DRAFT ENVIRONMENTAL IMPACT STATEMENT

NEW RIVER INLET MASTER MANAGEMENT PLAN
NORTH TOPSAIL BEACH, NORTH CAROLINA

August 2026

US Army Corps of Engineers
Wilmington District

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1.0 INTRODUCTION

This Draft Environmental Impact Statement (DEIS) has been prepared in accordance with the National Environmental Policy Act (NEPA) and the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR 1500 et. seq.) to address the environmental effects of proposed shore protection activities on the north end of Topsail Island at New River Inlet (NRI) in Onslow County, North Carolina (NC). The Wilmington District, US Army Corps of Engineers (USACE) is evaluating a request from the Town of North Topsail Beach (Town) for Department of the Army (DA) authorization pursuant to Section 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act (RHA) to implement a long-term beach and inlet management plan. The proposed New River Inlet Master Management Plan (NRIMMP) has been put forth to address severe and chronic inlet-induced erosion of the Town's north end oceanfront shoreline at NRI. This DEIS has been developed in support of the USACE decision-making process.

1.1 Project Location

The Town of North Topsail Beach is located on Topsail Island; a 22-mile-long southwest-northeast trending barrier island along the southern NC coast in Pender and Onslow Counties (Figure 1-1). The Town encompasses the 11.1-mile-long northern half of the island between the central-island municipality of Surf City and NRI. The proposed project area encompasses NRI and the Town's northernmost 5,100-ft-long oceanfront shoreline reach.

1.2 EIS Purpose

NEPA requires federal agencies to consider the environmental effects of their actions; including regulatory actions involving the issuance of federal permits and approvals for non-federal projects. A decision by the USACE to issue or deny Section 404/Section 10 permits for the Town's proposed project is a federal action requiring environmental review under NEPA. The purpose of this DEIS is to support an informed decision by the USACE based on an understanding of environmental consequences and available alternative courses of action. This DEIS is also intended to inform the public and provide opportunities for public involvement in the federal decision-making process. The information and analyses presented in this DEIS, in combination with input received through public involvement, will provide the basis for a USACE decision regarding the Town's proposed action.

1.3 EIS Process

As the federal decision-making agency, the USACE is responsible for implementing the NEPA EIS process. The EIS process is initiated through the publication of a Notice of Intent (NOI) in the Federal Register, which informs the public of the action agency's intent to prepare an EIS and initiates the public scoping process that is used to define the range of issues and alternatives to be addressed in the EIS. Information garnered through public scoping is applied to the development of a DEIS that is made available to the public for a minimum 45-day review and comment period. Upon closure of the DEIS comment period, the action agency considers all substantive comments, conducts any additional analyses that are warranted, and prepares a Final EIS (FEIS) that is made available to the public for a minimum 30-day review and comment period. Upon closure of the FEIS comment period, the action agency decides on a course of action to be taken and concludes the EIS process through the issuance of a Record of Decision (ROD). The ROD states the agency's decision, identifies the alternatives that were considered, and describes any measures that were adopted to avoid or minimize the environmental effects of the selected course of action.

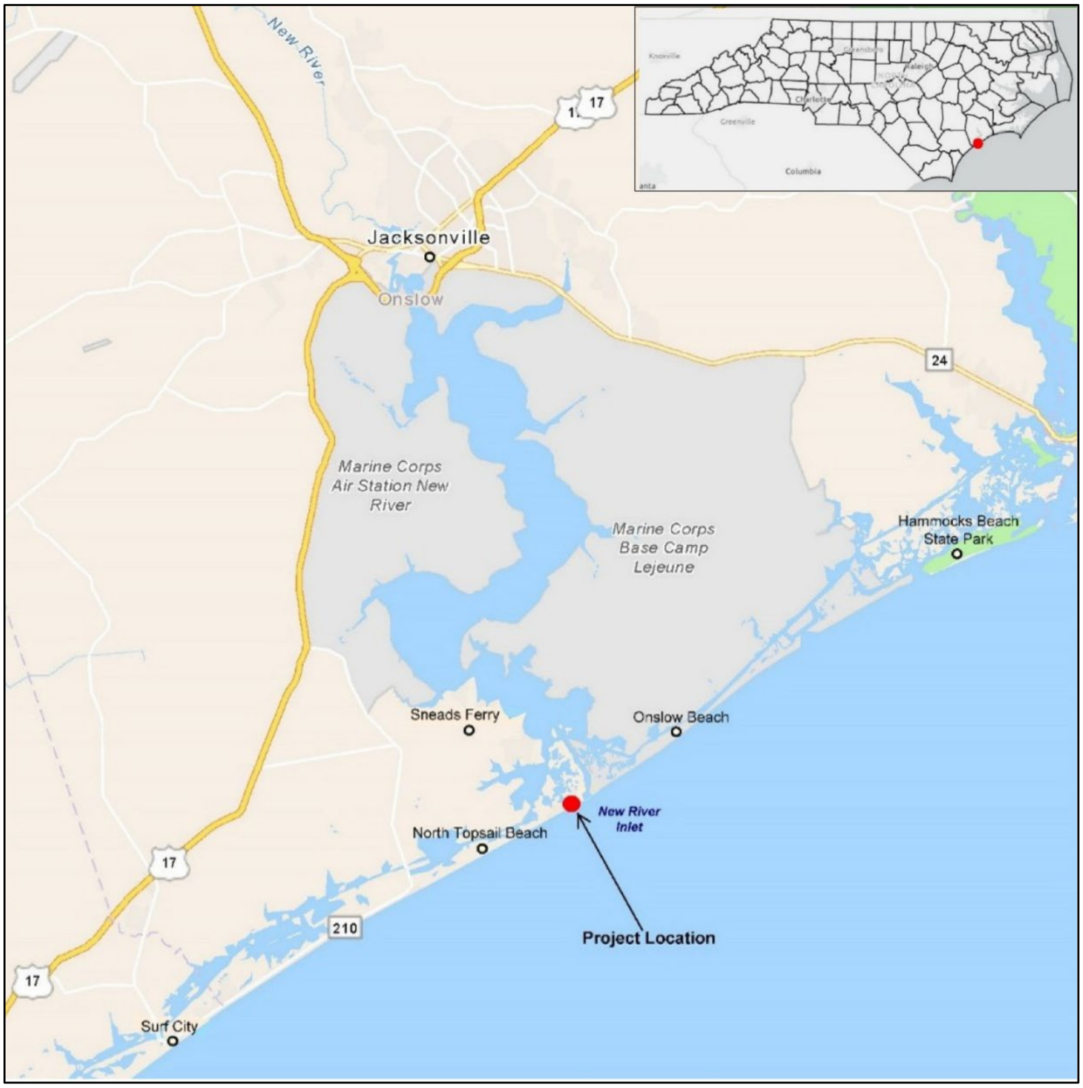


Figure 1-1. Location of the proposed action

1.4 Public Involvement

A principal goal of the NEPA EIS process is to involve the public in federal decision-making. The USACE initiated public scoping for the NRIMMP DEIS through issuance of a Public Notice on 15 March 2021. The Public Notice opened a 30-day public comment period and solicited public and agency participation in a public scoping meeting that was held on March 25, 2021. Due to COVID-19 restrictions, the initial public scoping meeting was conducted virtually through Facebook Live. The scoping meeting was recorded and uploaded to the Wilmington District Facebook page for further viewing (https://www.facebook.com/USACE.Wilmington). Comments received during the initial public scoping period were compiled and categorized by topic for application to the DEIS development process (see Appendix A: Public Scoping Report). All comments received were considered in the development of this DEIS. Public involvement will continue throughout the EIS process, with major opportunities for public participation occurring through the DEIS and FEIS public review and comment processes. Pursuant to the NC SEPA, the DEIS and FEIS will be distributed to state agencies through the NC State Clearinghouse process.

1.5 Related Environmental Laws and Regulations

1.5.1 Federal Laws and Regulations

The USACE regulatory action that is driving the NEPA EIS process also triggers regulatory consultation and permitting requirements under a number of other federal environmental laws. Although these additional consultations are conducted independently of NEPA under separate federal authorities, they are a vital component of the EIS scoping and analysis process that must be completed prior to the release of the FEIS.

Section 10 of the Rivers and Harbors Act of 1899

Section 10 of the RHA (33 U.S.C. 403) authorizes the USACE to issue permits for work in navigable waters; including construction, excavation, and the deposition of material. Navigable waters are those 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" (33 CFR Part 329). USACE Section 10 regulatory authority extends seaward to the 3-nm limit between state and federal waters.

Sections 404 and 401 of the Clean Water Act of 1972

Section 404 of the CWA (33 USC 1344) authorizes the USACE to issue permits for the discharge of dredged or fill material into waters of the United States, including wetlands. USACE regulatory authority under Section 404 extends seaward to the 3-nm limit between state and federal waters. Section 401 of the CWA (33 USC 1341) delegates federal authority to the state to issue 401 Water Quality Certifications for the discharge of dredged and fill material into Waters of the State. All projects that require a federal Section 404 permit for the discharge of dredged and fill material also require a corresponding 401 Water Quality Certification from the NC Division of Water Resources (NCDWR).

Section 7 of the Endangered Species Act (ESA) of 1973

Pursuant to Section 7 of the ESA (16 USC 1536), federal agencies are required to consult with the US Fish and Wildlife (USFWS) and the National Marine Fisheries Service (NMFS) to ensure that actions they undertake, fund, or authorize are not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. The USACE is the federal action agency responsible for consulting with the USFWS and NMFS on the Applicant's proposed action. Pursuant to Section 7, the USACE is currently preparing a Biological Assessment (BA) that will evaluate the potential effects of the proposed action on listed species and critical habitats. Submittal of the BA will initiate the formal Section 7 consultation process with the USFWS and NMFS. The Section 7 consultation process will conclude with the issuance of Biological Opinions (BOs) by the USFWS and NMFS.

Magnuson-Stevens Fishery Conservation and Management Act of 1996

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (16 USC 1801 et seq.) requires federal agencies to consult with NMFS to ensure that actions they undertake, fund, or authorize incorporate Essential Fish Habitat (EFH) conservation into the planning process. EFH habitats are defined as those "necessary to fish for spawning, breeding, feeding, or growth to maturity." The Fisheries Management Councils (FMCs), with assistance from NMFS, are responsible for identifying and delineating EFH in Fishery Management Plans (FMPs). The

USACE is the federal action agency responsible for consulting with NMFS on the Applicant's proposed action. Pursuant to the EFH provisions of the MSFCMA, the USACE is currently preparing an EFH Assessment report that will evaluate the potential effects of the proposed action on EFH and federally managed fisheries. Submittal of the EFH Assessment will initiate the formal EFH consultation process with NMFS.

Fish and Wildlife Coordination Act of 1958

The Fish and Wildlife Coordination Act (FWCA) (16 USC 661 et seq.), as amended, requires federal agencies to incorporate fish and wildlife resource conservation into the planning process for water resources development projects that they undertake, fund, or authorize. Section 2(b) of the FWCA requires the federal action agencies for water resource projects to consult with the USFWS and the state fish and wildlife agency [i.e., the NC Wildlife Resources Commission (NCWRC)] to ensure that conservation is fully incorporated. The USFWS and NCWRC are responsible for identifying potential adverse impacts on fish and wildlife resources and developing recommendations to avoid, minimize, and/or compensate for impacts. The USFWS and NCWRC are responsible for presenting their findings and recommendations to the USACE in a FWCA report that describes the affected resources, anticipated impacts, and recommended mitigation measures.

Marine Mammal Protection Act of 1972

The Marine Mammal Protection Act (MMPA) (16 USC 1361 et seq.) prohibits the take of marine mammals in US waters and authorizes programs to conserve, protect, and recover declining marine mammal populations. Although take is generally prohibited, the MMPA makes allowances for limited take through permits and incidental take authorizations. The responsibilities for implementing the MMPA are divided between the NMFS (cetaceans and pinnipeds) and the USFWS (manatees, dugongs, sea otters, walruses, and polar bears). In regard to the Applicant's proposed action, the MMPA does not impose any specific consultation requirements on the federal action agencies; however, the USFWS comments on federal actions potentially affecting marine mammals under its jurisdiction through the FWCA consultation process, and both the NMFS and the USFWS may provide comments pursuant to the MMPA through the NEPA review process.

Migratory Bird Treaty Act of 1918

The Migratory Bird Treaty Act (MBTA) (16 USC 703 et seq.) prohibits the take of migratory birds and authorizes the USFWS to implement programs to conserve, protect, and recover declining migratory bird populations. The MBTA does not make any allowances for incidental take; however, incidental take for species listed as threatened or endangered under the ESA may be authorized through the ESA Section 7 consultation process. In regard to the Applicant's proposed action, the MBTA does not impose any specific consultation requirements on the federal action agencies; however, the USFWS comments on federal actions potentially affecting migratory birds through the FWCA consultation process.

Coastal Zone Management Act of 1972

The Coastal Zone Management Act (CZMA) (16 USC 1451 et seq.) established a cooperative program between the federal government and the coastal states for the management and protection of coastal resources. The CZMA is carried out primarily by the coastal states through the development and implementation of federally approved coastal management programs. As described in greater detail below, the proposed action is subject to the NC Coastal Area Management Act (CAMA) Major Permit process.

National Historic Preservation Act of 1966

Pursuant to Section 106 of the National Historic Preservation Act (NHPA) (16 USC 470 et seq.), federal agencies are required to consider the effects of actions they undertake, fund, or authorize on historic properties that are listed or may be eligible for listing in the National Register of Historic Places (NRHP). Federal action agencies are required to consult with the Advisory Council on Historic Preservation (ACHP), either directly or through State Historic Preservation Offices (SHPOs) for the purpose of identifying historic properties potentially affected by the action, assessing the effects, and mitigating adverse impacts. The consultation provisions of Section 106 apply to state lands, including submerged lands underlying state waters, as well as the OCS. The USACE conducts Section 106 consultations in accordance with USACE NHPA implementing regulations (33 CFR 325 - Appendix C). The USACE is responsible for consulting with the NC SHPO on proposed actions that occur within the 3-nm limit.

1.5.2 Applicable State Laws and Regulations

North Carolina State Environmental Policy Act of 1971

NC's State Environmental Policy Act (SEPA) (GS 113A-1-13) is a law requiring state agencies to consider the environmental effects of their actions through an environmental review process that is essentially the state-level equivalent of the federal NEPA review process. In the case of federal actions, the NEPA process also fulfills the requirements of SEPA. SEPA specifies that federal NEPA documents must be reviewed through the State Clearinghouse process, which is standard USACE practice for all regulatory EIS documents. The State Clearinghouse in the NC Department of Administration is responsible for implementation and administration of the SEPA review process. The Clearinghouse forwards SEPA/NEPA documents to state/local agencies for review and comment and publishes Notices of Availability (NOAs) in the NC Environmental Bulletin soliciting public review and comment. The Clearinghouse provides for a 30-45 day agency/public comment period, and is responsible for compiling agency and public comments.

North Carolina Coastal Area Management Act (CAMA) of 1974

NC's coastal management program was established by the NC Coastal Area Management Act (CAMA) of 1974 (GS 133A-100 et seq.). The coastal management program is implemented jointly by the state and local coastal county governments. The NC Division of Coastal Management (NCDCM) implements state CAMA responsibilities, which include the designation of Areas of Environmental Concern (AECs), the establishment of management objectives and use standards for development activities within AECs, and issuance of state CAMA Major Permits for work in AECs and excavation or filling in estuarine waters, tidelands, marshlands, and state-owned lakes pursuant to the NC Dredge and Fill Law (GS 113-229). AECs are state-designated areas of natural importance that fall under four broad categories: the estuarine and ocean system, ocean hazard system, public water supplies, and natural and cultural resource areas. The Applicant's proposed action encompasses work in AECs associated with the estuarine and ocean system and the ocean hazard system, and will require a CAMA Major Permit from the NCDCM.

NC Coastal Policy Reform Act of 2013[1] (SB 151/SL 2013-384)

The NC Coastal Policy Reform Act (NCCPRA) of 2013 authorized the NCDCM to issue CAMA Major Permits for four terminal groins along the NC coast. Subsequent provisions included in the 2015 NC State Budget allowed for the issuance of Major Permits for two additional terminal groins, raising the cap on groins from four to six. Pursuant to the NCCPRA and its implementing regulations (GS 113A-115.1), applicants for groin permits are required to provide: evidence that structures or infrastructure are threatened by erosion; an EIS prepared pursuant to SEPA; a list of property owners and local governments that may be affected by the groin along with proof that each has been notified of the groin permit application; a construction and maintenance plan for the groin and its associated beach fill component prepared by a professional engineer licensed to practice in NC; a plan for the management of inlet, estuarine, and ocean shorelines that are adjacent to and under the influence of the inlet; and proof of financial assurance sufficient to implement long-term maintenance and monitoring, mitigation measures, and modification or removal of the groin if necessary.

NC Sedimentation Pollution Control Act of 1973

The NC Sedimentation Pollution Control Act (SPCA) authorizes the NC Division of Energy, Mineral and Land Resources (NCDEMLR) to approve erosion and sedimentation control plans for all land-disturbing activities other than agriculture and mining. The SPCA requires the development and implementation of effective temporary and permanent control measures to prevent accelerated erosion and off-site sedimentation. An erosion and sedimentation control plan must be submitted by the applicant and approved by the NCDEMLR before any land disturbance is initiated on sites one acre or larger.

[1] Short Title for: An Act to Amend Marine Fisheries Laws; Amend the Laws Governing the Construction of Terminal Groins; and Clarify that Cities May Enforce Ordinances within the State's Public Trust Areas

2.0 PURPOSE AND NEED

2.1 Purpose and Need for the Proposed Action

The purpose of the proposed NRI Management Master Plan (proposed action) is to mitigate ongoing severe and chronic erosion of the NTB north end oceanfront shoreline and provide for the protection of residential structures, infrastructure, recreational assets, and natural resources. The inlet-influenced north end shoreline has experienced high rates of background erosion since the early 1990s. During the mid to late 1990s, Hurricanes Bertha and Fran (1996) and Floyd (1999) severely eroded the NTB shoreline and frontal dune system and caused catastrophic damage to homes and infrastructure. Since 1996, the 5,100-ft north end shoreline has receded by 70 to 240 ft (Figure 2-1). The inlet management component of the Town's currently authorized shore protection project is a long-range strategy that may not provide significant north end protection for 15 to 20 years. North end erosion rates have accelerated during the early phases of the inlet management project, with some shoreline reaches experiencing erosion rates as high as 100 ft/yr. Extreme erosional sand losses necessitated the emergency construction of a 2,000-linear-foot (lf) sandbag revetment during 2014-2015. Currently, sandbag revetments are protecting ~3,600 ft of severely eroded shoreline on the north end (Figure 2-2). More than 40 structures along the landward margin of the revetment are imminently threatened with erosional damage or destruction (Figure 2-3).

Due to the severity of the erosional threat, additional action is needed to supplement the existing NTB Shoreline Protection Project, which is authorized under a 30-year permit that expires in 2041. As described in detail below (Section 2.3), the existing project includes an inlet management component that is designed to promote north end shoreline accretion through realignment and maintenance of the NRI outer ebb channel. However, the realigned NRI ebb channel is expected to require a number of maintenance dredging events over the next 15 to 20 years before significant shore protection benefits for the north end shoreline are realized (CPE 2015). Associated beach fill placements under the existing project, which are projected to provide two years or less of shore protection, will be insufficient to protect the north end shoreline under the required minimum ebb channel maintenance interval of four years. Consequently, additional supplemental shore protection measures are needed to protect the north end shoreline.

2.2 North End Shoreline Erosion Trends

Erosional and accretional trends along the Town's north end oceanfront shoreline are dictated by NRI ebb channel migration patterns and associated changes in the inlet ebb-tidal delta symmetry [Coastal Planning and Engineering, Inc. (CPE) 2009]. Although net sediment transport is predominantly southwestward at a regional scale, the influence of the inlet is reflected in a localized northeastward reversal of the regional net transport pattern along the extreme north end oceanfront shoreline. Relatively large volumes of sediment are transported northeastward along the shoreline and into the inlet where they are retained within the inlet flood shoal system and navigation channels. Analyses of historical shoreline and inlet ebb tidal delta changes indicate that the north end shoreline has experienced periods of accretion when the outer ebb channel was aligned to the south, whereas northerly channel alignments have produced erosional conditions along the north end (CPE 2009). These analyses further indicate that the current erosional trend along the north end of NTB was initiated by a northeastward shift in the NRI ebb channel alignment that began in the early 1990s. The northeastward shift in the channel alignment initiated a corresponding northeastward shift in the inlet ebb tidal delta. The shift in the ebb tidal delta away from NTB exposed the north end shoreline to onshore wave energy, thereby initiating the current erosional trend. During the mid to late 1990s, the north end beach and frontal dune system experienced severe erosional storm damage during Hurricanes Bertha (1996), Fran (1996), and Floyd (1999). Since 1996, the 5,100-ft north end shoreline has receded by 70 to 240 ft. The Town's 2012-2013 inlet ebb channel realignment and nourishment project was followed by accelerated north end erosion, with annual erosion rates as high as 100 ft/yr occurring in the vicinity of the Topsail Reefs condominium complex. During the latter part of 2014, the Town was issued an emergency permit to construct a 2,000-ft-long sandbag revetment along the north end shoreline. In total, sandbag revetments are currently protecting ~3,600 lf of shoreline on the north end.

2.3 Past and Present Beach and Inlet Management Activities

In the wake of the destruction caused by Hurricanes Bertha (1996), Fran (1996), and Floyd (1999), the Town initiated efforts to develop a comprehensive long-term shore protection project for the entire 11.1-mile oceanfront shoreline. The Town ultimately developed a 30-year beach nourishment and inlet management program (NTB Shore Protection Project) that was authorized in 2011. The NTB Shore Protection Project encompasses recurring nourishment of the Town's 11.1-mile ocean shoreline and the realignment and maintenance of the NRI ocean bar channel. Beach nourishment is divided into five phases (Phases 1-5) that were originally scheduled to occur in sequence over a period of five years (Figure 2-4, Table 2-1). Phases 1-4 were designed as an engineered beach project in accordance with Federal Emergency Management Agency (FEMA) eligibility requirements for Public Assistance reimbursement of damages incurred during federally declared disasters (i.e., storms). However, Phase 5 was originally designed as a low-density interim beach fill project under the assumption that long-term protection would eventually be provided by the federal Surf City and NTB Coastal Storm Risk Management (CSRM) project[2]. Phase 5 was subsequently redesigned to FEMA engineered beach standards and rescheduled as the second event following Phase 1. The Phase 5 changes were authorized through a modification of the Town's permit in 2013. Sand sources for the five nourishment phases include an offshore borrow site along NTB and dredged material derived from realignment and periodic maintenance of the NRI ocean bar channel. The initial Phase 1 event consisting of inlet ebb channel realignment and nourishment of the Phase 1 shoreline reach was completed during 2012-2013. Phase 1 removed ~592,000 cy of material from NRI and placed ~568,360 cy of beach compatible material on the northernmost 1.5-mile (7,735 linear ft) oceanfront shoreline reach of NTB. Phase 5 nourishment was completed during 2014-2015 using sand from the offshore borrow site. In 2016, the Phase 5 reach incurred significant sand losses during Hurricane Matthew; leading the Town to pursue a FEMA reimbursed sand replacement project. The resulting FEMA reimbursed Phase 5 sand replacement project was completed in 2018-2019 using truck-hauled material from an upland sand mine. A chronological history of the Town's prior shoreline management activities is presented in Table 2.2.

The inlet management component of the NTB Shore Protection Project is specifically designed to mitigate inlet-induced erosion along the ~5,100-lf north end shoreline reach by realigning the NRI outer ebb channel to a more southerly orientation along the north end of NTB. Analysis of historical ebb channel alignments and corresponding shoreline positions indicates that maintenance of a southerly ebb channel alignment perpendicular to the NTB ocean shoreline will eventually shift the ebb tide delta southward and promote accretion along the north end shoreline. The design ebb channel consisting of a 500-ft-wide, 3,450-ft-long, and -18 ft-deep (NAVD88) channel across the ebb tide delta was initially constructed during 2012-2013 in conjunction with the initial Phase 1 beach fill construction event. The success of the inlet management plan is

[2]Currently known as the Surf City CSRM Project. Town of NTB formally withdrew from the federal project in 2021.

dependent on long-term maintenance of the design channel alignment via periodic maintenance dredging. Maintenance dredging events are triggered by established quantitative thresholds; including channel shoaling that is ≥85 percent of the original dredged material volume and/or thalweg migration outside of the originally constructed 500-ft-wide channel. Based on estimated shoaling rates, the projected frequency of ebb channel maintenance events is once every four years. A minimum interval of four years is required between successive maintenance events, regardless of channel conditions.

