Island is approximately $1,189,810,926 based on the 2007 reappraisal. Also, periods of severe shoreline recession have adversely affected a number of biological resources including nesting habitat for endangered and threatened sea turtles.

To alleviate these problems attributed to erosion, several potential solutions were evaluated within this EIS. These include abandoning the existing infrastructure and retreating from the oceanfront shoreline; continued management of the ocean shoreline with present and past activities such as beach scraping, periodic nourishment, and placement of sandbags; relocating the inlet to a more optimal orientation accompanied with beach nourishment along the eroding shorelines; beach nourishment alone; and the construction of a terminal groin accompanied with beach nourishment. After consideration of the costs, benefits and environmental consequences of the proposed and alternative actions, the initial evaluation of project alternatives indicated that the optimal solution would entail the relocation of the inlet to the south which would allow the northern shoreline to regain protection from the ebb tide shoal. At that time, hardened structures including terminal groins were illegal in the State of North Carolina. However,

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. With this law in place, the terminal groin alternatives were revisited as a feasible solution to the erosion problem.

Following further extensive alternatives analysis, the applicant determined that the most effective solution would entail the construction of a terminal groin 213 m (700 ft) in length with a 273m (900 ft) shore anchorage section 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. This structure is intended to control tidal current induced shoreline changes immediately south of Rich Inlet. In addition to the construction of the terminal groin, several areas of the shoreline would be nourished with material excavated from the previously permitted area within Nixon Channel and three dredge disposal islands located along the AIWW behind Figure Eight Island. Beach fill will be placed along 548.6 m (1,800 ft) of the Nixon Channel shoreline just south of Rich Inlet. In addition, material will be used to nourish 3,810 m (12,500 ft) of ocean shoreline extending from Rich Inlet south to Bridge Road (see Figure 1.1). The existing navigation feature in Nixon Channel would be maintained to its permitted depth of -2.7 m (-9 ft) MLW (or -3.5 m (-11.4 ft) NAVD) and widths. Periodic nourishment of the beach fill would be accomplished approximately every four years in conjunction with maintenance dredging of the existing navigation feature in Nixon Channel.

This EIS contains the following information:

- **Chapter 1, Introduction** – Explains the purpose of the development of an EIS, describes agency and public coordination efforts, issues and concerns elicited by the development of the EIS and discusses applicable laws, rules and regulations.
- **Chapter 2, Purpose and Needs** – Identifies purpose and needs of the project and discusses how the shoreline along Figure Eight Island has been managed in the past.
- **Chapter 3, Alternatives Development** – Describes project rationale and alternatives considered.
- **Chapter 4, Affected Environment** – Identifies existing resources which occur in the study area.
- **Chapter 5, Environmental Consequences** – Evaluates the project alternatives and discusses the anticipated changes to the existing environment including direct, indirect, and cumulative effects.
- **Chapter 6, Avoidance and Minimization** – Describes several actions and measures incorporated to avoid or minimize adverse effects to resources.

Major Conclusions

Chronic erosion has been a major threat to many of the resources along the northern portion of Figure Eight Island. Action is needed to alleviate this threat. The Figure Eight

Beach Homeowners Association (F8 HOA) is seeking Federal and State permits to allow development of a management plan for Rich Inlet, which includes the construction of a terminal groin with supplemental dredging, that would mitigate chronic erosion on the northern portion of Figure Eight Island so as to preserve the integrity of its infrastructure, provide protection to existing development, and ensure the continued use of the oceanfront beach along the northernmost three miles of its oceanfront shoreline.

Issues to be Resolved

The Applicant's Preferred Alternative involves the construction of the first terminal groin since becoming legal in the State of North Carolina since the passage of Senate Bill 110 in July 2011. Hardened structures, including terminal groins, had been illegal within the state since 1985. A full understanding of how certain conditions related to the implementation of SB 110 continues to be evaluated. It is expected that State and Federal agencies along with the public will provide comments to this draft which will result in a comprehensive Avoidance and Minimization chapter including proposed monitoring initiatives. On-going coordination with the North Carolina Division of Coastal Management will continue and the details of the implementation stages are expected by the release of the Final Environmental Impact Statement.

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Appendix B *Engineering Analysis*

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Appendix D *Geotechnical Investigation Report*

Appendix E *Impact Summary Table*

Appendix F *Cumulative Effects Assessment*