Table 2-1. NTB Shore Protection Project - Phase 1-5 Nourishment Reaches

Phase	Year[1]	Length (ft)	Volume (cy)
Phase 1	2010-2011	9,000	544,400
Phase 2	2012-2013	10,120	940,700
Phase 3	2014-2015	11,500	393,800
Phase 4	2016-2017	6,880	721,500
Phase 5	2017-2018	20,320	1,500,000[2]
Total		**57,820**	**3,112,800**

[1]Original schedule per 2009 EIS
[2]Original 2011 permit volume was 512,400 cy

Table 2-2. Chronological History of the NTB Shore Protection Project

2010	CAMA Permit	CAMA Major Permit 79-10 issued
2011	Final EIS-ROD Section 404/10 Permit	Section 404/10 Permit SAW 2005-00344 issued
2012	Permit Modification	Inlet compatible material volume increased Phase 1 beach fill density increased
2012/2013	Phase 1 Construction	Inlet channel realignment Phase 1 (north end) nourishment
2013	Permit Modification	Phase 5 beach fill density increased to meet FEMA criteria Phase 5 rescheduled as the 2nd event to follow Phase 1
2014/2015	Sandbag Revetment	Construction of 2,000-linear-ft north end sandbag revetment
2014/2015	Phase 5 Construction	Phase 5 nourishment using offshore borrow site
2017	Permit Modification	Original ebb channel alignment modified
2018/2019	Phase 5 Sand Replacement	FEMA reimbursement for Hurricane Matthew Phase 5 nourishment via upland sand source/truck haul

The inlet management plan is designed to shift the ebb tidal delta and restore the north end shoreline over the course of multiple ebb channel maintenance events. CPE (2009) originally projected significant north end accretion within five years of the initial realignment and full restoration of the north end shoreline within 15 years. However, the initial Phase 1 realignment/nourishment event in 2012-2013 was followed by higher than expected north end erosion rates. Essentially all of the material that was placed on the north end shoreline was eroded and returned to the inlet during the initial post-construction year (2013). Furthermore, ebb channel shoaling and thalweg migration exceeded the established thresholds in just 18 to 24 months. By August 2014, extreme shoreline erosion led the Town to seek an emergency permit for construction of a sandbag revetment to protect threatened homes and infrastructure on the north end (CPE 2015). In February 2015, the Town completed emergency construction of a 2,000-lf sandbag revetment along the north end from the existing Topsail Reefs revetment to NRI. Based on the shoreline response to the initial Phase 1 event, the Town authorized engineering investigations to assess contingency shore protection measures for the north end shoreline. The resulting Phase 1 Contingency Plan recommended additional modeling to assess alternative ebb channel alignments and the initiation of design analysis for a terminal groin on the north end (CPE 2015). The resulting alternative channel alignment modeling study recommended a 17-degree clockwise pivot in the channel alignment (CPE 2016a). The modified "pivot channel" alignment was subsequently authorized through a 2017 modification of the Town's permit. Construction of the modified pivot channel was originally scheduled to occur in 2018-2019 as a component of the Town's third shore protection project event. However, the Town opted to delay additional ebb channel maintenance while undertaking efforts to identify and assess potential contingency shore protection measures, including the potential construction of a terminal groin on the north end at NRI.

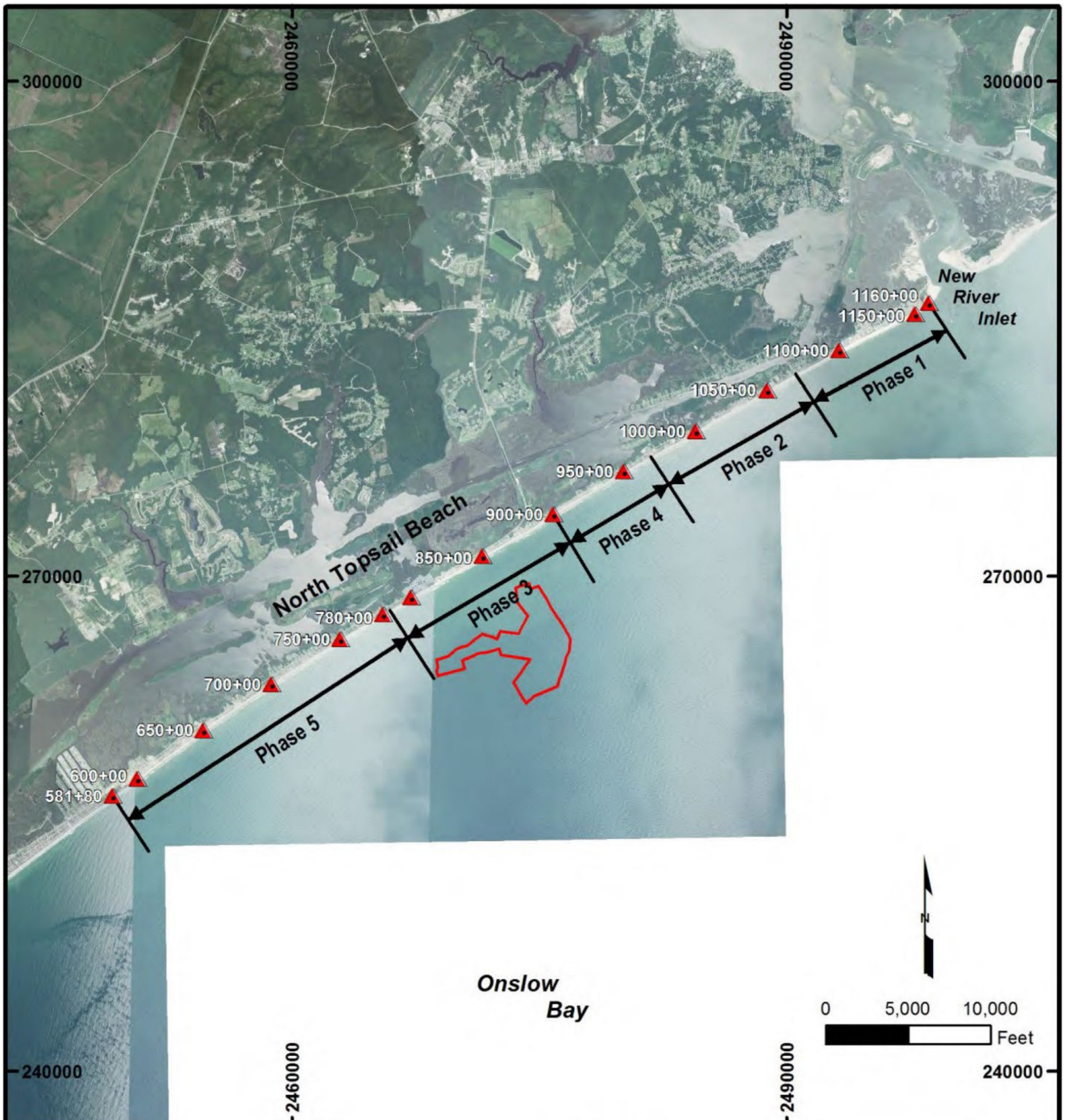
USACE Activities

Over the last several decades, the USACE has routinely placed dredged material from routine maintenance of the Atlantic Intracoastal Waterway (AIWW) NRI Crossing, Channel to Jacksonville, and Cedar Bush Cut on the northernmost two-mile oceanfront shoreline reach of NTB. According to the National Beach Nourishment Database (APTIM 2018), USACE north end placement events from 1997-2016 placed a combined total sand volume of ~800,000 cubic yards (cy) on the north end (average of ~75,000 cy per event). Although historically routine, USACE channel maintenance and associated north end beach placement events have more recently been infrequent and unpredictable due to limited federal funding. The most recent USACE north end disposal events occurred during 2010, 2013, 2020, and 2023. Channel maintenance is conducted by cutterhead pipeline dredges that pump the material directly onto the north end shoreline via submerged and/or floating pipelines. Due to the potential for placed material to erode back into the inlet navigation channel, the current USACE north end beach placement plan excludes the northernmost shoreline reach within 1,500 ft of NRI.

Figure 2-1. North End shoreline recession (ft) 1997 to 2020 (Shoreline Data Source: NCDCM 2022)

Figure 2-2. Existing sandbag revetments along north end shoreline

Figure 2-3. Threatened structures along NTB north end shoreline - March 2016 aerial imagery



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2014 background imagery is the USDA's National Agricultural Imagery Program.

Legend:

Offshore Borrow Area

USACE Baseline Station

Figure 2-4. NTB Shoreline Protection Project - Project Phases (CPE 2016b)

3.0 ALTERNATIVES

The Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR 1500 *et. seq.*) direct federal agencies to identify and evaluate reasonable alternatives to the proposed action that are “technically and economically feasible and meet the purpose and need.” This section describes the alternatives that were considered by the USACE as part of the DEIS development process, including alternatives that were carried forward for detailed analysis and alternatives that were initially evaluated and eliminated from further consideration. The alternatives carried forward for detailed analysis in this DEIS include two no action alternatives (Alternatives 1 and 2) and three action alternatives (Alternatives 3, 4, and 5) (Table 3-1). Alternative 1 interprets no action as the continuation of existing north end beach and inlet management practices without modification, whereas Alternative 2 assumes that no management activities requiring USACE authorization would be undertaken. Alternatives 3, 4, and 5 represent alternative management plans for maintaining a 5,100-ft-long dune and berm beach fill project along the north end shoreline over the next 30 years. Alternative 3 would employ beach nourishment alone using a two-year cycle of recurring maintenance nourishment events. Alternative 4 would employ recurring beach nourishment with the addition of a terminal groin to reduce inlet-induced erosion rates and extend the life of maintenance beach fills. Alternative 5, representing the Town’s preferred alternative, would employ recurring beach nourishment with the addition of both a terminal groin and inlet management to reduce inlet-induced erosion and extend the life of beach fills.

Table 3-1. Alternatives carried forward for detailed analysis.

Alternative 1	No Action (Continuation of exiting beach and inlet management practices)
Alternative 2	Abandon and Retreat (No USACE-authorized management activity)
Alternative 3	Beach Nourishment
Alternative 4	Beach Nourishment and Terminal Groin
Alternative 5 (Applicant’s Preferred Alternative)	Beach Nourishment, Terminal Groin, and Inlet Management

3.1 Alternatives Carried Forward for Detailed Analysis

3.1.1 Alternative 1: No Action (Continuation of Existing Management Practices)

Alternative 1 represents the continuation of existing north end beach and inlet management practices without modification, including inlet management and beach nourishment by the Town as currently authorized under the comprehensive NTB Shoreline Protection Project, USACE beach placement of navigation dredged material, maintenance of the existing north end sandbag revetments, and periodic beach bulldozing to repair dunes and berms.

3.1.1.1 Inlet Management Plan

The existing inlet management plan is designed to mitigate inlet-induced erosion along the ~5,100-ft-long north end shoreline reach through realignment of the NRI outer ebb channel to a more southerly orientation along the north end of NTB. Analysis of historical ebb channel alignments and corresponding shoreline positions indicates that maintenance of a southerly ebb channel alignment perpendicular to the north end shoreline will shift the ebb tidal delta to a southward configuration that in turn will promote shoreline accretion along the north end. The existing project encompasses construction and periodic maintenance of a 500-ft-wide, 3,450-ft-long, and -18 ft-deep NAVD design ebb channel extending seaward from the inlet throat across the ebb tidal delta (Figure 3-1). Maintenance dredging events are triggered by established quantitative thresholds, including channel shoaling that is ≥85 percent of the original dredged material volume and/or thalweg migration outside of the originally constructed 500-ft-wide channel. Based on estimated shoaling rates, the ebb channel is projected to require maintenance dredging every four years. Ebb channel maintenance events every four years are projected to yield ~627,000 cy of beach compatible dredged material for maintenance of beach fills along and adjacent shoreline reaches of the existing NTB Shoreline Protection Project. Based on morphological modeling (CPE 2010), the predicted reconfiguration of the ebb tidal delta and the resulting establishment of an accretional north end shoreline are expected to occur gradually over the course of multiple ebb channel maintenance events. CPE (2010) predicted full establishment of target shoreline conditions within 15 years of the initial realignment event, while noting that actual shoreline response times could not be predicted with a high degree of certainty. Initial construction of the design channel was completed during 2012/2013 in conjunction with the Phase 1 beach fill construction event. As previously described, the alignment of the design ebb channel was subsequently adjusted to improve project performance. The currently authorized "pivot channel" is simply the original channel rotated 17 degrees clockwise about its central axis (Figure 3-2). Under Alternative 1, the Town would implement the existing inlet management plan as currently authorized under the NTB Shoreline Protection Project.

3.1.1.2 Beach Nourishment

The existing NTB Shoreline Protection Project includes a +14-ft NAVD dune and +6-ft NAVD berm beach fill project along the Town's entire 11.1-mile oceanfront shoreline (Figure 3-3). The existing beach fill project is designed as an "engineered and maintained beach" in accordance with FEMA disaster assistance eligibility requirements. As defined by FEMA, engineered and maintained beaches are: "1) beaches that have been constructed to a designed elevation, width, and slope using imported sand of proper grain size and 2) beaches that are maintained on a scheduled basis through periodic renourishment with imported sand" [44 CFR §206.226(j)(2)]. The 5,100-ft north end shoreline is part of the Phase 1 beach fill project reach that was originally constructed during 2012/2013. The existing beach fill project, in combination with the inlet management plan, is designed to continuously maintain a minimum +6-ft flat berm width of ~57 ft on the north end under a four-year nourishment cycle. Construction beach fills incorporate additional advance fill volume and berm width to account for the redistribution of material during the post-construction beach profile equilibration process and losses of material to background erosion over the course of the interim four-year periods between recurring maintenance nourishment events. Each four-year maintenance nourishment is expected to require ~200,000 cy of beach fill. Based on a four-year nourishment cycle, Alternative 1 would require a total 30-year beach fill volume of ~1.5 mcy. Beach fill for maintenance nourishment events is derived from ebb channel maintenance dredging events. Ebb channel maintenance is conducted by cutterhead dredges with direct pumping of the dredged material via pipeline onto the north end shoreline and adjacent shoreline reaches of the existing NTB Shoreline Protection Project.

Onshore beach fill construction would employ methods that are currently authorized under the existing NTB Shoreline Protection Project. In the case of hydraulic pipeline beach fill delivery methods, temporary containment berms would be constructed at the beach discharge points to allow for dewatering and sediment redeposition. Bulldozers operating on the beach would distribute and grade the dewatered fill according to the beach profile design specifications. Front-end loaders would be used to transport and position emergent sections of the discharge pipeline on the beach. As nourishment activities progress, the emergent pipeline would be extended along the beach through the addition of extra sections of pipe.

In the case of truck haul delivery, dump trucks would deliver beach fill to a beachside stockpiling area. At the stockpiling area, the material would be reloaded onto off road trucks for transport to the active beach construction area. Existing public access points would provide beach access for off road trucks and construction equipment. The north end public access parking lot at NRI would serve as the construction staging and storage area for beach fill placement events.

3.1.1.3 USACE Beach Placement of Navigation Dredged Material

In addition to Town nourishment events, it is anticipated that continuing USACE beach placement of navigation dredged material from the AIWW NRI Crossing, Channels to Jacksonville, and Cedar Bush Cut would account for a portion of the required 30-yr volume. Although historically routine, USACE channel maintenance and associated north end beach placement events have more recently been infrequent and unpredictable due to limited federal funding. The most recent USACE north end placement events occurred during 2010, 2013, 2020, and 2023. USACE placement events have historically placed an average of ~75,000 cy of material on the north end shoreline [APTIM 2018 (National Beach Nourishment Database)]. Channel maintenance is conducted by cutterhead pipeline dredges that pump the material directly onto the north end shoreline via submerged and/or floating pipelines.

3.1.1.4 Sandbag Revetment Maintenance and Beach Bulldozing

Additional continuing beach management activities under Alternative 1 would include maintenance of the existing north end sandbag revetments and beach bulldozing by the Town and/or individual property owners. Pursuant to NC Coastal Management rules, sandbags and beach bulldozing are allowed as temporary measures to protect threatened structures. The use of sandbags is limited to imminently threatened structures that are within 20 feet of the MHW line. As previously described, sandbag revetments are currently protecting ~3,300 ft of the north end oceanfront shoreline and more than 40 structures that are threatened with erosional damage or destruction (Figure 3-4). Typical sandbag maintenance activities would include repairing and refilling damaged geotubes and/or replacing geotubes that are damaged beyond repair. Beach bulldozing is typically employed as a post-storm emergency measure to repair damage to primary dunes and berms. The Town currently has a CAMA Major Permit for beach bulldozing along its entire oceanfront shoreline, including Inlet Hazard Areas (IHAs) where a dune previously existed. Individual homeowners can request authorization from the Town to conduct beach bulldozing under the existing Major Permit. Furthermore, beach bulldozing to protect imminently threatened structures that are within 20 feet of the MHW line is exempt from the CAMA permitting process. NC Coastal Management rules limit beach bulldozing to the movement of sand between MLW and the first line of stable and natural vegetation.

3.1.1.5 Cost

Under Alternative 1, pivot channel maintenance dredging and concurrent north end nourishment events every four years would cost approximately $48,000,000 over the 30-year life of the project. Additional costs associated with continuing maintenance of the existing north end sandbag revetments would total approximately $5,000,000 over the 30-year life of the project. Based on projected shoreline changes under Alternative 1, 54 oceanfront properties and 783 individually-owned housing units are projected to be at risk over the next 30 years (see Section 1.1.8.1 in Appendix D). Based on current property values, lost property value could total $277,273,067 over the next 30 years. Based on the current municipal property tax rates, an additional $35,768,226 in tax revenue could be lost over 30 years. The total combined cost of inlet management, beach nourishment, and lost property value/tax revenue under Alternative 1 could be $366,041,293 over the next 30 years.

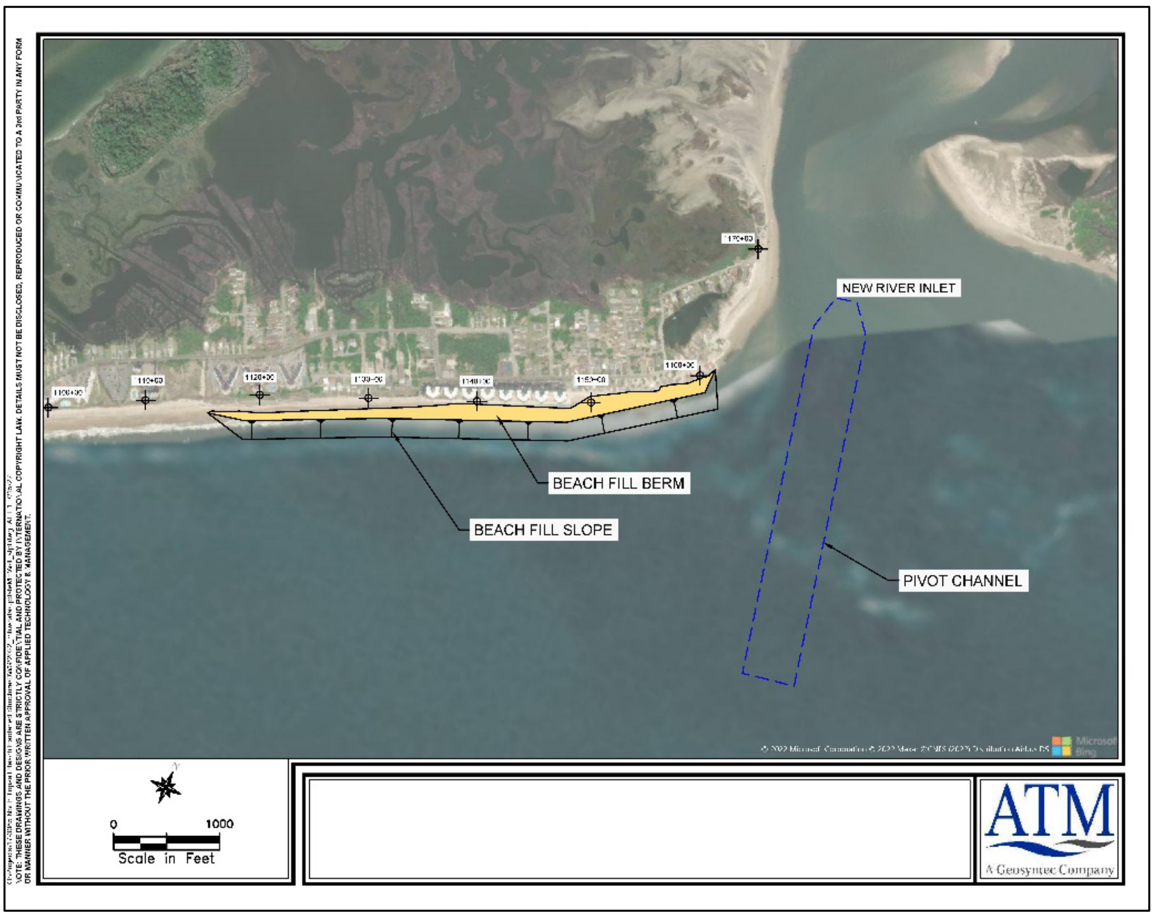


Figure 3-1. Alternative 1 Beach Fill and Pivot Channel Layout

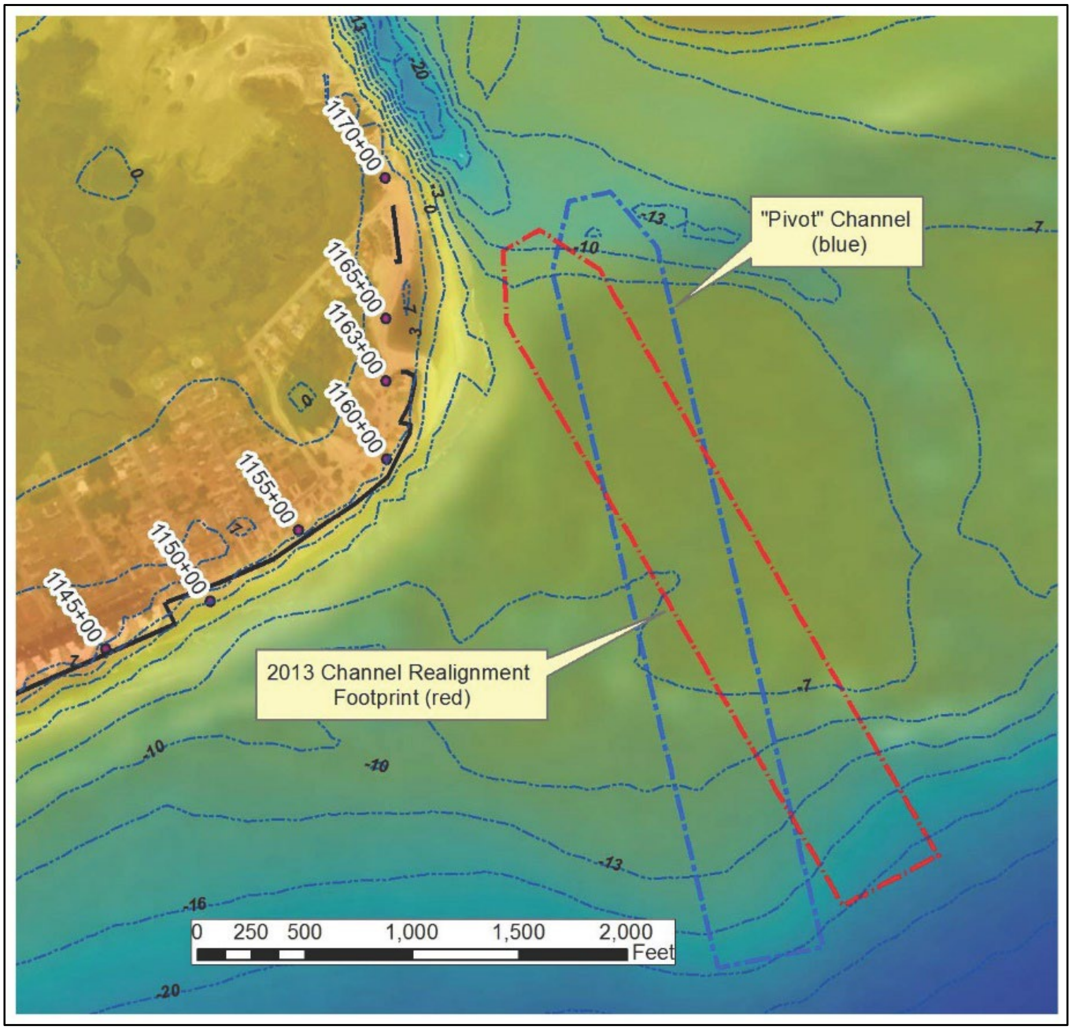


Figure 3-2. Currently Authorized Pivot Channel and 2013 Constructed Channel Alignments

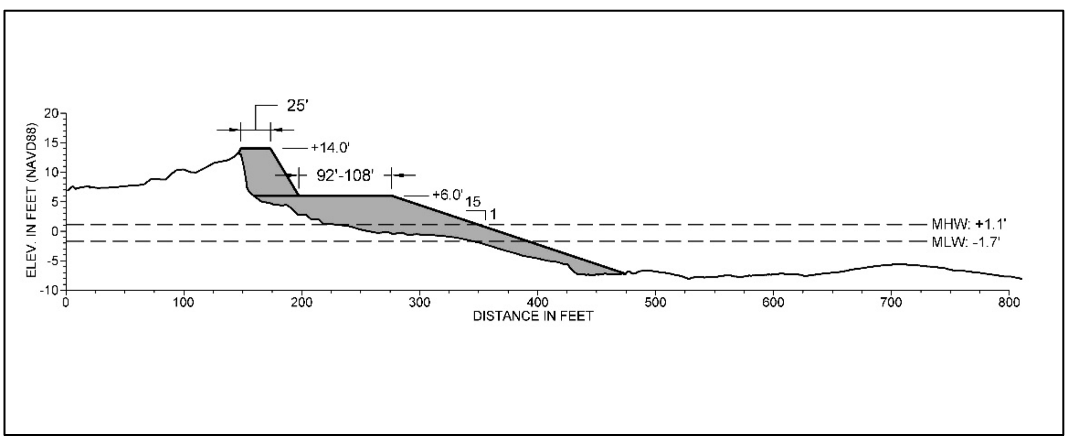


Figure 3-3. Alternative 1 Typical Beach Fill Profile

Figure 3-4. North Topsail Beach existing sandbag revetments

3.1.2 Alternative 2: Relocation and Abandonment

Under Alternative 2, no beach or inlet management activities that require USACE authorization would be undertaken to mitigate erosion along the 5,100-lf north end oceanfront shoreline. Specifically, there would be no beach fill placement on the north end, no management of the NRI outer ebb channel, and no construction of a terminal groin on the north end. Maintenance of the existing sandbag revetments is not subject to federal authorization; however, the current CAMA Major Permits that have allowed the revetments to remain in place for an extended period are contingent on continuing efforts by the Town to develop an effective long-term engineered shore protection project for the north end. In the absence of such efforts by the Town, it is assumed that removal of the existing sandbag revetments would be required upon expiration of the existing permits. Structures that become imminently threatened and have not been previously protected would be eligible for temporary sandbag permits, but not for permit extensions. Beach bulldozing below the MHW line is subject to USACE authorization and thus would not be a management option under Alternative 2. Bulldozing between the MHW line and the first line of stable and natural vegetation does not require USACE authorization and could potentially be performed by the Town and/or individuals. USACE beach placement of navigation dredged material on the north end, which is not subject to USACE regulatory authorizations, would be expected to continue. Although historically routine, USACE channel maintenance and associated north end beach placement events have more recently been infrequent and unpredictable due to limited federal funding. The most recent USACE north end placement events occurred during 2010, 2013, 2020, and 2023. USACE placement events have historically placed an average of ~75,000 cy of material on the north end shoreline [APTIM 2018 (National Beach Nourishment Database)]. Channel maintenance is conducted by cutterhead pipeline dredges that pump the material directly onto the north end shoreline via submerged and/or floating pipelines.

In the absence of federally authorized shore protection measures, oceanfront structures and infrastructure on the north end would eventually need to be relocated or demolished. The Town would coordinate with individual property owners in circumstances where a structure is damaged or threatened by erosion. However, the decision and responsibility to relocate or demolish a home would ultimately fall to the property owner, unless the structure is deemed a safety hazard to the public. Relocation would involve the detachment and transport of the structure to a new lot, and the demolition and transport of the existing foundation, driveway pavement, patio concrete, and other remaining exterior components to an appropriate landfill. In the case of demolition, heavy equipment would be used to take down the structures, and all material would be hauled to an appropriate landfill. In limited cases, the use of sandbags and/or beach bulldozing could delay structure relocations and demolitions, with the extent of the delay being dependent on site-specific erosion rates.

3.1.2.1 Cost

In the absence of federally authorized shore protection measures, no implementation costs would be incurred by the Town. Based on projected shoreline changes under Alternative 2, 152 oceanfront properties and 895 individually-owned housing units are projected to be at risk over the next 30 years (see Section 1.2.8.1 in Appendix D). Based on current property values, lost property value could total $371,216,529 over the next 30 years. Based on the current municipal property tax rates, an additional $47,886,932 in tax revenue could be lost over the next 30 years. The total combined cost associated with lost property value/tax revenue under Alternative 2 could be $419,103,461 over the next 30 years.

3.1.3 Alternative 3: Beach Nourishment

3.1.3.1 Beach Fill Design

Alternative 3 would maintain a 5,100-lf dune and berm beach fill on the north end through a two-year cycle of recurring nourishment events. Construction beach fills would consist of a +14-ft-high NAVD dune, a +6-ft-high NAVD variable width flat berm, and a seaward 15H:1V fill slope (Figure 3-5). The +14-ft dune would have a crest width of 25 feet, a landward slope of 3H:1V, and a seaward slope of 5H:1V. The +6-ft berm would extend 70 to 200 feet seaward of the dune toe, and the fill slope would extend ~200 feet seaward of the flat berm to a depth of -8 ft NAVD on the subtidal shoreface (Figure 3-6). Dune construction would be limited to shoreline reaches that do not have sandbag revetments. Currently, only the southernmost ~2,000-ft reach of the north end project shoreline is without sandbag revetments. Dune construction and/or augmentation would be undertaken as needed to reestablish a continuous +14-ft dune along eligible shoreline reaches. Depending on endpoint conditions at the time of nourishment events, the northern and southern ends of the construction beach fill would be tapered to tie into the existing shoreline. Repaired and/or restored dunes would be aligned with existing adjacent dune ridges.

The described dimensions of the construction beach fill are those of the dune and berm that would be reestablished by each maintenance nourishment event. The construction beach fill is designed to continuously maintain a minimum +6-ft flat berm width of 57 ft under a two-year nourishment cycle. The construction berm incorporates additional advance fill volume and width to account for the redistribution of material during the post-construction beach profile equilibration process and losses of material to background erosion over the course of the interim two-year periods between recurring maintenance nourishment events. Initial construction and each two-year nourishment event would require ~310,000 cy of beach fill, which would be placed on the north end project shoreline at linear unit fill densities ranging from ~20-100 cy/ft (avg = 61 cy/ft). Based on a two-year maintenance nourishment cycle, Alternative 3 would require a total 30-year beach fill volume of ~4.7 mcy.

3.1.3.2 Borrow Sites

Beach fill for Town nourishment events would be acquired from multiple sources including the Town's existing offshore borrow site, AIWW Disposal Area 143 (DA-143), and upland borrow sites. Additionally, it is anticipated that continuing USACE beach placement of navigation dredged material on the north end would account for a portion of the required 30-yr volume. The Town's existing inlet management plan would not be implemented, and thus would not constitute a potential source of beach fill under Alternative 3.

<u>Offshore Borrow Site</u>

The Town's currently authorized offshore borrow site is located approximately 0.4 to 1.6 miles offshore of the central NTB shoreline reach between baseline stations 780+00 to 870+00 (Figure 3-7). The original pre-construction analysis of composite grain size characteristics (Table 3-2) showed the offshore borrow site sediments to be native beach compatible in accordance with the NC Technical Standards for Beach Fill Projects (15A NCAC 07H.0312). The original estimated volume of compatible material at the offshore borrow area was ~6.55 mcy, including ~6.19 mcy of finer grained sand [composite mean grain size = 0.21 millimeters (mm)] and ~357,000 cy of coarser grained sand (composite mean grain size = 0.33 mm). Use of the offshore borrow site to date has been limited to the initial Phase 5 construction event during 2014/2015, which placed ~1.26 mcy of sand on the Phase 5 reach between Stations 767+00 and 581+00. Based on the

Phase 5 extraction volume, the estimated remaining volume of available material is 5.29 mcy (Table 3-3). During Phase 5 construction, previously undetected deposits of incompatible rocky material were extracted from the offshore borrow site and placed on the beach. Consequently, future use of the offshore borrow site will likely require additional geotechnical investigations to ensure avoidance of incompatible deposits. All future uses of the offshore borrow site for beach nourishment would employ effective measures to filter and remove oversized rock at the at the delivery pipe outfall. Beach fill extraction from the offshore borrow site would employ a hydraulic cutterhead pipeline dredge. Sand delivery would involve direct pumping from the borrow site to the north end shoreline via submerged or floating pipeline.

<u>DA-143 (AIWW Disposal Area 143)</u>

DA-143 is a 48-acre USACE upland confined disposal facility (CDF) located ~1.8 miles northwest of the north end oceanfront beach at the intersection of the AIWW NRI Crossing and Cedar Bush Cut navigation channels (Figure 3-8). DA-143 is an active CDF that is used by the USACE for the placement of dredged material from maintenance of the AIWW NRI Crossing and Channels to Jacksonville (including Cedar Bush Cut). The existing NTB Shoreline Protection Project, as originally authorized in 2010, included the use of DA-143 as a placement site for incompatible dredged material derived from initial construction/realignment of the NRI outer ebb channel. However, DA-143 was never used for this purpose, as the incompatible material was avoided during channel construction. DA-143 was subsequently evaluated as a potential supplemental borrow site for the existing NTB Shoreline Protection Project. Based on analysis of sediment cores collected in 2011, DA-143 contains an estimated 1.9 mcy of material that is native beach compatible in accordance with the NC Technical Standards for Beach Fill Projects (CPE 2013) (Tables 3-2 and 3-3).

Beach fill extraction from DA-143 would most likely involve pump-outs by a cutterhead dredge with direct pipeline delivery to the beach. This method would involve the creation of a water-filled pond within the disposal area that would allow for the extraction of sediment in slurry form. Figure 3-8 depicts the proposed dredge cuts from the original 2011 evaluation; however, the use of DA-143 under Alternative 3 would require additional geotechnical investigations and the development of an updated borrow site plan. Dredged material would be hydraulically pumped to the north end shoreline via a floating and/or submerged pipeline. The proposed delivery pipeline route would extend southwestward from DA-143 along the AIWW behind the north end of NTB (Figure 3-9). In order to avoid broad expanses of tidal marsh along the back-barrier side of the north end, the pipeline route would extend ~2.5 miles along the AIWW navigation channel before crossing over to the oceanfront beach. The 2.5-mile in-water route would consist of a 45-ft-wide pipeline corridor located adjacent to, but not within, the AIWW navigation channel. The pipeline would cross the island at Marina Way. After emerging onto the oceanfront beach, the pipeline would extend ~0.7-mile northeastward to the north end project reach.

<u>Upland Borrow Sites</u>

The Town identified several potential upland borrow sites for the recent FEMA Phase 5 sand replenishment project; including the ST Wooten Site (active mine), 421 Sand Mine (active mine), Wellman Site, and Haulsville Site. Sediment characteristics for the two active mines are provided in Table 3-2. The ST Wooten Site, an active sand mine located ~50 miles from the north end of NTB, was ultimately selected for the FEMA project. The Wellman and Haulsville sites are not active mines and would require vegetation clearing and removal of ~1 foot of organic topsoil (overburden). The identified sites are estimated to contain >2 mcy of compatible sand and can potentially be expanded to yield additional material. The transport of beach fill from upland borrow sites to the project beach would be accomplished by dump trucks. Beach fill would be unloaded at a beachside stockpiling area and subsequently reloaded onto off road trucks for transport to the active beach construction area. Existing public access points would provide beach access for off-road trucks and construction equipment.

USACE Beach Placement of Navigation Dredged Material

In addition to Town nourishment events using the above-described borrow sites, it is anticipated that continuing USACE beach placement of navigation dredged material from the AIWW NRI Crossing, Channels to Jacksonville, and Cedar Bush Cut would account for a portion of the required 30-yr volume. Although historically routine, USACE channel maintenance and associated north end beach placement events have more recently been infrequent and unpredictable due to limited federal funding. The most recent USACE north end placement events occurred during 2010, 2013, 2020 and 2023. USACE placement events have historically placed an average of ~75,000 cy of material on the north end shoreline [APTIM 2018 (National Beach Nourishment Database)]. Channel maintenance is conducted by cutterhead pipeline dredges that pump the material directly onto the north end shoreline via submerged and/or floating pipelines (Figure 3-10).

3.1.3.3 Beach Fill Construction

Onshore beach fill construction methods would be the same as those that are currently authorized under the existing NTB Shoreline Protection Project (see Section 3.1.1.2 for a detailed description of currently authorized construction methods).

3.1.3.4 Cost

Under Alternative 3, concurrent offshore borrow site dredging and north end nourishment events every two years would cost approximately $117,000,000 over the 30-year life of the project. Based on projected shoreline changes under Alternative 3, 54 oceanfront properties and 782 individually-owned housing units are projected to be at risk over the next 30 years (see Section 1.3.8.1 in Appendix D). Based on current property values, lost property value could total $277,853,131 over the next 30 years. Based on the current municipal property tax rates, an additional $35,843,054 in tax revenue could be lost over 30 years. The total combined cost of inlet offshore borrow site dredging, beach nourishment, and lost property value/tax revenue under Alternative 3 could be $430,696,185 over the next 30 years.

Figure 3-5. Alternative 3 Beach Fill Layout

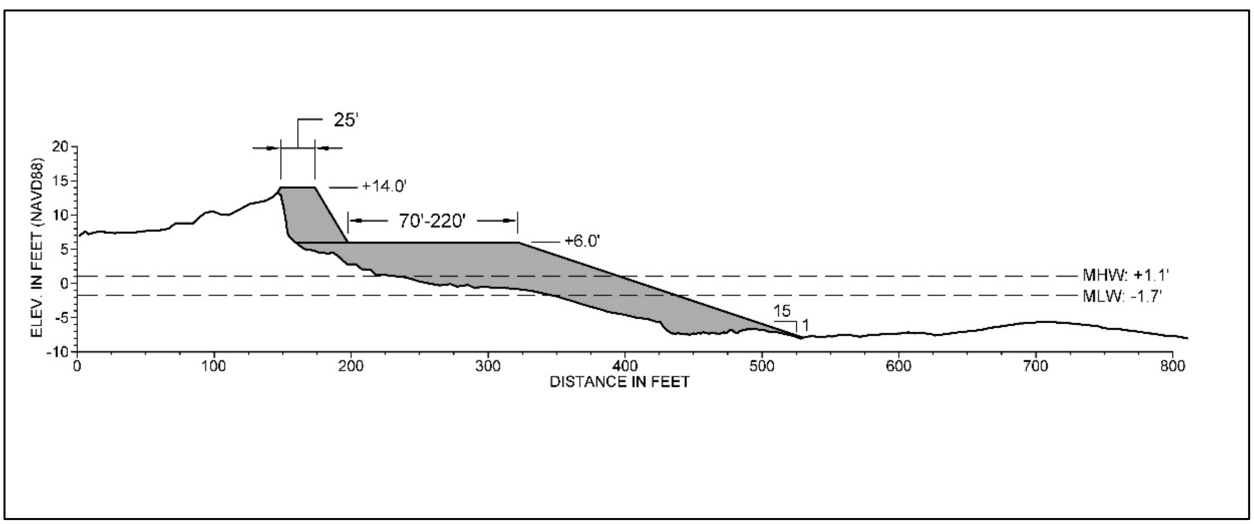
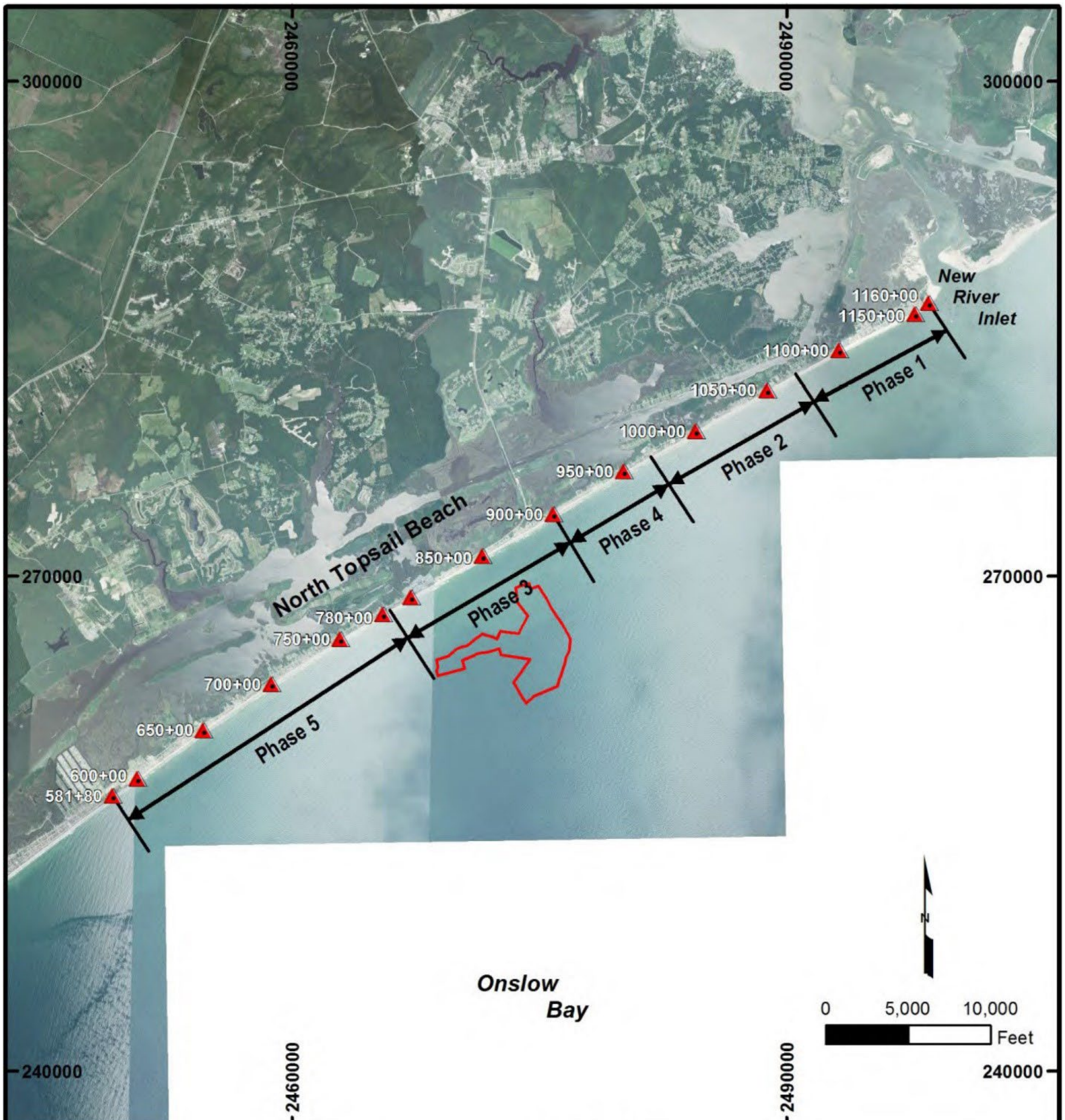


Figure 3-6. Alternative 3 Typical Beach Fill Profile



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2014 background imagery is the USDA's National Agricultural Imagery Program.

Legend:

Offshore Borrow Area

USACE Baseline Station

Figure 3-7. Existing offshore borrow site

Table 3-2. Alternative 3 Borrow Site Sediment Characteristics

Site	Mean Grain Size	Average Percent by Weight			
		Silt	Carbonate	Granular	Gravel
Native Beach (North End)	0.23	1.5	26	1.07	0.43
NC Beach Fill Standard (max)[1]	NA	6.5	41	11.07	5.43
Offshore Borrow Site (coarse)	0.33	1.75	20	0.63	0
Offshore Borrow Site (fine)	0.21	6.4	16	1.13	1.43
DA-143 (AIWW Disposal Area 143)	0.22	3.7	7	0.99	1.49
ST Wooten Upland Sand Mine	0.27	1.8	<1	0.3	0.1
421 Upland Sand Mine	0.41	0	0	1.1	0

[1] NC Technical Standards for Beach Fill Projects (15A NCAC 07H.0312)

Silt	Native Beach Avg % by Weight + 5 %
Carbonate	Native Beach Avg % by Weight + 15%
Granular	Native Beach Avg % by Weight + 10%
Gravel	Native Beach Avg % by Weight + 5 %

Table 3-3. Alternative 3 Borrow Site Volumetric Availability

Borrow Site	Volume Available (cy)	Reusable
Offshore Borrow Area	5,290,000	Potentially
DA-143 (AIWW Disposal Area 143)	1,900,000	No
Upland Borrow Areas	>2,000,000	Potentially expandable

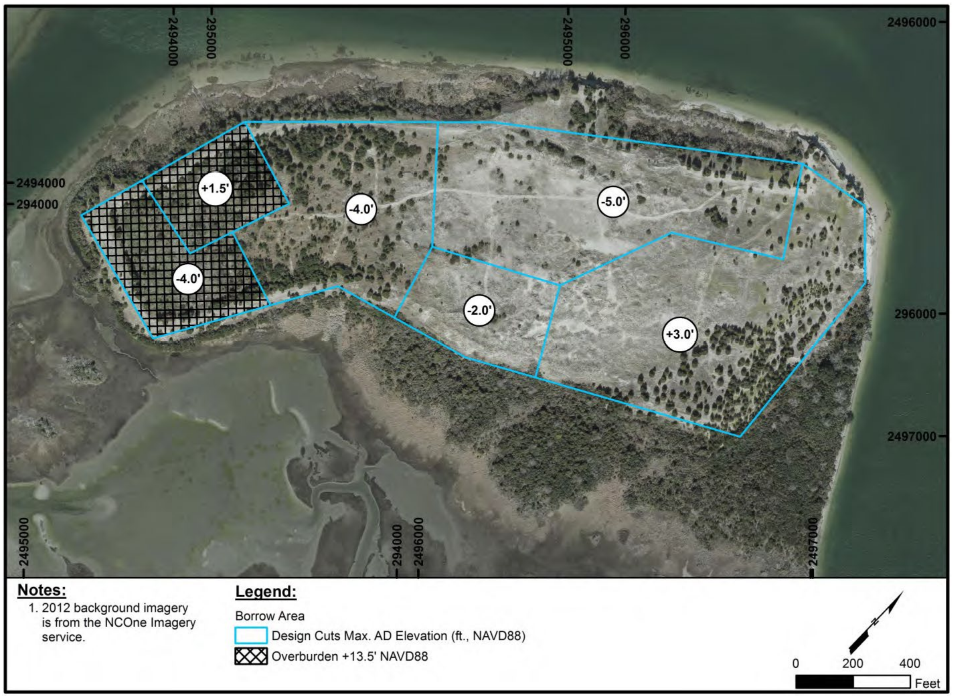


Figure 3-8. DA-143 Conceptual Dredge Cuts (CPE 2011)

Figure 3-9. DA-143 Pipeline Route for North End Beach Placement

Figure 3-10. USACE North Topsail Beach Placement Plan

3.1.4 Alternative 4: Terminal Groin and Beach Nourishment

Alternative 4 would maintain a 5,100-ft-long dune and berm beach fill on the north end through a four-year cycle of recurring nourishment events and the construction of a terminal groin on the north end shoreline at NRI. The purpose of the terminal groin would be to reduce inlet-induced erosion rates along the north end shoreline, thereby extending the protective life of constructed beach fills and reducing the frequency of required maintenance nourishment events. Numerical modeling was used to evaluate the effectiveness of various alternative groin designs in terms of model-predicted sediment volume changes along the north end shoreline. Details regarding the modeling analyses and the selection of the proposed terminal groin design are provided in the Engineering Report (Appendix B).

3.1.4.1 Terminal Groin Design and Construction

The proposed terminal groin would consist of a 2,021-ft-long sheet pile and rubble-mound structure with several distinct components; including a 345-ft-long sheet pile anchor section extending landward of the primary dune, an 894-ft-long sheet pile upland section extending seaward from the primary dune across the inlet/oceanfront dry beach, and a 782-ft-long rubble mound in-water section extending seaward of the MHW line (Figure 3-11). The anchor segment is designed to prevent flanking of the groin by landward inlet shoreline migration. The anchor design length and alignment account for historical north end shoreline positions while providing an additional buffer against potential future shoreline positions (Figure 3-12). The anchor and upland sheet pile groin sections would have maximum crest elevations of +5 feet NAVD that are slightly lower than the natural beach berm elevation of +6 ft NAVD. The low profile is designed to maintain pedestrian and vehicular beach access while minimizing sand trapping and allowing for sand overpassing throughout each nourishment cycle. To protect against undercutting, scour aprons consisting of buried armor stone would be installed along the inlet (north) side of the anchor section and both sides of the upland section (Figure 3-13). The in-water rubble-mound section, consisting of 4- to 6-ft-diameter granite armor stone, would have a crest elevation of +5 feet NAVD, a crest width of 5 feet, and a base width of ~40 feet (Figure 3-14). An additional 25-ft-wide armor stone scour apron would be installed along the inlet side of the in-water section. The use of large 4- to 6-ft-diameter armor stone would allow for construction of the groin to a design void ratio of 25 percent, thereby allowing sand to pass through the structure. To prevent settlement of the stone and, if necessary, to facilitate modification or removal of the groin and scour apron, a 1-ft-thick base layer of geo-textile matting would be installed below grade prior to armor stone placement. The geo-textile base layer underlying the groin and scour apron would have a total width of ~75 ft (Figure 3-14).

Conventional land-based heavy equipment would be used to construct both the onshore and in-water groin sections. Construction of the onshore (anchor and upland) sections would involve excavating the groin footprint, installing sheet pile and armor stone scour aprons to design specifications, covering the completed structure with the original excavated material, and grading the work area to reestablish pre-construction beach profiles. Depending on the position of the shoreline, construction of the in-water groin section may require work from a temporary trestle or an embankment built out from the shoreline using existing beach material. If an embankment is required, the placed material would be incorporated into the groin fillet. It is anticipated that all of the stone for groin construction would be hauled in by trucks from the quarry site. Once the structure is in place, beach fill material would be placed southward of the terminal groin to construct the north end beach fill and groin fillet. Details regarding the groin fillet are provided below.

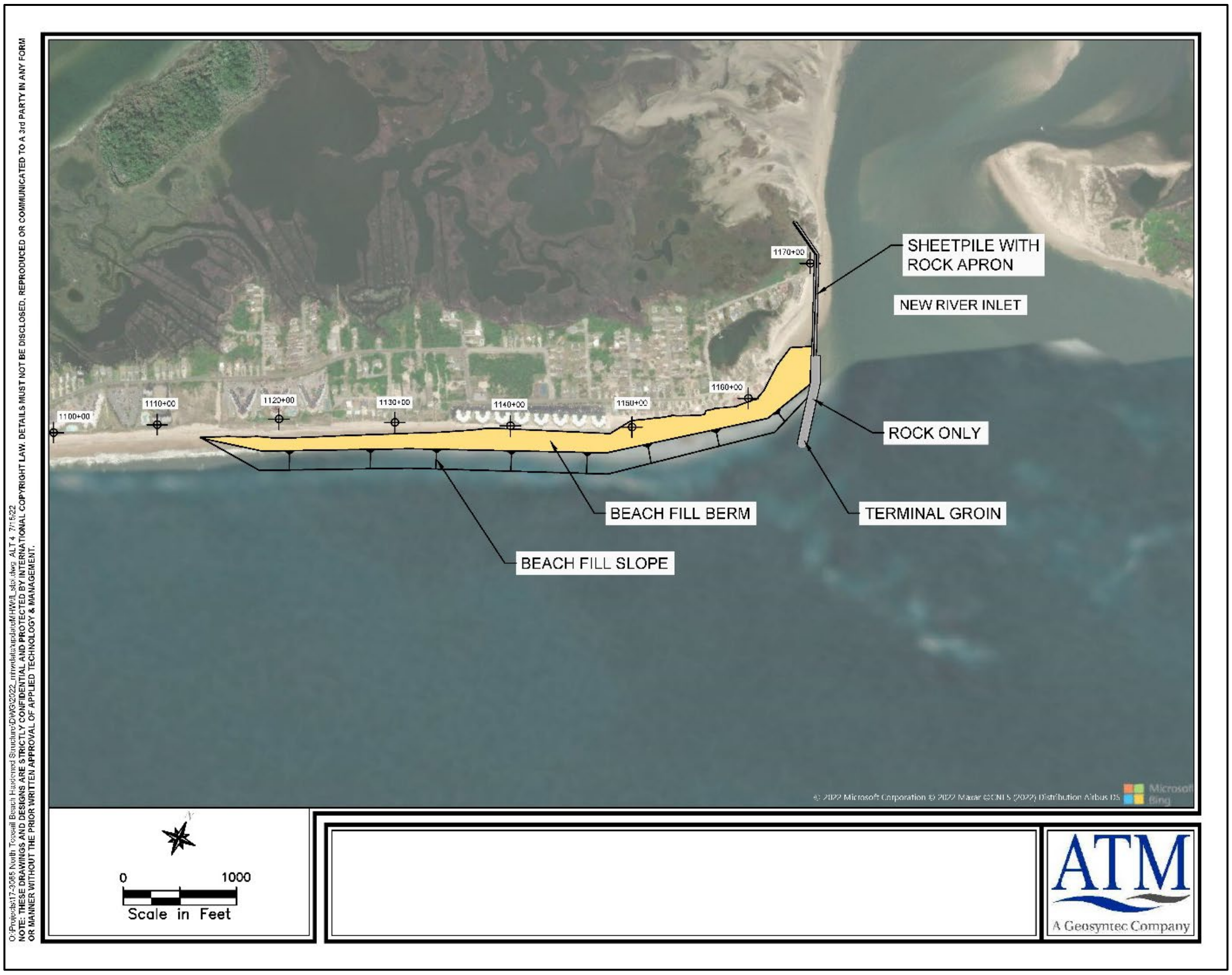


Figure 3-11. Alternative 4 Terminal Groin and Beach Fill Layout

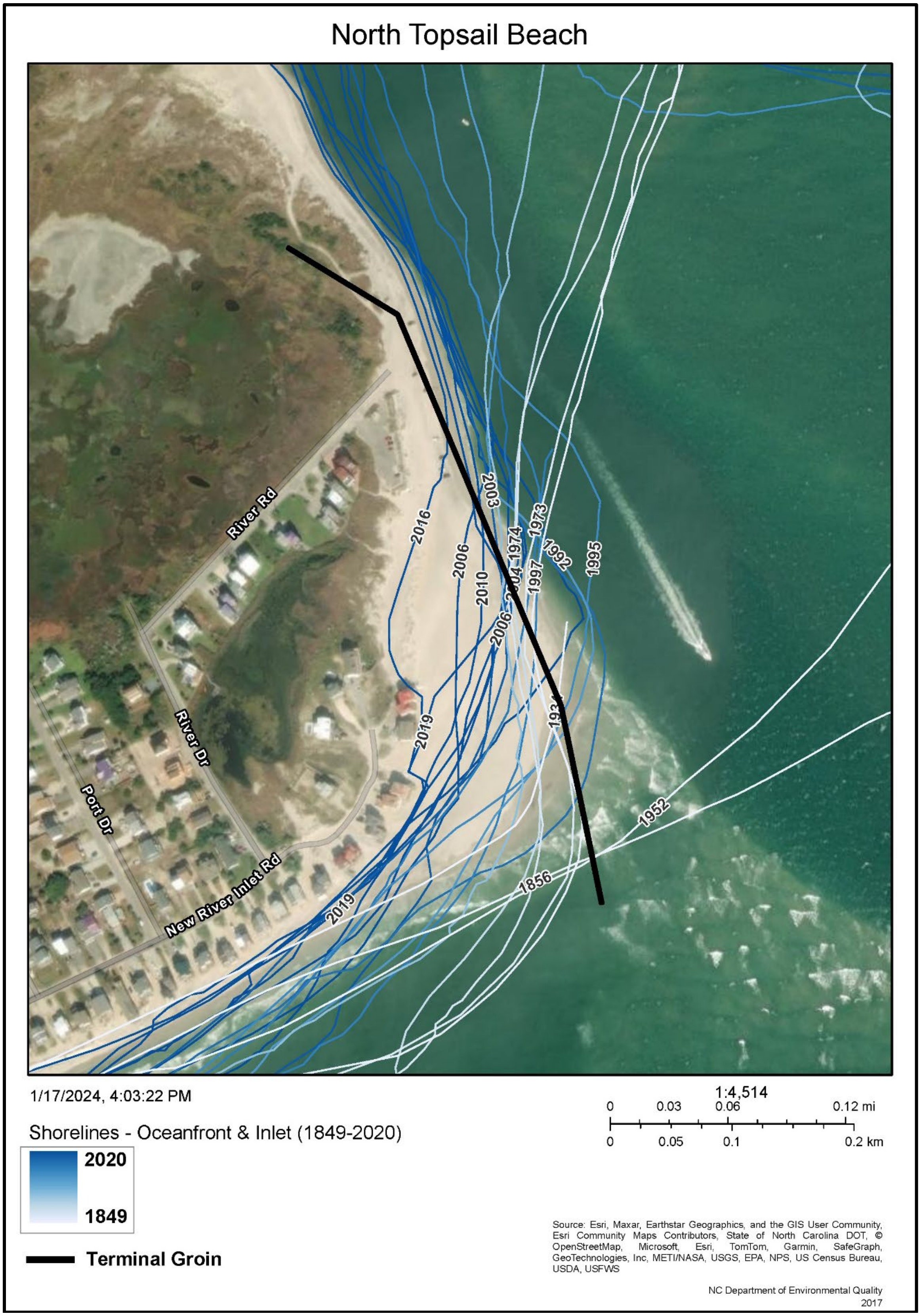


Figure 3-12. Proposed Terminal Groin in Relation to Historical Shorelines

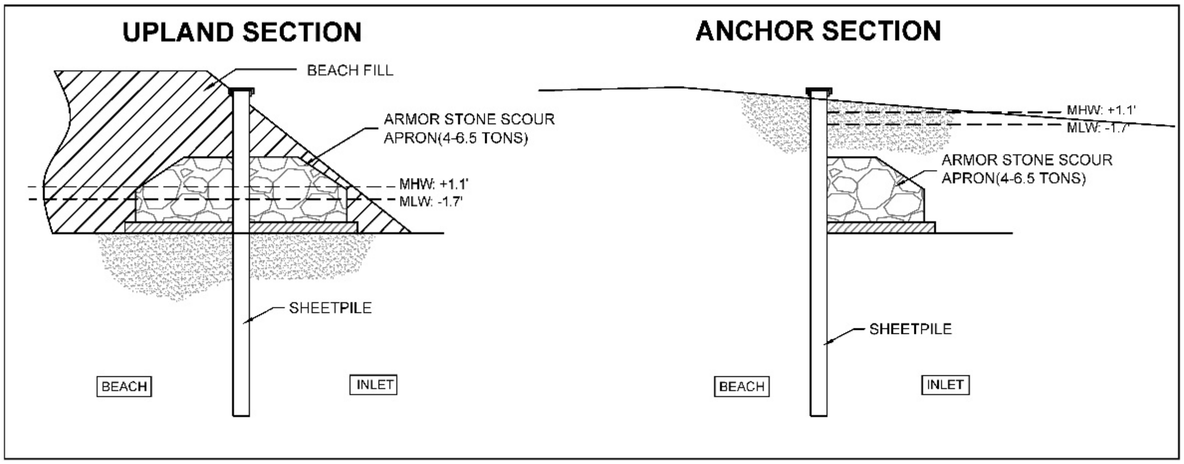


Figure 3-13.Terminal Groin Anchor and Upland Cross Sections

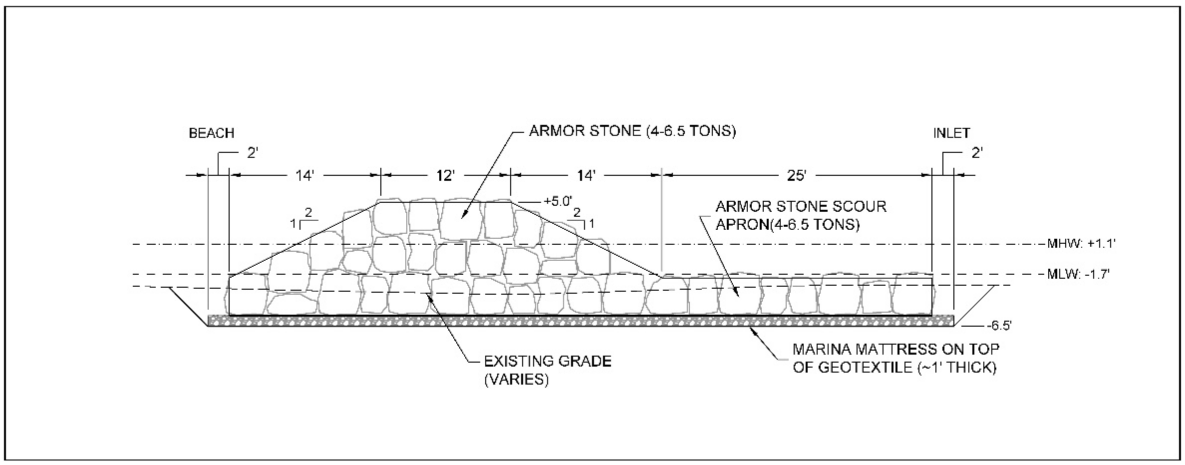


Figure 3-14. Terminal Groin In-water Cross Section

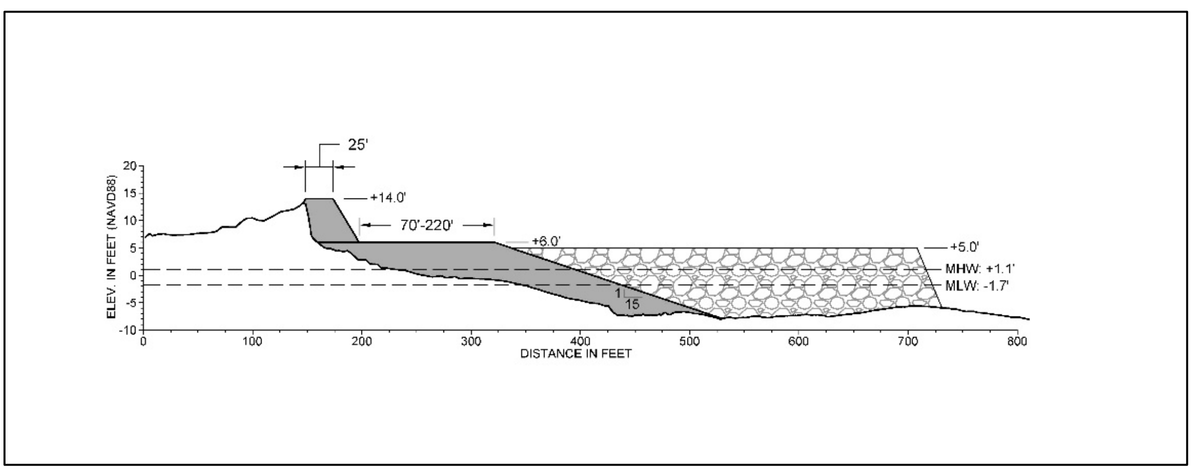


Figure 3-15. Alternative 4 Terminal Groin and Beach Fill Profile.

3.1.4.2 Beach Fill Design and Construction

Construction beach fills would consist of a +14-ft-high NAVD dune, a +6-ft-high NAVD variable width flat berm, a 2,000 ft-long triangular groin fillet, and a seaward 15H:1V fill slope (Figures 3-11 and 3-15). The +14-ft dune would have a crest width of 25 feet, a landward slope of 3H:1V, and a seaward slope of 5H:1V(Figure 3-15). The main +6-ft berm would extend 70 to 220 feet seaward of the dune toe. The groin fillet would consist of a tapered fill section extending 2,000 feet south from the groin along the seaward margin of the +6-ft berm. The fillet would have a maximum width at the groin where it would extend to the seaward end of the structure. The fillet would be tapered to the south, eventually tying into the +6-ft berm. The outer fill slope would extend seaward of the berm/fillet to a depth of -8 ft NAVD on the subtidal shoreface. Dune construction and/or augmentation would be undertaken as needed to reestablish a continuous +14-ft dune. Depending on endpoint conditions at the time of nourishment events, the southern end of the main construction beach fill would be tapered to tie into the existing shoreline.

The described dimensions of the construction beach fill are those of the dune, berm, fillet, and fill slope that would be reestablished by each maintenance nourishment event. The construction beach fill, in combination with the terminal groin, is designed to continuously maintain a minimum +6-ft flat berm width of 57 ft under a four-year nourishment cycle. Maintenance of the minimum width would allow for removal of the existing north end sandbag revetments. The main construction beach fill (exclusive of the fillet) incorporates additional advance fill volume and berm width to account for the redistribution of material during the post-construction beach profile equilibration process and losses of material to background erosion over the course of the interim four-year periods between recurring maintenance nourishment events. The groin fillet provides additional fill volume that is necessary to facilitate immediate sand bypassing around the groin structure, thereby minimizing the potential for adverse downdrift effects on adjacent shorelines. Initial construction and each four-year maintenance nourishment event would require ~310,000 cy of beach fill. Based on a four-year nourishment cycle, Alternative 4 would require a total 30-year beach fill volume of ~2.35 mcy.

Sources of beach fill and associated extraction and delivery methods would be the same as those previously described under Alternative 3. Beach fill for Town nourishment events would be acquired from the existing NTB offshore borrow site, DA-143, and/or upland borrow sites; with additional material from USACE, beach placement accounting for a portion of the required 30-yr volume. See the description of Alternative 3 for detailed information on the proposed borrow areas; including location, sediment compatibility, volumetric availability, and extraction and delivery methods. Onshore beach fill construction methods would be the same as those that are currently authorized under the existing NTB Shoreline Protection Project (see Section 3.1.1.2 for a detailed description of currently authorized construction methods).

3.1.4.3 Cost

Under Alternative 4, concurrent offshore borrow site dredging and north end nourishment events every four years would cost approximately $67,000,000 over the 30-year life of the project. Construction and maintenance of the terminal groin would cost approximately $18,000,000 over the 30-year life of the project. Based on projected shoreline changes under Alternative 4, 38 oceanfront properties and 767 individually-owned housing units are projected to be at risk over the next 30 years (see Section 1.4.8.1 in Appendix D). Based on current property values, lost property value could total $268,149,474 over the next 30 years. Based on the current municipal property tax rates, an additional $34,591,282 in tax revenue could be lost over 30 years. The total combined cost of inlet offshore borrow site dredging, beach nourishment, and lost property value/tax revenue under Alternative 4 could be $387,740,756 over the next 30 years.

3.1.5 Alternative 5: Beach Nourishment, Inlet Management, and Terminal Groin

Alternative 5 would maintain a 5,100-ft-long dune and berm beach fill on the north end through a regular cycle of recurring nourishment events, continuation of the Town's currently authorized inlet management plan, and construction of a terminal groin on the north end shoreline at NRI. The purpose of both inlet management and the terminal groin would be to reduce inlet-induced erosion rates along the north end shoreline, thereby extending the protective life of constructed beach fills and reducing the frequency of required maintenance nourishment events.

3.1.5.1 Inlet Management Plan

Alternative 5 would implement the existing inlet management plan in accordance with the currently authorized NTB Shoreline Protection Project. The existing inlet management plan is designed to mitigate inlet-induced erosion along the 5,100-ft north end shoreline reach through realignment of the NRI outer ebb channel to a southerly position along the north end of NTB. Analyses of historical ebb channel alignments and corresponding shoreline positions indicate that maintenance of a southerly ebb channel alignment perpendicular to the north end shoreline will shift the ebb tidal delta to a southward configuration that in turn will promote shoreline accretion along the north end. The existing project encompasses construction and periodic maintenance of a 500-ft-wide, 3,450-ft-long, and -18 ft-deep NAVD design ebb channel extending seaward from the inlet throat across the ebb tidal delta (Figure 3-16). Maintenance dredging events are triggered by established quantitative thresholds, including channel shoaling that is ≥85 percent of the original dredged material volume and/or thalweg migration outside of the originally constructed 500-ft-wide channel. Based on estimated shoaling rates, the ebb channel is projected to require maintenance dredging every four years. The predicted shift in the ebb tidal delta and the resulting establishment of an accretional north end shoreline are expected to occur gradually over the course of multiple ebb channel maintenance events. CPE (2010) predicted full establishment of target shoreline conditions within 15 years of the initial realignment event, while noting that actual shoreline response times could not be predicted with a high degree of certainty. Initial construction of the design channel was completed during 2012/2013 in conjunction with the Phase 1 beach fill construction event. As previously described, the alignment of the design ebb channel was subsequently adjusted to improve project performance. The currently authorized "pivot channel" is simply the original channel rotated 17 degrees clockwise about its central axis. Maintenance events every four years are predicted to yield ~627,000 cy of beach compatible dredged material for maintenance of beach fills along the north end and adjacent shoreline reaches of the existing NTB Shoreline Protection Project. Ebb channel maintenance would be conducted by cutterhead dredges with direct pumping of the dredged material via pipeline onto the north end shoreline reach.

3.1.5.2 Terminal Groin Design and Construction

Alternative 5 would employ the same terminal groin design and construction methods that were described under Alternative 4. As previously described under Alternative 4, the groin would consist of a 2,021-ft-long structure with a 345-ft-long sheet pile anchor section extending landward of the primary dune, an 894-ft-long sheet pile upland section extending seaward from the primary dune across the inlet/oceanfront dry beach, and a 782-ft-long rubble mound in-water section extending seaward of the MHW line (Figures 3-11 through 3-15).

3.1.5.3 Beach Fill Design and Construction

Construction beach fills under Alternative 5 would be the same those described under Alternative 4. As previously described under Alternative 4, constructed beach fills would include a +14-ft-high NAVD dune, a +6-ft-high NAVD variable width flat berm, a 2,000 ft-long triangular groin fillet, and a seaward 15H:1V fill slope (Figure 3-1). The described dimensions of the construction beach fill are those of the dune, berm, fillet, and fill slope that would be reestablished by each maintenance nourishment event. The construction beach fill, in combination with the terminal groin and inlet management, is designed to continuously maintain a minimum +6-ft-high flat berm width of 57 ft under a four-year nourishment cycle. Maintenance of the minimum width would allow for removal of the existing north end sandbag revetments. The main construction beach fill (exclusive of the fillet) incorporates additional advance fill volume and berm width to account for the redistribution of material during the post-construction beach profile equilibration process and losses of material to background erosion over the course of the interim four-year periods between recurring maintenance nourishment events. The terminal groin is expected to have an immediate mitigating effect on north end shoreline erosion that would account for short term erosion rate increases that may result from implementation of the inlet management plan. Over the long-term, the combined mitigating effects of the terminal groin and inlet management may allow for continuous maintenance of a berm width greater than 57 feet, thereby increasing the level of protection for north end structures and infrastructure. Initial construction and each four-year maintenance nourishment event would require ~310,000 cy of beach fill. Based on a four-year nourishment cycle, Alternative 5 would require a total 30-year beach fill volume of ~2.35 mcy.

Beach fill for Town nourishment events would be derived from ebb channel maintenance dredging events. As described above, ebb channel maintenance events every four years are projected to yield ~627,000 cy of beach compatible dredged material. Approximately 310,000 cy of material would be used to construct the north end beach fill and groin fillet, with the balance of the material being placed on the south-adjacent Phase 1 through 4 shoreline reaches in accordance with the currently authorized NTB Shoreline Protection Project. Ebb channel sediment characterization via analysis of sediment cores would be a prerequisite for each ebb channel maintenance event. Previous analyses of sediment cores from the 2012/2013 construction channel (2003, 2006, 2008 data) and the adjusted pivot channel (2016 data) have demonstrated native beach sediment compatibility in accordance with the NC Technical Standards for Beach Fill Projects (Table 3-4). In addition to ebb channel maintenance events, it is anticipated that continuing USACE beach placement of navigation dredged material on the north end would account for a portion of the required 30-year volume. Although ebb channel maintenance dredging events are expected to satisfy the entire 30-year volumetric requirement, Alternative 5 would include the use of additional supplemental beach fill sources in the event that ebb channel maintenance thresholds (shoaling and/or thalweg migration) have not been met by the end of a four-year nourishment cycle. Supplemental sources would include the existing offshore borrow site, DA-143, and/or upland sand mines. Operations associated with the use of these supplemental sources would be the same as those previously described for Alternatives 3 and 4.

3.1.5.4 Cost

Under Alternative 5, concurrent pivot channel maintenance dredging and north end nourishment events every four years would cost approximately $58,000,000 over the 30-year life of the project. Construction and maintenance of the terminal groin would cost approximately $18,000,000 over the 30-year life of the project. Based on projected shoreline changes under Alternative 5, 48 oceanfront properties and 779 individually-owned housing units are projected to be at risk over the next 30 years (see Section 1.5.8.1 in Appendix D). Based on current property values, lost property value could total $275,179,326 over the next 30 years. Based on the current municipal property tax rates, an additional $35,498,133 in tax revenue could be lost over 30 years. The total combined cost of inlet offshore borrow site dredging, beach nourishment, and lost property value/tax revenue under Alternative 5 could be $386,677,459 over the next 30 years.

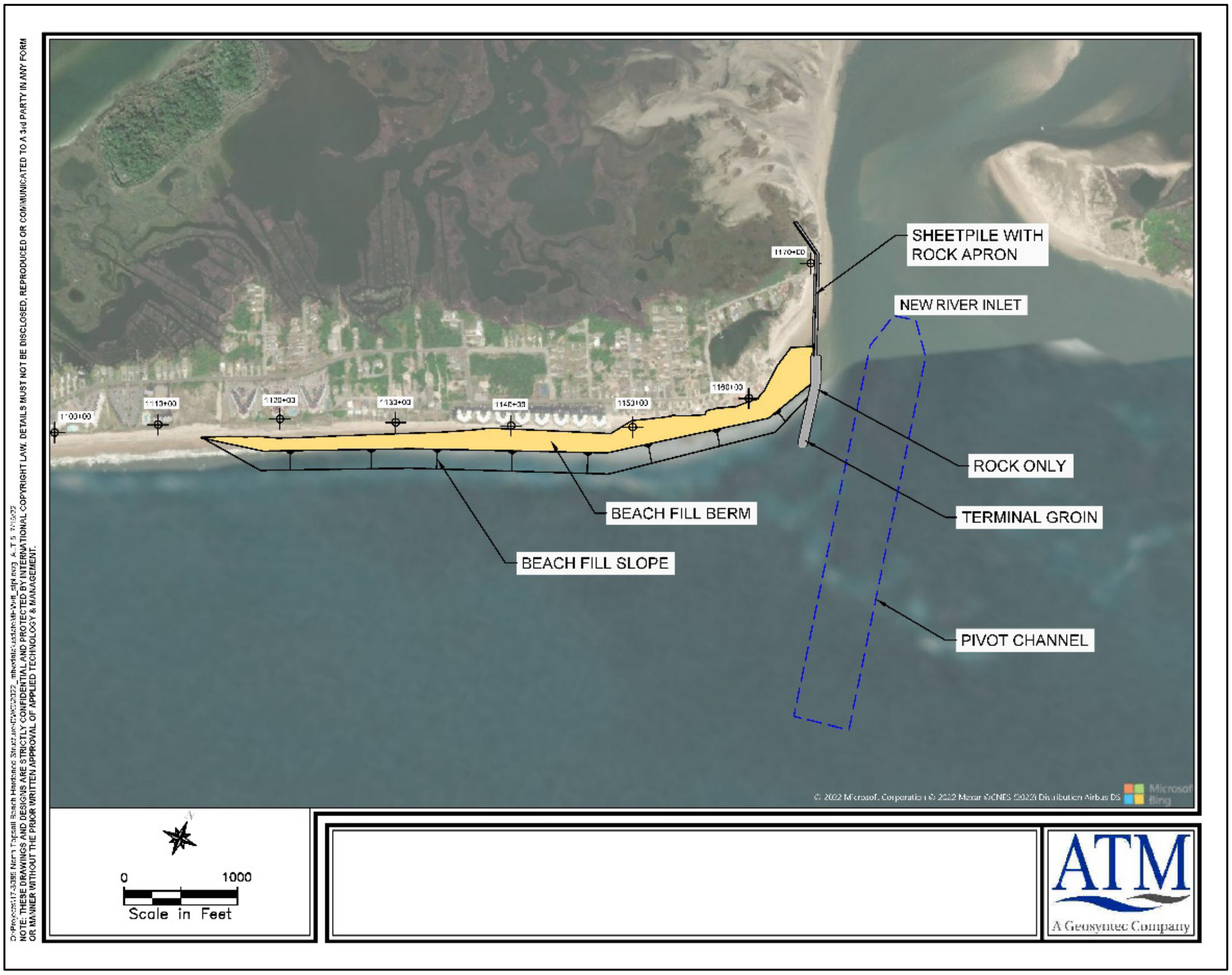


Figure 3-16. Alternative 5 Beach Fill, Terminal Groin, and Pivot Channel Layout

Table 3-4. Pivot channel sediment characteristics

Site	Mean Grain Size	Average Percent by Weight			
		Silt	Carbonate	Granular	Gravel
Native Beach (North End)	0.23	1.5	26	1.07	0.43
NC Beach Fill Standard (max)[1]	NA	6.5	41	11.07	5.43
2012/2013 Outer Ebb Channel[2]	0.39	1.53	22	5.38	3.64
Pivot Channel[3]	0.51	1.02	27	7.29	7.85

[1] NC Technical Standards for Beach Fill Projects (15A NCAC 07H.0312)

Silt	Native Beach Avg % by Weight + 5 %	Carbonate	Native Beach Avg % by Weight + 15%
Granular	Native Beach Avg % by Weight + 10%	Gravel	Native Beach Avg % by Weight + 5 %

[2]Composite data for sediment cores collected in 2003, 2006, and 2008 (CPE 2010)

[3] Composite data for 10 sediment cores collected in 2016 (CPE 2016)

3.1.6 Alternatives Eliminated from Detailed Analysis

3.1.6.1 Jetties

During the scoping process, representatives of the Town and Onslow County as well as commercial and recreational fishermen expressed interest in exploring the construction of a jetty system at NRI for purposes of both shore protection and maintenance of inlet navigability. A conceptual jetty system consisting of two 3,000-ft-long jetties extending out to a depth of -10 feet NAVD was considered. However, the jetty system would block the majority of natural sediment bypassing across NRI, likely resulting in adverse downdrift erosional effects on adjacent shorelines. Furthermore, the estimated cost of such a jetty system was high at $20 to $25 million, and jetties are prohibited by current NC Coastal Management rules. Based on these factors, it was determined that a jetty system was neither technically nor economically feasible.

3.1.6.2 Inlet Relocation

An inlet relocation project similar to one that successfully relocated Mason Inlet in New Hanover County was considered as a potential alternative. A conceptual inlet relocation project would involve excavating a new 500-ft-wide inlet through Onslow Beach and placing the excavated material in the existing inlet to close it. However, the estimated cost was high at $10 to $15 million, and the excavation of a new channel through Onslow Beach was considered to have substantial impacts on coastal resources and military training capabilities at Camp Lejeune. Therefore, it was determined that inlet relocation was neither economically nor technically feasible.

3.1.6.3 Nearshore Berm

Nearshore berms can potentially function as a source of sand for eroding beaches and provide a limited measure of storm protection to oceanfront property through wave energy attenuation. Berm construction entails the placement of material in shallow water just off the beach to create a nearshore sand feature that functions in the same manner as a natural sandbar. Dredging technology allows for berm construction in water depths as shallow as 15 feet, and the dissipation of waves as they pass over the berm during normal water levels could provide some mitigation of background shoreline erosion. However, during storm events when water levels are elevated, storm waves would pass over the berm, erode the beach, and present a threat to upland property. The volumetric extent of sand that would potentially be transferred from the berm to the beach would be insufficient to maintain a functional protective berm. Based on these considerations, it was determined that nearshore berm construction was not technically feasible.

4.0 AFFECTED ENVIRONMENT

4.1 Environmental Setting

The study area encompasses NRI and the adjacent barrier island reaches that are influenced by inlet processes; specifically, the ~1.5-mile-long north end reach of Topsail Island (1090+00 to 1170+00) and the ~1.0-mile-long south end reach of Onslow Beach (0+00 to 60+00) (Figure 4-1). Topsail Island and Onslow Beach are southwest-northeast trending barrier islands that face the Atlantic Ocean to the southeast and are backed to the northwest by shallow lagoonal estuaries. The islands are separated by NRI, which drains the New River and connects the back-barrier lagoonal estuaries with the Atlantic Ocean. Topsail Island is a 22-mile-long developed barrier island that is divided from north to south among the residential/resort communities of NTB, Surf City, and Topsail Beach. Onslow Beach is a 7.5-mile-long, primarily undeveloped barrier island that is part of Marine Corps Base Camp Lejeune. The south end study area reach of Onslow Beach is managed primarily for conservation, but also supports low-impact, non-mechanized training operations and seasonal recreational off-road vehicle use.

The north end study area reach of Topsail Island is low and narrow with elevations <10 ft MSL and a subaerial (above MHW) width of ~600 to 1,200 ft. The oceanfront shoreline is generally comprised of a narrow upland beach berm and a single discontinuous line of low constructed foredunes; however, the northernmost oceanfront shoreline reach within ~3,300 feet of NRI lacks frontal dunes and is currently armored by a continuous sandbag revetment. The subaerial island between the oceanfront and back-barrier estuarine shorelines has largely been developed for residential use. Development has largely displaced the island's natural upland maritime vegetation, although small fragmented areas of natural maritime shrub vegetation are scattered throughout the developed areas and along the back-barrier estuarine shoreline. The back-barrier estuary behind the north end encompasses an expansive tidal salt marsh complex that extends northwest to the AIWW. The south end of Onslow Beach is morphologically similar to the north end of Topsail Island, with elevations ≤10 ft MSL and subaerial island widths ranging from ~100 to 1,000 ft. The oceanfront beach is backed by expansive overwash fans and fields of small isolated dunes that extend to the back-barrier estuary. Vegetation of the subaerial island is characterized by a typical ocean-to-sound sequence of maritime plant communities, including dune grass, maritime grassland, and maritime shrub (Figure 4-1). Similar to the north end of Topsail Island, the back-barrier estuary behind Onslow Beach encompasses an expansive tidal salt marsh complex that extends north to the AIWW.

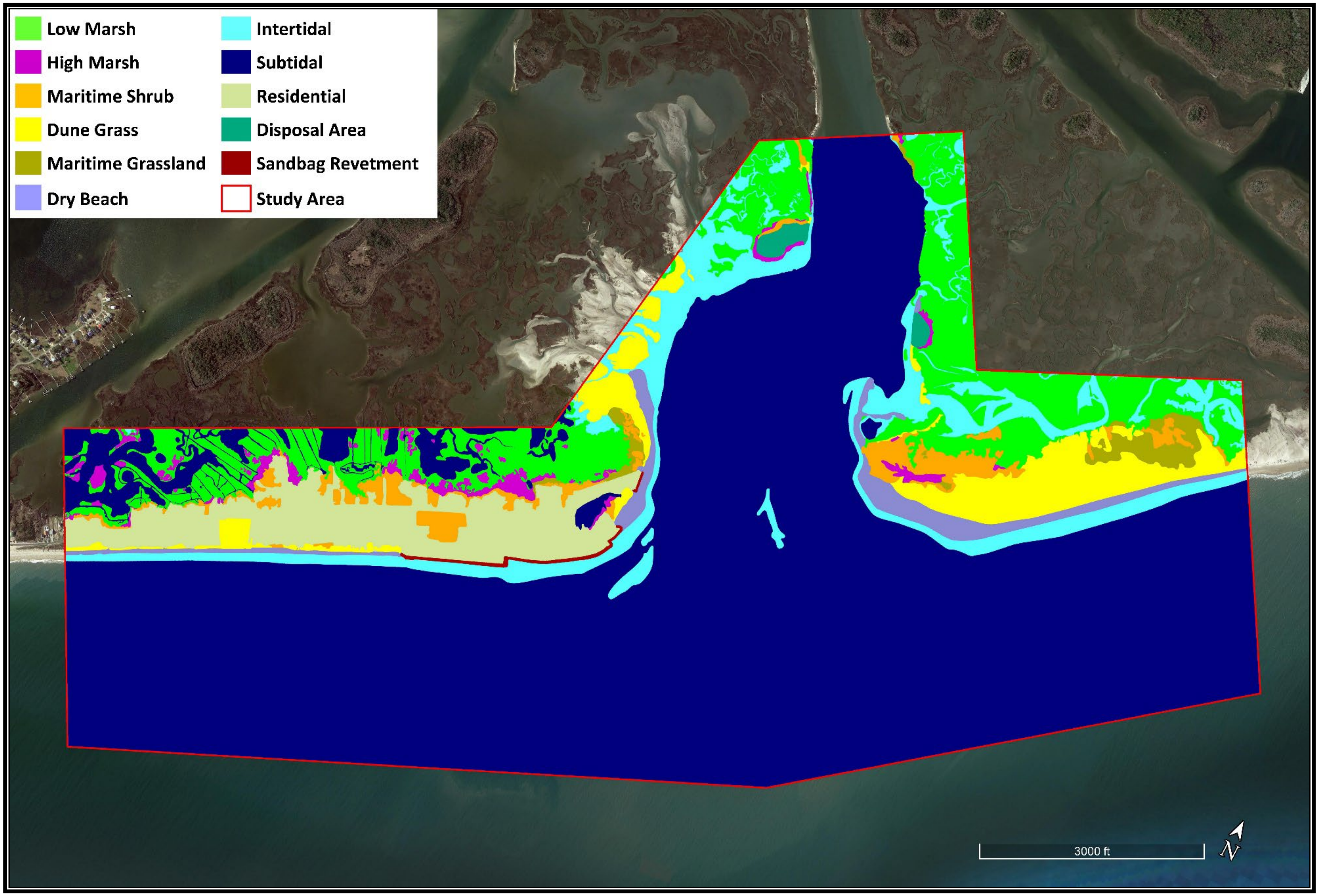


Figure 4-1. Study Area Biotic Communities

4.2 Geology, Geomorphology, and Sediments

The barrier island system along the southern NC coast is maintained by a very limited supply of new sediment, resulting in characteristically thin subaerial barriers that are perched on top of older geologic units (Riggs et al. 1995). The underlying geologic strata comprise the subtidal shoreface and dominate the associated shoreface processes that in large part control the dynamics and physical characteristics of the barriers, inlets, and back-barrier estuaries. The study area is underlain by a submarine, seaward-protruding limestone unit of Oligocene age (HDR 2003). The platform-like limestone formation extends seaward from the estuary beneath the barriers and crops out on the subtidal shoreface. The outcrops comprise low to high relief scarps and intervening flat hardbottoms that dominate the shoreface. The majority of the limestone outcrops are flat, low-relief features; however, high relief scarps are associated with the ancestral New River channel seaward of the NRI ebb tidal delta. The high relief scarps are remnants of calcareous sandstone channel fill sequences that are more resistant to erosion than the surrounding limestone formation (HDR 2003). A patchy and very thin (<4 inches) veneer of sediment occurs across the Oligocene limestone that crops out over the majority of the study area shoreface. The surface sediment layer is easily reworked and redistributed during storms exposing low relief scarps and flat hardbottoms. Accumulations of unconsolidated sediments are generally confined to linear, shore-normal, shallow depressions on the limestone platform that have been interpreted as remnant channels or dissolution features. The channel-like features contain thin (<3 ft) sediment layers consisting of 88% sand and 12% gravel (Johnston 1998).

Sediment mobilization and transport on the shoreface are driven primarily by waves and wave-generated currents. Significant sediment mobilization under fair-weather conditions is largely confined to the upper shoreface where seafloor sediments are agitated by onshore waves. Significant sediment mobilization on the lower shoreface is driven by high-energy storms (i.e., hurricanes and nor'easters) (Marshall 2004). The seaward extent of significant fair-weather sediment mobilization along the study area barriers occurs at a depth of ~30 ft (HDR 2003). Sediments mobilized on the shoreface are picked up by wave-generated longshore currents and transported along the beach in a process known as longshore or littoral drift. The predominant direction of longshore sediment transport in the vicinity of the study area is to the southwest. Gross annual longshore sediment transport has been estimated to be ~819,000 cy/yr, with 522,000 cy (64%) directed to the southwest and 297,000 cy (36%) directed to the northeast (Jarrett 2009). Northeasterly transport is most common during the months of May through July when the predominant direction of wave approach is from the south.

Along the seaward margin of the inlet throat, longshore sediment transport is disrupted by outgoing (ebb) and ingoing (flood) tidal currents. Sediments that are reworked and deposited by the ebb tidal current form a large ebb tidal shoal (a.k.a. ebb tidal delta) along the seaward margin of the inlet throat that is estimated to contain up to 7 mcy of sediment. Conversely, sediments transported and deposited by flood tidal currents form an inshore flood tidal shoal along the landward margin of the inlet. At wave-dominated inlets such as NRI, the dominant mode of longshore sediment bypassing across the inlet is transport along the outer (seaward) periphery of the ebb tidal delta (Cleary 2014). Although longshore sediment transport is predominantly southwestward at a regional scale, wave refraction (i.e., bending) around the ebb tidal delta produces a localized reversal of the net transport direction to the northeast along the ~1-mile-long north end shoreline reach adjacent to the inlet. Relatively large volumes of sediment are transported northeastward along the north end shoreline and into the inlet where they are retained within the inlet flood shoal system and navigation channels. Erosional and accretional shoreline trends along the north end of Topsail Island and the south end of Onslow Beach are heavily influenced by ebb channel migration patterns and associated changes in ebb-tidal delta symmetry

(CPE 2009). The ebb tidal delta has a wave sheltering effect on the north end that varies according to the ebb channel alignment and ebb tidal delta configuration. Analyses of historical shoreline and inlet ebb tidal delta changes indicate that the north end shoreline has experienced periods of accretion when the outer ebb channel was aligned towards the southwest, whereas northeasterly ebb channel alignments have produced erosional conditions.

4.3 Marine Habitats and Communities

4.3.1 Marine Soft Bottom

Marine subtidal soft bottom habitats consisting of unconsolidated, unvegetated sediments support diverse assemblages of benthic invertebrate infauna (burrowing organisms that live within the sediment) and epifauna (organisms that live on the surface of the sediment). Along the southeastern NC coast, nearshore ocean soft bottom communities are dominated by deposit- and filter-feeding invertebrates; including polychaetes, bivalve mollusks, nematodes, amphipod crustaceans, echinoderms (sand dollars), and gastropods (snails) (Hague and Massa 2010, Posey and Alphin 2002, Peterson and Wells 2000, and Peterson et al. 1999). Soft bottom areas also provide important habitat for large, mobile decapod crustaceans (e.g., crabs and shrimp). Annual nearshore trawl surveys in Onslow Bay indicate that the large decapod assemblage is dominated by white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), and the iridescent swimming crab (*Portunus gibbesii*).

Soft bottom habitats and their associated benthic invertebrate communities comprise important habitat and food resources for demersal (bottom-dwelling) marine fishes. The Southeast Area Monitoring and Assessment Program (SEAMAP-SA) has conducted annual coastal trawl surveys for demersal fishes in Onslow Bay since 1986. Catches have been consistently dominated by sciaenid fish, many of which utilize estuaries during part of their life cycle (SEAMAP-SA 2000). Overall patterns of demersal fish abundance are strongly influenced by the abundance of spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*), which consistently dominate the catches. Other numerically important demersal fishes include Atlantic bumper (*Chloroscombrus chrysurus*), scup (*Stenotomus* sp.), pinfish (*Lagodon rhomboides*), star drum (*Stellifer lanceolatus*), banded drum (*Larimus fasciatus*), gray trout (*Cynoscion regalis*), silver seatrout (*C. nothus*), southern kingfish (*Menticirrhus americanus*), and inshore lizardfish (*Synodus foetens*). Many of the demersal fishes that are associated with marine soft bottom habitats are ocean-spawning, estuarine-dependent species that spawn offshore and use estuarine habitats for juvenile development. During the fall and winter, large numbers of these estuarine-dependent species leave the estuaries and enter the nearshore ocean zone (NCDEQ 2016). The majority of the demersal fishes that forage on nearshore soft bottom habitats are predators of benthic invertebrates. Peterson and Wells (2000) analyzed the stomach contents of nearshore demersal fishes that were caught in northern Onslow Bay during November. The results showed that croakers and pinfish were primarily consuming polychaetes, bivalves, grass shrimp (*Palaemonetes* sp.), and pinnotherid crabs. Silver perch, pigfish, and spot consumed polychaetes, grass shrimp, and other small bottom-dwelling crustaceans. Gray trout consumed grass shrimp, penaeid shrimp, and portunid crabs; whereas kingfishes primarily consumed pinnotherid crabs, portunid crabs, and large polychaetes.

4.3.2 Marine Hardbottom

Marine hardbottom habitats are areas of exposed rock and hardened sediments on the ocean bottom that exhibit varying degrees of colonization by marine macroalgae and sessile invertebrates (e.g., sponges, soft corals, and hard corals). Marine macroalgae are the dominant colonizing organisms on nearshore hardbottoms in NC, and the coverage of attached, sessile invertebrates is generally ten percent or less (Peckol and Searles 1984). Dominant large attached invertebrates include soft corals (*Titandeum frauenfeldii and Telesto fructiculosa*) and the hard coral (*Oculina arbuscula*). The small macroinvertebrate community is dominated by mollusks, polychaetes, and amphipods, and the most common large mobile invertebrates are sea urchins (*Arbacia punctulata, Lytechinus variegatus*) (Kirby-Smith 1989). Hardbottom habitats along the NC coast provide important foraging habitat and protective cover for tropical, subtropical, and warm-temperate reef fishes. Nearshore hardbottoms support a higher proportion of temperate fishes such as black sea bass (*Centropristis striata*), spottail pinfish (*Diplodus holbrookii*), and estuarine-dependent migratory species (Huntsman and Manooch 1978, Grimes et al. 1982). Lindquist et al. (1989) recorded 30 species representing 14 families at a nearshore hardbottom site in Onslow Bay. Common species included juvenile grunts, round scad (*Decapterus punctatus*), tomtate (*Haemulon aurolineatum*), spottail pinfish, black sea bass, slippery dick (*Halichoeres bivittatus*), scup, pigfish, cubbyu (*Equetus umbrosus*), belted sandfish (*Serranus subligarius*), and sand perch (*Diplectrum formosum*). Nearshore hardbottom sites support spawning by smaller, more temperate reef species such as black sea bass and sand perch, and function as larval settlement sites and juvenile nursery habitats for reef-associated fishes, including a number of taxa that are thought to spawn in deeper offshore waters (Powell and Robins 1998).

Extensive hardbottom survey and mapping efforts have been undertaken along NTB and NRI in support of the federal Surf City and NTB Coastal Storm Damage Reduction project and the non-federal NTB Shore Protection Project (Figure 4-2). CPE conducted a series of remote sensing and diver verification surveys of the nearshore (≤2,000 ft from shore) shoreface and potential offshore borrow sites from 2004-2006. CPE confirmed the presence of flat to low-relief (≤35 cm) exposed hardbottom areas ~1,150 ft from shore at depths of -15 to -21 ft NAVD. Sessile organism coverage on the nearshore hardbottoms was dominated by the West Indian worm snail (*Vermicularia spirata*), bryozoans (moss animals), calcareous red algae (Rhodophyta), hard corals [robust ivory tree coral (*Oculina robusta*), northern star coral (*Astrangia poculata*)], and soft corals [sea fans/sea whips (*Leptogorgia* spp.)]. Additional sessile taxa include tunicates, sponges, hydroids, and annelids. Macroalgae consisted predominantly of red algae (Rhodophyta); including species of *Gracilaria, Gelidium, Cryptonemia*, and *Dasya*. Crowson (1980) described similar sessile organism assemblages on nearshore hardbottoms off NRI.

HDR and Cleary (2003) conducted remote sensing and diver verification surveys of the study area shoreface from the -30-ft contour seaward to a distance of approximately five miles offshore. As described by HDR and Cleary, a patchy, very thin [<0.33 ft (10 cm)] veneer of sediment occurs across the Oligocene limestone platform that crops out over the majority of the study area shoreface. The surface sediment layer is easily reworked and redistributed during storms, exposing low relief scarps and flat hardbottoms. The shoreface off NRI is dominated by low to moderate relief (0.65 - 6.5 ft) hardbottom scarps and intervening flat hardbottom areas. Several large, high-relief (6.6 - 16.4 ft) hardbottoms with step-like ledges occur seaward of the NRI ebb tidal delta. The relatively high-relief bathymetric features are composed of erosion-resistant calcareous sandstones that have been identified as erosional remnants of lithified channel fill sequences.

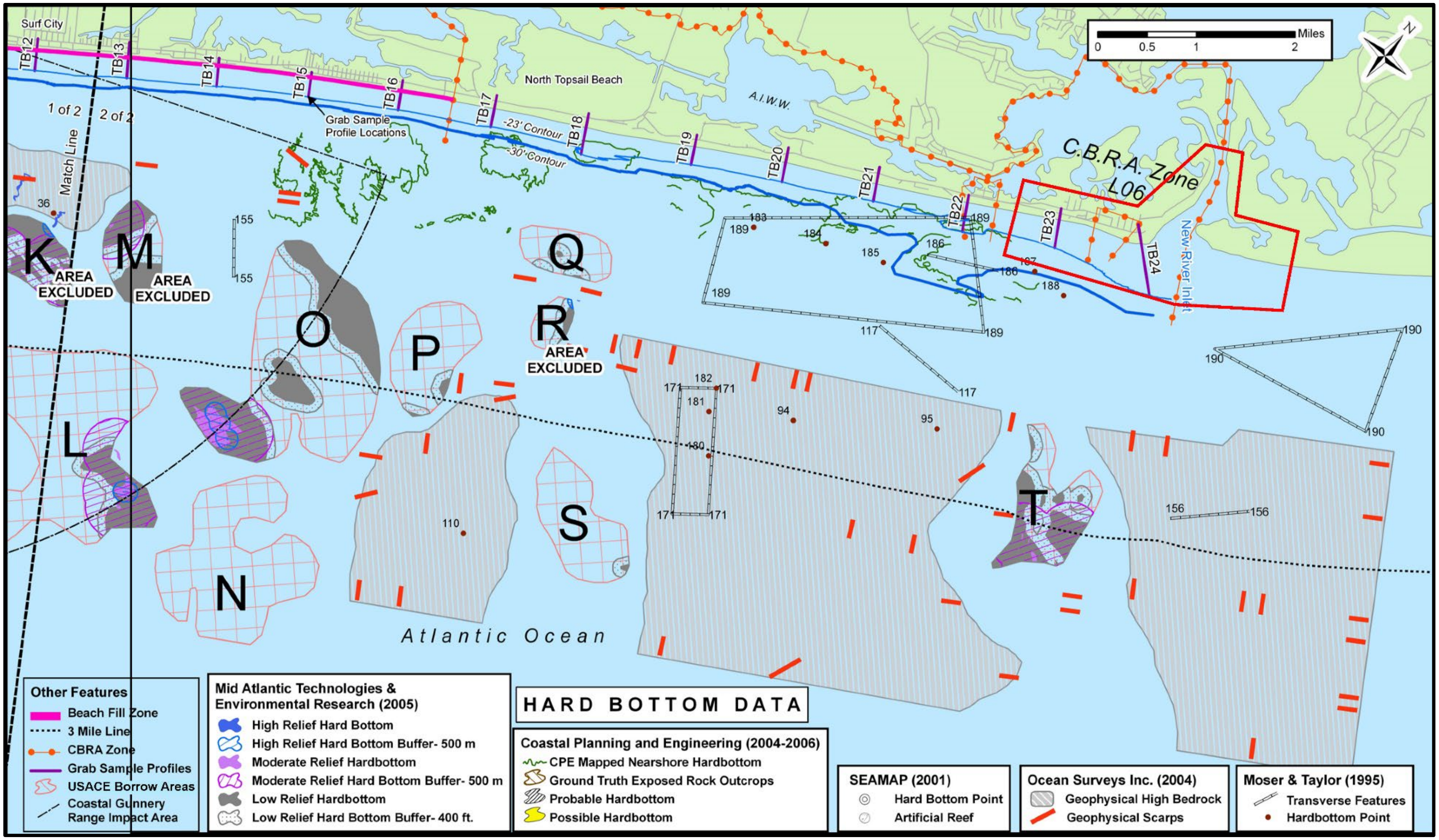


Figure 4-2. Hard bottom data compilation – Surf City and NTB Coastal Storm Damage Reduction Project (USACE 2010)

4.3.3 Marine Water Column

The ocean water column connects all marine habitats and is utilized by all marine organisms, including benthic, demersal, and pelagic fish and invertebrate species. Salinity, temperature, and water clarity are important water column physical properties that influence the distribution of marine organisms. Water column properties in Onslow Bay reflect relatively low riverine inputs of freshwater and sediments. Salinity is relatively high throughout the water column, with an observed range of approximately 34.0 to 36.5 practical salinity units (PSU) at inner shelf monitoring stations [Coastal Ocean Research and Monitoring Program (CORMP)]. The absence of significant riverine sediment input is reflected in relatively low turbidity values that are predominantly less than 4.0 Nephelometric Turbidity Units (NTU) at inner shelf monitoring stations (CORMP). High water clarity allows significant sunlight penetration to the bottom in relatively deep waters, thereby supporting abundant benthic microalgal growth to a distance of at least 45 kilometers (km) offshore (Mallin et al. 2005).

As pelagic habitat, the nearshore ocean column along the NC coast is utilized by anadromous, coastal migratory, and estuarine-dependent fishes; including alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), blueback herring (*A. aestivalis*), bay anchovy (*Anchoa mitchilli*), bluefish (*Pomatomus saltatrix*), cobia (*Rachycentron canadum)*, Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*S. cavalla*), Atlantic silverside, Atlantic menhaden, and striped mullet (NCDEQ 2016). Ocean spawning fish and invertebrates are dependent on the water column for egg and larval transport to suitable nursery habitats. Spawning generally occurs in areas where the prevailing currents carry eggs and larvae to nearshore and estuarine nursery habitats. Many of these species; including spot, Atlantic croaker, southern flounder, Atlantic menhaden, shrimp, and striped mullet; spawn offshore from fall to late winter and use low to high salinity estuarine habitats for juvenile development. Larvae spawned offshore are transported shoreward by the prevailing currents, eventually passing through tidal inlets and settling in estuarine nursery habitats. Studies conducted at Beaufort Inlet indicate that larvae accumulate in the nearshore ocean zone where they are picked up by longshore currents and transported to inlets (Churchill et al. 1999). Other ocean spawning species such as pinfish, black sea bass, gag grouper, and kingfish spawn during various times of the year and utilize high salinity nearshore and estuarine habitats for juvenile development. During late fall and winter, estuarine-dependent species such as Atlantic menhaden, spot, and Atlantic croaker are an important component of the ocean zooplankton community (Powell and Robbins 1994). Ichthyoplankton from estuarine-dependent species that spawn in the sounds and inlets [e.g., pigfish, silver perch, and weakfish (*C. regalus*)] were found in the ocean water column shortly after the spring/early summer spawning period. Reef fish larvae were most abundant during spring, summer, and early fall.

The marine water column functions as important foraging habitat for colonial nesting waterbirds such as terns (*Sterna* spp.), gulls (*Larus* spp.), brown pelicans (*Pelecanus occidentalis*), black skimmers (*Rynchops niger*), and double-crested cormorants (*Phalacrocorax auritus*). These species feed primarily on small fish that are captured via plunge diving (terns, gulls, and pelicans), skimming the water surface (black skimmer), or subsurface diving and pursuit (cormorant). Colonial nesting waterbirds are present year-round but are most abundant along the NC coast during spring and fall migration periods. Additional coastal waterbirds that utilize nearshore ocean waters in the vicinity of the study area include common and red-throated loons (*Gavia immer, G. stellata*), diving ducks [black scoter (*Melanitta americana*)], bufflehead (*Bucephala albeola*), common eider (*Somateria mollissima)*, common goldeneye (*B. clangula*), scaup (*Aythya* spp.), horned grebe (*Podiceps auritus*), and hooded and red-breasted mergansers (*Lophodytes cucullatus*, *Mergus serrator*) (USFWS 2002, Rice and Cameron 2008).

4.4 Beach and Dune Habitats and Communities

4.4.1 Intertidal Ocean Beach

The intertidal ocean beach is the portion of the beach between MHW and MLW that is alternately inundated and exposed by twice-daily ocean tides. Wave action in the intertidal zone generally precludes the growth of benthic algae; however, the re-suspension of inorganic nutrients supports primary production by phytoplankton (primarily diatoms), which in turn supports secondary production by filter-feeding benthic infaunal invertebrates (NCDEQ 2016). The dominant benthic invertebrate macrofauna of intertidal beaches along the NC coast are mole crabs (*Emerita talpoida*), coquina clams (*Donax variablis, D. parvula*), haustoriid amphipods, and the spionid polychaete (*Scolelepis squamata*). These four taxa comprised 97 percent of the individuals collected from intertidal beach monitoring stations on Onslow Beach over the course of the five-year Defense Coastal/Estuarine Research Program (DCERP) monitoring program (Cunningham 2013). Leber (1982) described seasonal changes in the intertidal macroinvertebrate community on the nearby island of Bogue Banks. Mole crabs and coquina clams dominated the macroinvertebrate community for most of the year, with haustoriid amphipods dominating the community briefly during early winter. Mole crab densities were highest from April through October, and densities of the coquina clam (*D. variabilis)* were highest from May through November. Densities of both species declined sharply in the late fall, and both were absent from mid-January to mid-February. Recolonization of the intertidal beach by juveniles and adults of both species was evident by late February.

The intertidal beach and adjoining shallow subtidal surf zone function as important foraging and nursery habitats for juvenile marine fishes, including many demersal species that prey on benthic infaunal invertebrates. Seine hauls conducted as part of the DCERP monitoring program captured 22 species at intertidal beach monitoring stations along Onslow Beach (Table 4-1) (Cunningham et al. 2013). Overall abundance was dominated by inland silversides and anchovies, which together accounted for 86 percent of the individuals collected over the course of the five-year monitoring period. The most abundant demersal species were Gulf kingfish and pompano, which together accounted for 6.5 percent of the individuals collected. More than 90 percent of the individuals of all species were juveniles. Intertidal beaches and their associated benthic infaunal invertebrate communities also comprise important foraging habitat and prey resources for ghost crabs and shorebirds. Wolcott (1978) found that mole crabs and coquina clams comprised nearly 90 percent of the food resources consumed by ghost crabs on Bogue Banks. After emerging from their terrestrial dry beach burrows at dusk, ghost crabs moved to the swash zone and spent the majority of their time actively pursuing infaunal prey, which they captured by excavating shallow holes in the exposed wet sand. The intertidal beach provides foraging habitat for resident, breeding, and migratory shorebirds that probe or search the surface of exposed wet intertidal sediments for benthic invertebrates. During spring and fall migration periods, intertidal habitats along the NC coast are used as stopover/refueling sites by large numbers of shorebirds as they undertake long distance migrations between arctic breeding grounds and southerly wintering areas. Preconstruction shorebird monitoring for the NTB Shoreline Protection Project recorded 26 species in the vicinity of NRI (CPE 2009). The most abundant species were sanderling, semipalmated plover, and dunlin, which together accounted for 54 percent of all shorebird observations during the November 2007 to May 2009 monitoring period. Other numerically important species included semipalmated sandpiper, short-billed dowitcher, black-bellied plover, western sandpiper, and willet. Detailed information regarding shorebird occurrences and habitat use within the study area is presented in Sections 4.5.2 and 4.5.3.

Table 4-1. Percent abundance of nekton captured by seine hauls at beach monitoring stations on Onslow Beach from 2007-2011

Species	Common Name	% Abundance
Menidia beryllina	Inland silverside	65.1
Anchoa hepsetus	Broad-striped anchovy	20.8
Menticirrhus spp.	Gulf kingfish	3.38
Trachinotus spp.	Pompano	3.11
Chloroscombrus chrysurus	Atlantic bumper	2.95
Caranx crysos	Blue runner	1.16
Ovalipes ocellatus	Lady crab	1.05
Mugil curema	White mullet	0.83
Pomatomus saltatrix	Bluefish	0.45
Monacanthus hispidus	Planehead filefish	0.31
Lagodon rhomboides	Pinfish	0.27
Callinectes sapidus	Blue crab	0.07
Pogonias cromis	Black drum	0.07
Scomberomorus maculatus	Spanish mackerel	0.07
Syngnathus sp.	Pipefish	0.07
Arenaeus cribrarius	Speckled swimming crab	0.04
Elops saurus	Ladyfish	0.04
Leiostomus xanthurus	Spot	0.04
Sphoeroides maculatus	Northern puffer	0.04
Gymnura sp.	Butterfly ray	0.02
Opisthonema oglinum	Atlantic thread herring	0.02
Selene vomer	Lookdown	0.02

4.4.2 Dry Beach, Dune, and Overwash Flats

The oceanfront dry beach lies above the influence of mean high tide water levels but is subject to occasional inundation by higher than average spring and storm tides. Vegetation is sparse and generally limited to a few species of annual succulents that occur on the uppermost beach near the toe of the dune (Schafale and Weakley 1990). Frontal dune system plant communities are typically dominated by sea oats (*Uniola paniculata*), American beach grass (*Ammophila breviligulata*), seaside little bluestem (*Schizachyrium littorale*), and other herbaceous species that are adapted to the stresses of continuous salt spray, excessive drainage, and shifting sands. The study area ocean dry beach on NTB is partially backed by a low and discontinuous line of narrow constructed dunes that are generally ≤10 ft in height; however, the northernmost ~3,600-linear-ft shoreline reach lacks frontal dunes and is currently armored by a continuous sandbag revetment. The area landward of the frontal dunes and revetment on NTB is comprised of residential development. On the south end of Onslow Beach, the ocean dry beach is backed by expansive overwash terraces that extend up to 1,000 feet landward to the back-barrier estuary. The overwash terraces were deposited during Hurricane Fran in September 1996. The higher portions of the terraces are characterized by sparsely vegetated supratidal sand flats and fields of small isolated dunes. The lower portions of the overwash terraces are characterized by maritime grassland, and maritime shrub plant communities (Figure 4-1). Vegetation of the dune fields and interdune sand flats is characterized by a typical dune grass community that includes sea oats as a dominant species. Maritime grassland is characterized by dense vegetation coverage and the dominance of saltmeadow cordgrass (*Spartina patens*) and other mesic to hydrophytic herbaceous species that are adapted to infrequent saltwater flooding via spring tides and storms.

Oceanfront dry beach habitats on Topsail Island and Onslow Beach comprise nesting habitat for sea turtles. Loggerheads account for the vast majority of sea turtle nesting on both islands. Green sea turtles nest intermittently in small numbers on both islands, and a single Kemps ridley nest has been recorded on Topsail Island. Adult female loggerheads return to their natal region to nest and show a high degree of site fidelity to the nesting beach selected during their initial reproductive season, typically nesting within zero to three miles of the initial nesting site (Miller et al. 2003). A variety of different substrates and beach slopes are used for nesting, but sea turtles appear to prefer relatively narrow, steeply sloped, coarse-grained beaches (Provancha and Ehrhart 1987). Slope has been found to have more influence on nest-site selection than temperature, moisture, and salinity, and nest sites along a given beach are typically located on the steepest slopes, which generally correspond to the highest elevations on the beach (Wood and Bjorndal 2000). Detailed information regarding sea turtle nesting within the study area is presented in Section 4.6.5.

Dry beach, dune, and overwash habitats comprise potential nesting habitat for a number of coastal waterbirds (i.e., shorebirds and colonial nesting waterbirds). Most shorebirds breed in the Arctic region; however, four species (American oystercatcher, piping plover, willet, and Wilson's plover) breed along the NC coast. Ground-nesting colonial waterbirds that breed along the NC coast include the black skimmer, several gulls (laughing, herring, and great black-backed), and eight species of terns (gull-billed, Caspian, royal, sandwich, common, Forster's, least, and sooty) (Parnell et al. 1995). Suitable nesting sites generally consist of wide, sparsely vegetated sand flats that are above the influence of tides and isolated from predators and human disturbance. Suitable nesting habitats are formed by natural processes of disturbance, including sediment deposition via storm-driven ocean-to-sound overwash events and dynamic inlet processes of erosion and accretion. The south end of Onslow Beach supports significant nesting by coastal waterbirds including Wilson's plover, willet, American oystercatcher, and least tern. Nesting on Onslow Beach is concentrated on interdune flats that are associated with overwash fans, with nesting in smaller numbers occurring along the oceanfront beach and on supratidal sand flats at NRI. Habitats associated with the developed oceanfront shoreline on NTB do not support nesting; however, a number of coastal waterbird species have nested on overwash fans that are associated with the back-barrier inlet shoreline of NTB. Detailed information regarding shorebird and colonial waterbird breeding activity in the study area is presented in Section 4.5.3.

4.4.3 Maritime Shrub

Maritime shrub communities occur on stabilized interior dunes and subaerial overwash flats that are protected from saltwater flooding and the most extreme salt spray. Maritime shrub communities are characterized by a very dense shrub stratum dominated by wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*), coastal red cedar (*Juniperus silicicola*), and stunted live oak (*Quercus virginiana*). On low and narrow barrier islands, maritime shrub communities are exposed to moderately heavy salt spray that limits shrub height and prevents succession to maritime forest. In the case of NTB, development of the subaerial island has largely displaced the island's natural upland maritime vegetation. Small fragmented areas of maritime shrub vegetation that remain on the north end are primarily located along the back-barrier estuarine shoreline (Figure 4-1). On the south end of Onslow Beach, a relatively large area (~16 ac) of contiguous maritime shrub vegetation extends ~2,000 feet northward from NRI along the island's estuarine shoreline. The maritime grassland community on Onslow Beach is gradually being invaded by maritime shrubs. Only small areas of closed maritime shrub vegetation have formed to date, but it appears that the majority of the maritime grassland area may be in the process of succeeding to a maritime shrub community.

4.5 Inlet and Estuarine Habitats and Communities

4.5.1 Larval Transport

NRI functions as an important conduit for the transfer of sediment, nutrients, and marine organisms between the back-barrier estuaries and the Atlantic Ocean. Estuarine-dependent fish and invertebrates that spawn offshore and use estuarine habitats for juvenile development are dependent on tidal inlets for larval recruitment to suitable nursery habitats. Larvae spawned offshore are transported shoreward by the prevailing currents and eventually pass through tidal inlets and settle in estuarine nursery habitats. Juveniles remain in the estuarine nursery areas one or more years before moving offshore and joining the adult spawning stock (NCDEQ 2016). Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies at Beaufort Inlet (~40 miles northeast of NRI) indicate that larvae accumulate in the nearshore ocean zone where they are picked up by longshore currents and transported to the inlet (Churchill et al. 1999). Overall larval densities within the inlet are generally highest from late May to early June and lowest in November (Hettler and Chester 1990).

Blanton et al. (1999) indicate that larvae are successfully drawn into Beaufort Inlet from a narrow, shallow-water [less than 7 meters (m)], withdrawal zone upwind of and just outside the mouth of the inlet. A long-term larval fish sampling program has been in place at Beaufort Inlet since 1986. Taxa dominating the samples in terms of total cumulative numbers of individuals collected include spot, pinfish, croaker, menhaden, speckled worm eel (*Myrophis punctatus*), flounders, pigfish, gobies (Gobiidae), and striped mullet (Table 4-2) (Taylor et al. 2009). Temporal patterns of larval transport through Beaufort Inlet were described by Hettler and Chester (1990). Overall larval densities within the inlet were highest from late May to early June and lowest in November. High densities during the late spring were largely attributable to high numbers of anchovies, which accounted for 85% of the individuals in the peak samples. Species richness was also highest (32 taxa) in the late spring and lowest (three taxa) in November. The most abundant species in the winter/early-spring samples were Atlantic menhaden, spot, Atlantic croaker, speckled worm eel, and summer flounder. Samples collected during late spring were dominated by anchovies, silver perch, weakfish, and pigfish; the most abundant taxa in the summer samples were striped anchovy, gobies, and Atlantic thread herring.

Table 4-2. Numerically dominant ichthyoplankton in Beaufort Inlet

Abundance Rank	Taxon
1	Spot
2	Pinfish
3	Atlantic croaker
4	Atlantic menhaden
5	Speckled worm eel
6	Gulf flounder
7	Pigfish
8	Gobies
9	Southern flounder
10	Striped mullet
11	Summer flounder

Source: Taylor et al. 2009

4.5.2 Intertidal Flats and Shoals

Intertidal sand and mud flats occur along the inlet and back-barrier estuarine shorelines of NTB and Onslow Beach. Intertidal sand shoals that are detached from the islands may also develop within NRI. Intertidal flats and their associated benthic infaunal invertebrate communities provide important foraging habitats and food resources for resident, breeding, and migratory shorebirds. During spring and fall migration periods, intertidal habitats along the NC coast are used as stopover/refueling sites by large numbers of shorebirds as they undertake long distance migrations between arctic breeding grounds and southerly wintering areas. Coastal waterbird monitoring for the NTB Shoreline Protection Project recorded 27 species of shorebirds at NRI (Table 4-3) (CPE 2009; Grant 2014, 2015, and 2016). The most abundant shorebird species were the dunlin, sanderling, semipalmated plover, and short-billed dowitcher, which together accounted for 70 percent of all shorebird observations. Other numerically important shorebirds included the black-bellied plover, semipalmated sandpiper, least sandpiper, Wilson’s plover, and willet. Total shorebird numbers at NRI were highest during the spring and fall migration periods and during the winter. Shorebird observations consisted predominantly of birds that were either foraging on exposed intertidal flats or roosting in dry beach habitats. Shorebirds were most abundant on the northside inlet shoreline of Onslow Beach and the southside inlet overwash flats on NTB. The overall shorebird community at NRI is comprised of various foraging guilds that differ in their prey preferences and foraging modes. A study of shorebird foraging patterns at NRI showed that shorebird distributions on intertidal flats were strongly correlated with benthic community composition and sediment composition (VanDusen et al. 2012). Intertidal foraging habitat selection varied among shorebird species according to the distributions of their preferred benthic infaunal prey and sediment grain size characteristics that influenced both infaunal community composition and the accessibility of those prey. The results of the study indicate that heterogeneous intertidal flats that vary in terms of sediment composition and elevation are necessary to support the full assemblage of shorebird species at NRI.

Intertidal flats at NRI also function as roosting and staging areas for large numbers of migratory colonial nesting waterbirds during the spring and fall. Coastal waterbird monitoring for the NTB Shoreline Protection Project recorded 32 species of colonial waterbirds at NRI (Table 4-4) (CPE 2009; Grant 2014, 2015, and 2016). The most abundant colonial nesting waterbird species were laughing gull, brown pelican, herring gull, double-crested cormorant, ring-billed gull, and royal tern, which together accounted for 73 percent of all colonial waterbird observations. Other numerically important colonial waterbirds included the black skimmer, Forster's tern, and Sandwich tern. Average total waterbird numbers at NRI were highest during the fall and lowest during the summer. Colonial waterbird observations consisted predominantly of birds that were either roosting on exposed intertidal flats or foraging over subtidal waters. Roosting activity was concentrated on the northside inlet shoreline of Onslow Beach and the southside mid-inlet overwash flats on NTB.

4.5.3 Supratidal Sand Flats

Supratidal sand flats at NRI are primarily associated with the accretional inlet shoreline/sand spit on Onslow Beach and overwash flats along the mid-inlet shoreline of NTB but also include narrow beach-like features along the inlet and back-barrier shorelines of the islands. As previously described (Section 4.4.2), additional expansive ocean-to-sound overwash flats occur just north of the inlet on Onslow Beach. Supratidal sand flats that are above the influence of mean high tide water levels are especially important as nesting sites for shorebirds and colonial nesting waterbirds. Most shorebirds breed in the Arctic region; however, five species of beach-nesting shorebirds (American oystercatcher, killdeer, piping plover, willet, and Wilson's plover) breed along the NC coast. Beach-nesting colonial waterbirds that breed along the NC coast include the black skimmer, several gulls (laughing, herring, and great black-backed), and eight species of terns (gull-billed, Caspian, royal, sandwich, common, Forster's, least, and sooty) (Parnell et al. 1995). Suitable nesting sites generally consist of wide, sparsely vegetated sand flats that are above the influence of tides and isolated from predators and human disturbance. Breeding activity at NRI in the form of breeding pair and/or nest observations has been reported for all five of NC's beach-nesting shorebird species and the least tern (Tables 4-5, 4-6, and 4-7). Reported breeding activity by shorebirds at NRI from 2000-2023 was concentrated on the Onslow Beach ocean-to-sound overwash flats and the southside mid-inlet overwash flats on NTB. Wilson's plovers accounted for the majority of the reported shorebird breeding activity, with significant numbers of breeding pairs being reported from both sides of the inlet. Least tern nesting from 2000-2023 was concentrated on the Onslow Beach overwash flats, with nesting in smaller numbers occurring on the Onslow Beach inlet shoreline and the mid-inlet overwash flats on NTB. American oystercatcher and willet breeding pairs and/or nests were observed sporadically in small numbers along both sides of the inlet.

Table 4-3. NRI Shorebird Observations - NTB Shoreline Protection Project (CPE 2009; Grant 2014, 2015, and 2016).

Species	Pre-Construction Nov 2007-May 2009	Post Construction			Total All Surveys
		Feb 2012-Jan 2013	Feb 2013-Jan 2014	Feb 2014-Jan 2015	
Dunlin	1066	4279	3886	3952	**13183**
Sanderling	1460	831	1155	864	**4310**
Semipalmated Plover	1374	706	1145	883	**4108**
Short-billed Dowitcher	457	728	851	1373	**3409**
Black-bellied Plover	451	680	489	369	**1989**
Semi-palmated Sandpiper	635	240	304	327	**1506**
Least Sandpiper	168	303	293	512	**1276**
Wilson's Plover	226	294	323	392	**1235**
Willet	270	223	272	288	**1053**
Red Knot	199	119	428	131	**877**
Ruddy Turnstone	141	177	279	221	**818**
Western Sandpiper	393	38	19	92	**542**
American Oystercatcher	181	100	70	69	**420**
Greater Yellowlegs	47	184	92	83	**406**
Lesser Yellowlegs	17	44	60	52	**173**
Piping Plover	37	40	38	35	**150**
Killdeer	13	28	27	30	**98**
Whimbrel	11	12	14	24	**61**

Table 4-3. Concluded.

Species	Pre-Construction Nov 2007-May 2009	Post Construction			Total All Surveys
		Feb 2012-Jan 2013	Feb 2013-Jan 2014	Feb 2014-Jan 2015	
Long-billed Dowitcher	49	0	0	0	**49**
Spotted Sandpiper	6	10	9	16	**41**
Pectoral Sandpiper	9	0	5	3	**17**
Marbled Godwit	3	0	9	1	**13**
Solitary Sandpiper	10	1	0	0	**11**
Black-necked Stilt	0	2	0	7	**9**
Stilt Sandpiper	1	0	4	1	**6**
American Golden Plover	1	0	0	0	**1**
White-rumped Sandpiper	1	0	0	0	**1**
Total	**7226**	**9039**	**9772**	**9725**	**35762**

Table 4-4. NRI Colonial Waterbird Observations - NTB Shoreline Protection Project (CPE 2009; Grant 2014, 2015, and 2016)

Species	Pre-Construction Nov 2007-May 2009	Post Construction			Total All Surveys
		Feb 2012-Jan 2013	Feb 2013-Jan 2014	Feb 2014-Jan 2015	
Laughing Gull	5334	5473	7353	3410	**21570**
Brown Pelican	3335	5347	3390	3457	**15529**
Herring Gull	4005	4744	3543	2627	**14919**
Double-crested Cormorant	4159	2344	2856	3812	**13171**
Ring-billed Gull	2455	3391	2922	3753	**12521**
Royal Tern	2632	3156	2186	1203	**9177**
Black Skimmer	1143	2102	1438	1567	**6250**
Forster's Tern	1404	1336	1561	1703	**6004**
Sandwich Tern	1627	1118	1371	1668	**5784**
Caspian Tern	754	699	782	649	**2884**
Least Tern	690	556	311	407	**1964**
Great Black-backed Gull	657	539	370	380	**1946**
Bonaparte's Gull	530	418	362	332	**1642**
Common Tern	454	169	575	436	**1634**
White Ibis	580	52	305	69	**1006**
Great Egret	171	217	301	186	**875**
Northern Gannet	371	115	3	366	**855**
Snowy Egret	42	81	79	220	**422**
Great Blue Heron	43	66	42	26	**177**

Table 4-4. Concluded.

Species	Pre-Construction Nov 2007-May 2009	Post Construction			Total All Surveys
		Feb 2012-Jan 2013	Feb 2013-Jan 2014	Feb 2014-Jan 2015	
Lesser Black-backed Gull	19	21	51	43	**134**
Great Cormorant	21	34	48	23	**126**
Tricolored Heron	6	18	23	15	**62**
Black Tern	31	7	2	1	**41**
Little Blue Heron	19	3	0	0	**22**
Glossy Ibis	0	0	20	2	**22**
Green Heron	0	3	6	0	**9**
Reddish Egret	0	1	6	0	**7**
Gull-billed Tern	0	0	2	3	**5**
White Pelican	0	2	0	0	**2**
Glaucous Gull	0	1	0	0	**1**
Parasitic Jaeger	0	1	0	0	**1**
Black-crowned Night-heron	0	0	1	0	**1**
Total	**30482**	**32014**	**29909**	**26358**	**118763**

Table 4-5. South End of Onslow Beach at NRI - Shorebird Breeding Records 2000-2023 (NCWRC PAWS 2024; Karpanty and Fraser 2011)

Year	Survey	Species	# Adults	# Breeding Pairs	# Nests	# Successful Nests	# Fledglings	# Chicks
2023	PIPL Breeding Season Best Estimate	Piping Plover	8	4			1	
2022	PIPL Breeding Season Best Estimate	Piping Plover	6	3				2
2021	PIPL Breeding Season Best Estimate	Piping Plover	1	3				
2020	PIPL Breeding Season Best Estimate	Piping Plover	4	2	2			
		American Oystercatcher	1		1			
2019	PIPL Breeding Season Best Estimate	Piping Plover	2	1	2	1	1	1
	AMOY/WIPL Survey	American Oystercatcher	4	2				
		Wilson's Plover	41	8				
2018	Unspecified	Piping Plover	2	1	1			
2017	PIPL Breeding Season Best Estimate	Piping Plover	8	2			2	
	Unspecified	American Oystercatcher	4	2	2			
	CWB Survey	Willet	2	2				
		Wilson's Plover	5	3	1			
2016	AMOY/WIPL Survey	American Oystercatcher	4	2	1			
2014	CWB Survey	Wilson's Plover	8	4				
2009	DCERP Shorebird Monitoring	American Oystercatcher			2			
		Killdeer			3			
		Piping Plover			1			
		Willet			3			
		Wilson's Plover		20	23	11	20	30
2008	DCERP Shorebird Monitoring	American Oystercatcher			1			
		Killdeer			2			
		Wilson's Plover		15	16	7	12	19
2007	AMOY/WIPL Survey	American Oystercatcher	2	1	1			
		Wilson's Plover	10	5				
2001	CWB Survey	American Oystercatcher	2	1				
		Wilson's Plover	6	3	1			

Table 4-6. North End of NTB at NRI - Shorebird Breeding Records 2000-2023 (NCWRC PAWS 2024)

Date	Survey	Species	# Adults	# Breeding Pairs	# Nests	# Successful Nests	# Fledglings	# Chicks
2023	PIPL Breeding Census Window	Wilson's Plover	22		2			
2022	Unspecified	American Oystercatcher	5	1				
	PIPL Breeding Season Best Estimate	Piping Plover	1					
	AMOY/WIPL Survey	Wilson's Plover	41	40	3			
2019	AMOY/WIPL Survey	American Oystercatcher	5	2				
		Wilson's Plover	60	30				
	PIPL Breeding Census Window	Piping Plover	1					
2018	Unspecified	American Oystercatcher	2	1	1	1		
	PIPL Breeding Season Best Estimate	Piping Plover	2	1	1	1	4	4
	PIPL Breeding Census Window	Willet	6	3				
		Wilson's Plover	10	4				
2017	PIPL Breeding Season Best Estimate	Piping Plover	3	2				
	PIPL Breeding Census Window	Willet	13		1			
	CWB Survey	Wilson's Plover	14	6				
2016	AMOY/WIPL Survey	American Oystercatcher	6					
		Wilson's Plover	16	8				
2016	International Shorebird Survey	Willet	8	2	2			
2015	PIPL Breeding Census Window	American Oystercatcher	2	1				
		Willet	8					
		Wilson's Plover	4					
2014	NRI Realignment	American Oystercatcher	4		1			
2013	AMOY/WIPL Survey	American Oystercatcher	4	1				
		Wilson's Plover	6	1				
2010	AMOY/WIPL Survey	Wilson's Plover	1	1				
2007	AMOY/WIPL Survey	Willet	10	5				
		Wilson's Plover	10	5				

Table 4-6. Concluded

2004	AMOY/WIPL Survey	Killdeer	4	2					
		Willet	4	2					
		Wilson's Plover	6	3					
2003	PIPL Breeding Census Window	Wilson's Plover	4	2	1				
2002	PIPL Breeding Census Window	American Oystercatcher	2	1					
		Wilson's Plover	2	1					
2001	CWB Survey	Willet	6	3					
		Wilson's Plover	4	2					

Table 4-7. NRI Least Tern Nest Survey Data 2001-2023 (NCWRC PAWS 2024; Karpanty and Fraser 2011)

Survey Date[1]	# Nests		
	Onslow Beach Overwash	**New River Inlet Northside**	**New River Inlet Southside**
06/03/2023		8	
05/11/2023			4
06/02/2022			5
06/01/2022	3	9	
06/08/2021			2
05/28/2021	6		
05/26/2021		16	
06/03/2020		11	
05/12/2020	6		
06/01/2019	40		5
06/01/2018			6
06/02/2017			3
06/13/2016	13	5	
06/04/2015			1
06/27/2011	111		
06/23/2008			30
05/08 - 06/17/2008[2]	6		
06/08/2007	20	6	
06/02/2004		2	
05/15/2001	5		
Total	**204**	**57**	**56**

[1]Prior to 2016, complete surveys were conducted every three years as part of the CWB survey. Annual surveys were initiated in 2016.
[2]DCERP Shorebird Monitoring - Nest discovery dates ranged from 8 May to 17 June 2008 (Karpanty and Fraser 2011).

4.5.4 Estuarine Soft Bottom Communities

Estuarine subtidal and intertidal unconsolidated bottom habitats function as highly productive foraging and nursery areas for estuarine-dependent fish and invertebrate species that spawn offshore and use estuarine habitats for juvenile development. Ocean-spawned larvae are transported shoreward by the prevailing currents and eventually pass through tidal inlets and settle in estuarine nursery habitats. For most estuarine-dependent species, larval settlement occurs in the uppermost reaches of shallow tidal creek systems (Weinstein 1979, Ross and Epperly 1985). Juveniles remain in the estuarine nursery areas for one or more years before moving offshore and joining the adult spawning stock (NCDEQ 2016). Shallow subtidal and intertidal soft bottom habitats provide abundant food resources for estuarine-dependent juveniles in an environment that is relatively inaccessible to large predators (SAFMC 1998). Highly productive benthic microalgae along with imported primary production in the form of phytoplankton and detritus support high secondary productivity by a diverse community of benthic infaunal and epifaunal invertebrates including nematodes, copepods, polychaetes, amphipods, decapods, bivalves, gastropods and echinoderms (SAFMC 1998, Peterson and Peterson 1979). Benthic invertebrates comprise the prey base for most estuarine-dependent demersal fishes including Atlantic croaker, spot, flounder, and estuarine-dependent species of the snapper-grouper complex. State-designated Primary Nursery Areas (PNAs) encompass essentially the entire inlet and estuarine complex of intertidal and subtidal habitats within the study area (Figure 4-3). PNAs are defined as “those areas in the estuarine system where initial post-larval development takes place” [15 North Carolina Administrative Code (NCAC) 3I .0101(b)(20)(E)]. Juvenile abundance in estuarine nursery areas generally peaks between April and July (Ross and Epperly 1985).

4.5.5 Shell Bottom

Shell bottom habitats include oyster reefs, aggregations of non-reef-building shellfish species [e.g., clams and scallops (*Argopecten irradians*, *A. gibbus*)], and surface concentrations of broken shell (i.e., shell hash). The eastern oyster (*Crassostrea virginica*) is the principal reef-building species of estuarine shell bottom habitats in NC. Non-reef-building shellfish species that occur at densities sufficient to provide structural habitat for other organisms include scallops, pen shells [saw-toothed (*Atrina seratta*), and stiff (*A. rigida*)] and rangia clams (*Rangia cuneata*) (SAFMC 2009). Shell bottom habitats perform important ecological functions such as water filtration, benthic-pelagic coupling, sediment stabilization, and erosion reduction (NCDEQ 2016, SAFMC 2009, and Coen et al. 2007). By filtering and consuming particulate matter, phytoplankton, and microbes, oysters and other suspension-feeding bivalves reduce turbidity and transfer material and energy from the water column to the benthic community. The structural relief provided by shell bottom moderates waves and currents, traps sediments, and reduces shoreline erosion.

Existing shell bottom habitats function as important larval settlement and accumulation sites for recruiting oysters and other shellfish (NCDMF 2008). Shell bottom structure concentrates macroinvertebrates [e.g., grass shrimp (*Palaemonetes* spp.), and mud crabs (*Scylla* spp.)] and small forage fishes (pinfish and gobies) that in turn attract larger predatory fish such as Atlantic croaker, black drum (*Pogonias cromis*), pigfish, (*Orthopristis chrysoptera*), southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), and spotted seatrout (*Cynoscion nebulosus*). Numerous finfish and decapod crustaceans use shell bottom habitats as nursery areas; including anchovies, black sea bass (*Centropristis striata*), blennies, gobies, oyster toadfish (*Opsanus tau*), pinfish, red drum, sheepshead (*Archosargus probatocephalus*), spot, weakfish (*C. regalis*), penaeid shrimp, blue crabs (*Callinectes sapidus*), and stone crabs (*Menippe mercenaria*) (NCDEQ 2016). NCDMF benthic habitat maps (Figure 4-4) do not show any shell bottom habitats within the study area; however, numerous small areas of shell bottom habitat are shown just outside of the study area in the back-barrier marsh complex behind NTB. More extensive shell bottom areas are shown farther outside the study area along the AIWW navigation channel.

4.5.6 Submerged Aquatic Vegetation

Submerged Aquatic Vegetation (SAV) in NC encompasses a number of bed-forming rooted aquatic vascular plant species that occur on subtidal and occasionally intertidal sediments in sheltered estuarine waters (NCDEQ 2016). Environmental requirements for SAV establishment and growth include unconsolidated sediments for root and rhizome development, adequate light reaching the bottom, and moderate to negligible current velocities (Thayer et al. 1984, Ferguson and Wood 1994). SAV beds provide important structural fish habitat and perform important ecological functions such as primary production, sediment and shoreline stabilization, and nutrient cycling (NCDEQ 2016). SAV habitats are important nursery areas for the juvenile life stages of estuarine-dependent fish and invertebrate species; including Atlantic croaker, spot, speckled trout, weakfish, red drum, southern kingfish, summer flounder, black sea bass, gag, and penaeid shrimp. Bay scallops, hard clams, and blue crabs are also strongly associated with SAV. NCDMF SAV maps (Figure 4-5) show several small areas of SAV in the study area along the shorelines of NRI and in the back-barrier marsh complex behind NTB. More extensive SAV areas are shown in the more landward portion of the back-barrier marsh complex that is just outside the study area.

4.5.7 Tidal Salt Marsh

Expansive areas of tidal salt marsh occupy the majority of the back-barrier estuaries behind NTB and Onslow Beach (Figure 4-1). The vast majority of the marshes consist of low marsh communities that are dominated by nearly monospecific smooth cordgrass stands. High marsh communities that are dominated by black needlerush are largely confined to a narrow fringing zone along the upland margins of the islands. The high marsh communities are frequently interspersed by scattered salt-tolerant shrubs such as marsh elder (*Iva frutescens*), silverling (*Baccharis halimifolia*), and coastal red cedar. The majority of the tidal marshes behind NTB were historically grid-ditched for mosquito control. As a result, the marshes behind NTB are fragmented by a series of parallel ditches on an approximately 100-ft spacing. The remaining smooth cordgrass marshes are dotted with hundreds of small (300-400 ft^2) circular dredged material deposits that support salt shrubs and other plant species that are typically associated with high marsh communities.

Tidal marshes exhibit high primary productivity in the form of detritus, microalgae, and bacteria (Hackney et al. 2000). Tidal flooding connects the marsh with adjacent estuarine waters, allowing utilization by fish and large mobile invertebrates. Resident marsh species such as grass shrimp, killifish, mummichogs, sheepshead minnows, gobies, bay anchovies, and silversides provide an important link between marsh primary production and transient predatory fish populations (Wiegert and Freeman 1990, SAFMC 1998). Tidal marshes are utilized as nursery and/or foraging areas by economically important species such as red drum, flounder, spotted seatrout, spot, Atlantic croaker, and blue crab. Other species such as Atlantic menhaden derive substantial food resources from the marsh via exported detritus and microalgae. Tidal salt and brackish marshes along the NC coast are important nursery habitats for estuarine-dependent species. The majority of the Primary and Secondary Nursery Areas in NC encompass shallow estuarine soft bottom habitats that are fringed by tidal marshes (NCDEQ 2016). In NC, penaeid shrimp and red drum are considered critically linked to marsh edge habitat (SAFMC 1998).

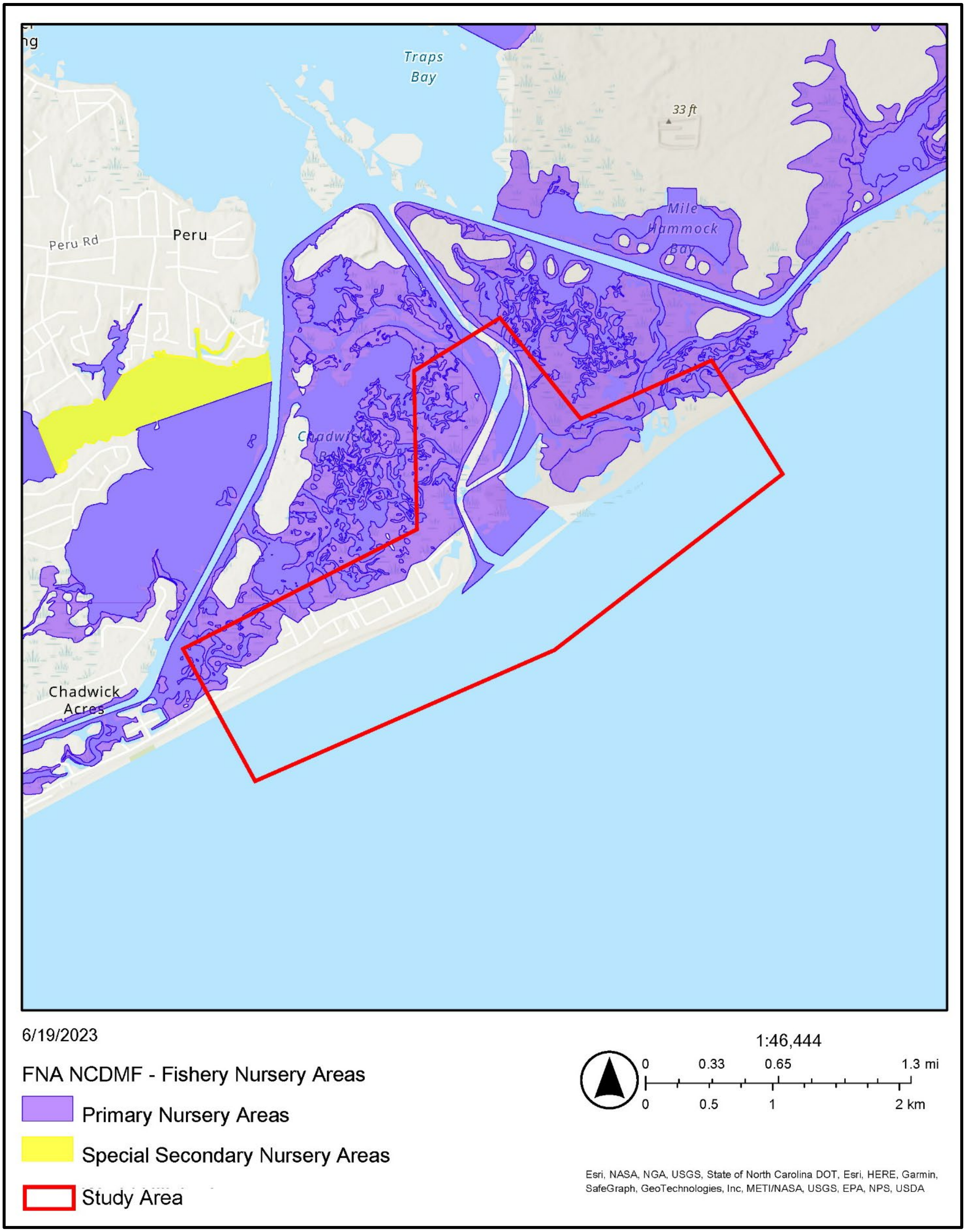


Figure 4-3. Designated Fish Nursery Areas

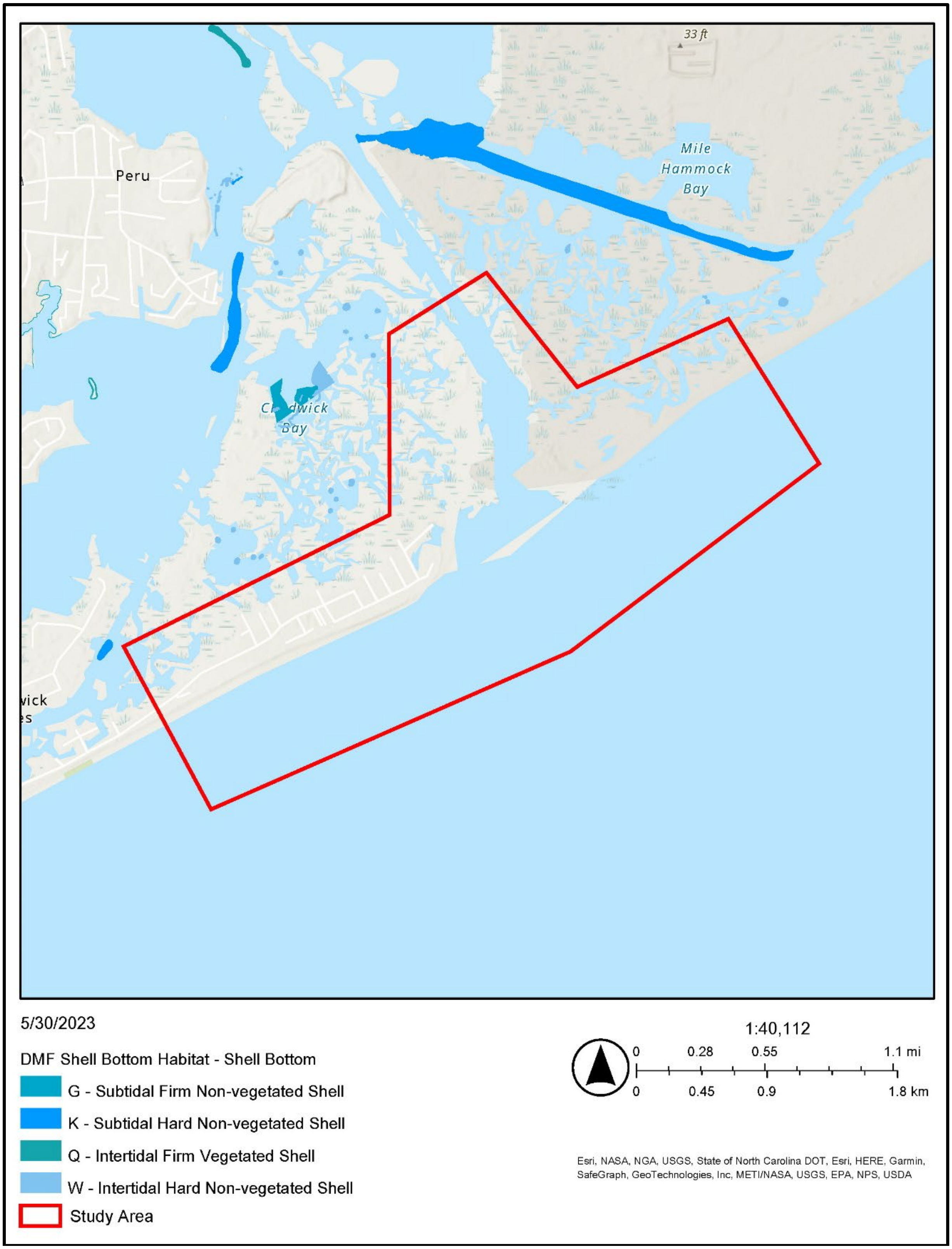


Figure 4-4. Mapped shell bottom habitat in the vicinity of the study area

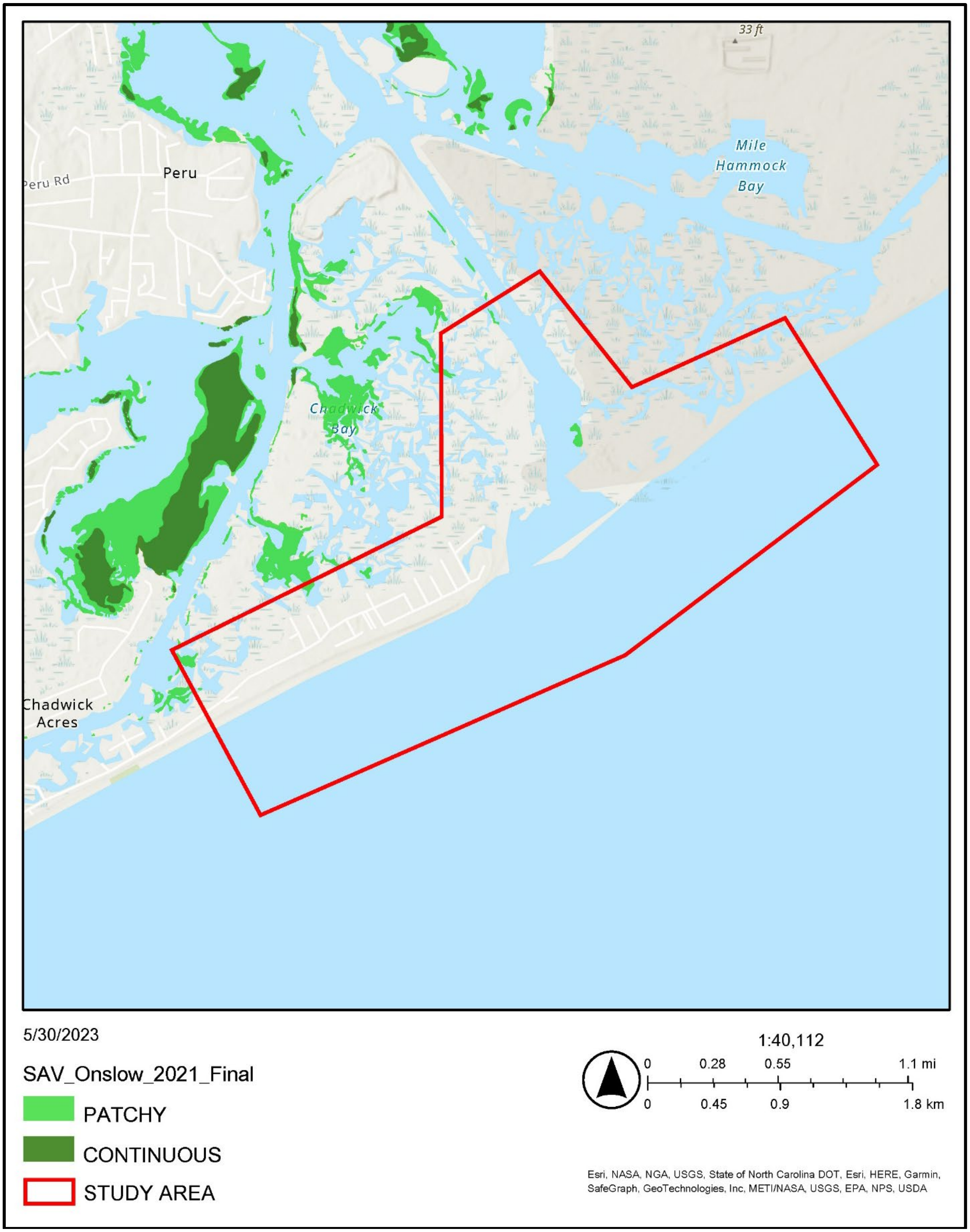


Figure 4-5. Mapped SAV habitat in the vicinity of the study area

4.6 Protected Species

A total of 11 ESA-listed threatened and endangered species may occur within the study area (Table 4-8). Additionally, the study area encompasses designated terrestrial and marine critical habitats for the threatened loggerhead sea turtle.

Table 4-8. ESA-listed species that may occur within the study area

Common Name	Scientific Name	Status
North Atlantic right whale	*Eubalaena glacialis*	Endangered
Florida manatee	*Trichechus manatus*	Endangered
Piping plover	*Charadrius melodus*	Threatened
Red knot	*Calidris canutus rufa*	Threatened
Loggerhead sea turtle	*Caretta caretta*	Threatened
Green sea turtle	*Chelonia mydas*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	Endangered
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Seabeach amaranth	*Amaranthus pumilus*	Threatened

4.6.1 Piping Plover

Piping plovers are divided into three distinct breeding populations; including the Atlantic Coast and Northern Great Plains breeding populations that are listed under the ESA as threatened and the Great Lakes breeding population that is listed as endangered (USFWS 2011). The breeding range of the Atlantic Coast population extends from NC to Newfoundland, Canada. Piping plovers arrive on the Atlantic Coast breeding grounds and initiate courtship in late March or early April, with clutch initiation occurring as early as mid-April and as late as mid-June. The incubation period ranges from 27 to 30 days and chicks fledge at an age of 25 to 35 days. Most chicks at Atlantic Coast breeding sites fledge by the end of July; although, flightless chicks may be present through late August (USFWS 1996). Southward migration to the wintering grounds occurs from late July through September. The overlapping wintering ranges of the three breeding populations encompass coastal areas from NC to Texas, as well as northern Mexico and the Caribbean (USFWS 1996). All piping plovers on the wintering grounds are considered threatened under the ESA, regardless of breeding origin (USFWS 2009a). The breeding, migratory, and wintering ranges overlap in NC, and consequently, piping plovers can be found in the state during every month of the year (Cameron et al. 2006). Suitable nesting sites in NC generally consist of large, sparsely vegetated sand flats that are above tidal influence and isolated from predators and human disturbance. Most nesting in NC occurs on undeveloped and unstabilized barrier islands, especially along the Outer Banks (USFWS 2009a). Suitable nesting sites on developed barrier islands are restricted to supratidal inlet habitats on the accreting ends of the islands. Piping plovers are very rarely seen on developed oceanfront beaches in NC and these areas are not considered suitable habitat (Cameron 2009).

Annual coast-wide breeding pair estimates for NC from 1986-20 ranged from 20 to 70 pairs (USFWS 2022). From 2000-2023, a total of 22 breeding pairs were observed at NRI, including 19 pairs on Onslow Beach and three pairs on NTB (Table 4-9). Non-breeding piping plovers use many of the inlets along the NC coast as stop over and wintering sites. Pre-construction shorebird monitoring for the NRI Realignment Project recorded a total of 37 piping plover observations at NRI during the November 2007 to May 2009 monitoring period, with a peak count of 10 individuals occurring during the month of March (Table 4-10) (CPE 2009). During the three-year (Feb 2013-Jan 2016) post-construction monitoring period, annual piping plover observations ranged from 35 to 40 (Grant 2014, 2015, and 2016). Annual peak counts for all three post-construction years consisted of seven individuals during the month of March. In total, the pre- and post-construction surveys recorded 150 piping plover observations including 54 from the southside inlet overwash flats on NTB, 94 from the northside inlet shoreline of Onslow Beach, and 2 from inlet shoals. The majority of the observations consisted of individuals that were either foraging in intertidal habitats or roosting in dry beach habitats. The NCWRC PAWS database contains additional records of piping plover observations from the southside of NRI; the majority of which occurred during the spring and fall migration periods (Table 4-11). Surveys of NRI for the 2001, 2006, 2011, and 2016 International Piping Plover Winter Census events yielded only a single piping plover observation, which occurred during the 2011 survey (Allen 2002, Cameron 2009, Schweitzer 2015, Kornegay et al. 2017). No designated critical habitat units for the piping plover occur within the study area. The nearest critical habitat units for the Atlantic Coast wintering population of piping plovers are located 22 miles to the south at New Topsail Inlet and 15 miles to the north at Bogue Inlet.

Table 4-9. 2000-2023 Piping Plover Annual Breeding Pair Estimates for NRI (NCWRC PAWS 2024)

Year	# Breeding Pairs (NCWRC Best Estimate)	
	Onslow Beach	**NTB**
2023	4	0
2022	3	0
2021	3	0
2020	2	0
2019	1	0
2018	1	1
2017	2	2
2016	1	0
2015	0	0
2014	0	0
2013	0	0
2012	1	0
2011	1	0
2010	0	0
2009	1	0
2008	0	0
2007	0	0
2006	0	0
2005	0	0
2004	0	0
2003	0	0
2002	0	0
2001	0	0
2000	0	0
Total	**19**	**3**
Source: NCWRC Annual Piping Plover Breeding Census Data		

Table 4-10. Piping Plover Observations - NRI Realignment Project Coastal Waterbird Monitoring (CPE 2009; Grant 2014, 2015, and 2016)

Transect[1]	Total Observations	Habitat Use (%)		Activity (%)			Peak Count (Month)
		Intertidal	Beach	Foraging	Roosting	Flying	
Pre-Construction (Nov 2007-May 2009)							
#1	8	25.0	75.0	25.0	75.0	0	10 (March)
#3	28	100	0	75.0	25.0	0	
#4	1	100	0	100	0	0	
Total	**37**						
Post Construction Year 1 (Feb 2013-Jan 2014)							
#1	5	100	0	100	0	0	7 (March)
#3	34	100	0	61.8	38.2	0	
#4	1	100	0	100	0	0	
Total	**40**						
Post Construction Year 2 (Feb 2014-Jan 2015)							
#1	19	94.7	5.3	89.5	0	10.5	7 (March)
#3	19	84.2	15.8	78.9	21.1	0	
Total	**38**						
Post Construction Year 3 (Feb 2015-Jan 2016)							
#1	22	95.5	4.5	86.4	13.6	0	7 (March)
#3	13	84.6	15.4	76.9	23.1	0	
Total	**35**						

[1]Trans 1 = Southside NTB overwash flats; Trans 3 = Northside Onslow Beach sand spit; Trans 4 = Mid-inlet shoals

Table 4-11. NRI Southside Piping Plover Observations 2016-2023 (NCWRC PAWS 2024)

Date	Survey	# Adults
7/26/2023	Unspecified	4
6/27/2023	Unspecified	1
3/16/2023	Unspecified	1
4/25/2022	Unspecified	1
12/30/2021	Unspecified	1
8/27/2021	Unspecified	2
7/6/2021	Unspecified	1
5/7/2021	Unspecified	2
5/5/2021	Unspecified	1
4/30/2021	Unspecified	1
4/25/2021	Unspecified	5
4/21/2021	Unspecified	1
4/18/2021	Unspecified	3
4/12/2021	Unspecified	3
4/9/2021	Unspecified	4
4/4/2021	Unspecified	4
3/31/2021	Unspecified	4
3/8/2021	Unspecified	1
8/5/2020	Unspecified	6
9/26/2019	International Shorebird Survey	2
9/18/2019	Unspecified	1
8/21/2019	Unspecified	1
8/6/2019	Unspecified	1
4/15/2019	Unspecified	1
4/10/2019	Unspecified	1
8/21/2018	International Shorebird Survey	2
11/16/2017	International Shorebird Survey	1
11/7/2017	International Shorebird Survey	1
9/19/2017	International Shorebird Survey	5
9/6/2017	International Shorebird Survey	5
7/20/2017	International Shorebird Survey	1
10/28/2016	Unspecified	1
10/4/2016	International Shorebird Survey	1
9/8/2016	International Shorebird Survey	5
8/31/2016	International Shorebird Survey	1
5/10/2016	International Shorebird Survey	1
4/26/2016	International Shorebird Survey	4

4.6.2 Red Knot

The red knot was listed as threatened under the ESA on 12 January 2015 (79 FR 73705 73748). Red knots migrate between breeding grounds in the central Canadian High Arctic and wintering grounds that range from the southeastern US coast to the southern tip of South America. Migration occurs primarily along the Atlantic coast, where red knots use key stopover and staging areas for feeding and resting. Departure from the Arctic breeding grounds occurs from mid-July through August, and the first southbound birds arrive at stopover sites along the US Atlantic coast in July. Southbound birds are most abundant along the US Atlantic coast in mid-August; and by late September most birds have departed for their wintering grounds. The wintering range along the US Atlantic Coast extends from NC to Florida. The core US Atlantic wintering area is thought to shift from year to year between Florida, Georgia, and South Carolina (USFWS 2014). As long-distance migrants, red knots are highly dependent on quality foraging habitat at key staging/stopover areas. The red knot is a specialized molluscivore, feeding on hard-shelled mollusks that are swallowed whole and crushed in the gizzard. The diet is sometimes supplemented with softer invertebrate prey such as shrimp- and crab-like organisms, marine worms, and horseshoe crab eggs. Migrating and wintering red knots use expansive intertidal sand and mud flats for foraging and sparsely vegetated supratidal sand flats and beaches for roosting. Both high-energy oceanfront intertidal beaches and sheltered estuarine intertidal flats are used for foraging (USFWS 2014). Foraging activity is largely dictated by tidal stage, as red knots rarely forage in waters more than 0.8 to 1.2 inches deep (Harrington 2001).

The largest numbers of red knots are observed along the NC coast during the spring migration period from mid-April to early June. Numbers of northbound birds generally peak during the first two weeks of May, and most spring migrants depart NC by mid-June. A small number of red knots consisting primarily of one-year-old subadults remain in NC throughout the summer (Dinsmore et al. 1998, USFWS 2014a). A smaller secondary peak occurs during late July and August as southbound migrants move along the NC coast. Numbers decline rapidly after the end of August; and by the end of September, most red knots have departed NC for their wintering grounds. Small numbers red knots winter along the NC coast, and these birds are present throughout the late fall and winter months. Pre-construction shorebird monitoring for the NTB Shore Protection Project recorded a total of 199 red knot observations at NRI during the November 2007 to May 2009 monitoring period, with a peak count of 54 individuals occurring during the month of October (Table 4-12) (CPE 2009). During the three-year (Feb 2013-Jan 2016) post-construction monitoring period, total annual red knot observations ranged from 119 to 428; with peak counts of 28, 86, and 31 individuals occurring during the months of October, November, and February, respectively (Grant 2014, 2015, and 2016). The pre- and post-construction surveys recorded a total of 877 red knot observations; including 728 from the southside inlet overwash flats on NTB, 138 from the northside inlet shoreline of Onslow Beach, and 11 from the oceanfront shoreline. The majority (98%) of the observations consisted of individuals that were foraging or roosting on intertidal flats. The NCWRC PAWS database contains additional records of red knot observations on the southside of NRI; the majority of which occurred during the spring and fall migration periods (Table 4-13).

Table 4-12. NRI Red Knot Observations - NTB Shoreline Protection Project Coastal Waterbird Monitoring (CPE 2009; Grant 2014, 2015, and 2016)

Transect[1]	Total Observations	Habitat Use (%)		Activity (%)			Peak Count
		Intertidal	Beach	Foraging	Roosting	Flying	
Pre-Construction (Nov 2007-May 2009)							
#1	153	100	0	85.0	13.0	2.0	54 (Oct)
#3	36	100	0	94.4	0	5.6	
#5a	10	80	20	100	0	0	
Total	**199**						
Post Construction Year 1 (Feb 2012-Jan 2013)[2]							
#1	88	-	-	-	-	-	28 (Oct)
#3	30	-	-	-	-	-	
#5a	1	-	-	-	-	-	
Total	**119**						
Post Construction Year 2 (Feb 2013-Jan 2014)							
#1	362	100	0	82.9	16.3	0.8	86 (Nov)
#3	66	78.8	21.2	71.2	28.8	0	
Total	**428**						
Post Construction Year 3 (Feb 2014-Jan 2015)							
#1	125	100	0	56.0	37.6	6.4	31 (Feb)
#3	6	100	0	100	0	0	
Total	**131**						

[1]Transect 1 = Southside overwash flats; Transect 3 = Northside sand spit; Transect 5a =Oceanfront surf zone
[2]Habitat use and activity data not available for Post-Construction Year 1

Table 4-13. NRI Southside - Additional Red Knot Observations (NCWRC PAWS 2024)

Date	Survey	# Adults
6/2/2022	AMOY/WIPL Survey	11
5/26/2022	ISS	128
05/23/2021	Unspecified	5
09/18/2019	Unspecified	14
12/14/2017	ISS	45
11/29/2017	ISS	25
11/16/2017	ISS	4
10/26/2017	ISS	4
12/1/2016	ISS	6
10/28/2016	Unspecified	48
10/4/2016	ISS	79
5/10/2016	ISS	12
02/06/2011	International Piping Plover Census	1

4.6.3 Sea Turtles

Loggerhead Sea Turtle

The loggerhead sea turtle was originally listed under the ESA as threatened throughout its range in 1978 (43 FR 32800). In 2011, loggerheads throughout the major ocean basins of the world were reclassified as nine separate Distinct Population Segments (DPSs). Loggerheads that nest along the US Atlantic and Gulf Coasts are included in the threatened Northwest Atlantic DPS. Nesting in the US occurs from southern Virginia to Texas but is concentrated from NC through Alabama (NMFS and USFWS 2008). The revised 2009 Recovery Plan for the Northwest Atlantic DPS designated five recovery units, including the Northern Recovery Unit (NRU) that includes nesting sea turtles from southern Virginia to the Florida-Georgia border. Although analysis of NRU nesting data from 1989-2007 showed a declining trend in annual nest totals, nesting in the NRU has been increasing since 2007, with the annual number of nests exceeding 14,000 for the first time in 2019 (Bolten et al. 2019). The NRU has a long-term annual rate of increase in number of nests of 1.3% based on 37 years of nesting data (1983-2019). The annual rate of increase remains below the recovery criterion of 2 percent that has been established for the NRU.

Adult female loggerheads return to their natal region to nest and show a high degree of site fidelity to the nesting beach selected during their initial reproductive season, typically nesting during subsequent years within zero to three miles of the initial nesting site (Miller et al. 2003). A variety of different substrates and beach slopes are used for nesting, but loggerheads appear to prefer relatively narrow, steeply sloped, coarse-grained beaches (Provancha and Ehrhart 1987). Post-hatchling loggerheads initially reside in neritic waters where they inhabit convergence zones with concentrated floating material such as sargassum. Post-hatchlings eventually move to oceanic waters and begin a juvenile oceanic phase of development. Oceanic phase juveniles appear to move with the predominant ocean gyres for several years before returning to neritic waters where juvenile development continues to adulthood. During the spring, summer, and fall; neritic phase juveniles inhabit essentially all continental shelf waters along the Atlantic Coast from Cape Cod to Florida and into the Gulf of Mexico, including nearshore coastal waters, coastal inlets, sounds, bays, estuaries, and lagoons. During the winter, juveniles are found off the Atlantic Coast from North Carolina to Florida. Adult loggerheads are primarily neritic, but tend to inhabit deeper, more offshore continental shelf waters along the Atlantic and Gulf Coasts. Adult loggerheads are less likely than juveniles to utilize enclosed shallow estuarine waters that have limited ocean access; however, shallow estuaries with expansive ocean access comprise important foraging habitats for both juveniles and adults (NMFS and USFWS 2023).

The USFWS and NMFS have designated terrestrial (79 FR 39756) and marine (79 FR 39855) critical habitat units for the loggerhead sea turtle along the US South Atlantic and Gulf Coasts from NC to Mississippi. In NC, eight loggerhead terrestrial critical habitat units encompassing approximately 96 miles of nesting beaches have been designated along the southern coast from Beaufort Inlet to the Shallotte River in Brunswick County. Designated marine critical habitat units along the NC coast include areas containing nearshore reproductive habitat, wintering habitat, breeding areas, and migratory corridors. Three designated nearshore reproductive critical habitat units encompass all nearshore waters along the 96 miles of designated nesting beaches from the MHW line to 1.6 km offshore. A single migratory critical habitat unit encompasses offshore waters between the 20-m and 100-m bathymetric contours between Cape Hatteras and Cape Fear, and a single winter habitat unit encompasses waters between the shoreline and the 200-m bathymetric contour from Cape Lookout north to Oregon Inlet.

Green Sea Turtle

The green sea turtle (*Chelonia mydas*) was originally listed under the ESA in 1978 as threatened, except for the Florida and Mexican Pacific Coast breeding populations, which were listed as endangered (43 FR 32800). In 2011, the green sea turtle was reclassified as 11 separate DPSs, including the North Atlantic and South Atlantic DPSs, which were both listed as threatened (81 FR 20057). Green sea turtles from the North Atlantic DPS account for all nesting in the continental US; however, juveniles from the South Atlantic DPS co-occur with adults and juveniles of the North Atlantic DPS in continental US waters (NMFS 2022a). Nesting in the continental US is concentrated in Florida, but also occurs in relatively small numbers along the Gulf Coast of Texas and the southeastern US Atlantic Coast from GA to NC. The revised 1991 Recovery Plan for the US Atlantic population established a recovery criterion of 5,000 nests per year for at least six years in Florida. Nesting in Florida has increased exponentially over the last 30 years, with record high annual nest totals recorded in 2011, 2013, 2015, 2017, and 2019 (FWC 2023).

Nesting green sea turtles appear to prefer high wave energy barrier island beaches with coarse sands, steep slopes, and prominent foredunes, with the highest nesting densities occurring on sparsely developed beaches that have minimal levels of artificial lighting (Witherington et al. 2006). In continental US waters, green sea turtles occur along the Atlantic and Gulf Coasts from Massachusetts to Texas (NMFS and USFWS 2007a). Post-hatchlings migrate to oceanic waters and begin an oceanic juvenile phase of development. Oceanic phase juveniles appear to move with the predominant ocean gyres for several years before returning to shallow coastal waters where juvenile development continues to adulthood. Neritic phase juveniles inhabit shallow estuarine waters and nearshore continental shelf waters that are rich in seagrasses and/or marine macroalgae. Adults generally remain in relatively shallow foraging habitats, but may enter the oceanic zone when migrating between foraging grounds and nesting beaches.

Leatherback Sea Turtle

The leatherback sea turtle (*Dermochelys coriacea*) was listed under the ESA as endangered throughout its range in 1970 (35 FR 8491). The leatherback has a circumglobal oceanic distribution that extends north and south into sub-polar regions, with adults undertaking extensive migrations between northern foraging grounds and tropical and subtropical nesting beaches (NMFS and USFWS 2007e). During the summer and fall, the highest densities of adult and subadult leatherbacks in the North Atlantic are found in Canadian waters (James et al. 2005). Although leatherbacks are commonly known as highly pelagic animals, recent telemetry studies have documented high use foraging sites in continental shelf and slope waters. Little is known of the distribution and developmental habitat requirements of leatherbacks from hatchling to adulthood (NMFS and USFWS 2007). Nesting in the US is primarily restricted to Florida, Puerto Rico, and the US Virgin Islands, with additional nesting in small numbers occurring along the Gulf Coast of Texas and the southeastern Atlantic Coast from Georgia to NC (NMFS and USFWS 2013). The 1992 Recovery Plan for the US Caribbean, Atlantic, and Gulf of Mexico populations established a recovery criterion of an increasing adult female population over 25 years for nesting populations in Florida, Puerto Rico, and the US Virgin Islands (NMFS and USFWS 1992). Nesting in Florida has increased exponentially over the last 30 years, but has undergone recent fluctuations, with nest numbers declining sharply from 2015-2017 and rebounding from 2018-2022 (FWC 2023).

Kemp's Ridley Sea Turtle

The Kemp's ridley sea turtle (*Lepidochelys kempii*) was listed as endangered throughout its range in 1970 (35 FR 18320). Kemp's ridley sea turtles occur primarily in coastal waters of the Gulf of Mexico and western North Atlantic Ocean. Adults are commonly found in nearshore waters over crab-rich sandy or muddy bottoms (NMFS and USFWS 2007b). Nesting is primarily restricted to the northeastern coast of Mexico, with a small number of turtles nesting consistently along the Texas coast and rare nesting occurring along the US Gulf and Atlantic Coasts from Alabama to North Carolina (TEWG 1998). Hatchlings migrate to the oceanic zone where they are carried by currents into various areas of the Gulf of Mexico and the North Atlantic Ocean (NMFS and USFWS 2007b). At approximately two years of age, juveniles leave the oceanic zone and move to coastal benthic habitats in the Gulf of Mexico and the Atlantic Ocean along the eastern US. During this stage, juveniles occupy protected coastal waters such as bays, estuaries, and nearshore waters that are less than 165 ft deep. Juveniles utilize a wide range of bottom substrates, but apparently depend on habitats with an abundance of crabs and other invertebrates.

Hawksbill Sea Turtle

The hawksbill sea turtle (*Eretmochelys imbricate*) was listed as endangered throughout its range in 1970 (35 FR 8491). Hawksbill sea turtles are globally distributed in tropical, and to a lesser extent, subtropical waters of the Atlantic, Indian, and Pacific Oceans. Nesting occurs on coastal beaches throughout the tropical and subtropical regions of the Atlantic, Pacific, and Indian Oceans. Rare nesting in the continental US is primarily restricted to the Atlantic Coast of southeastern Florida and the Florida Keys (Meylan 1992, Meylan et al. 1995). Hatchlings are carried by currents to the oceanic zone where they reside in major ocean gyres (NMFS and USFWS 2007c). Juveniles eventually depart the oceanic zone and move to nearshore coastal habitats. Juveniles and adults are primarily associated with coral reef habitats, but may use other habitats such as hardbottom, seagrass beds, algal beds, mangrove bays and creeks, and mud flats. Adults undertake extensive migrations between foraging grounds and nesting beaches.

Hawksbills have been reported from US waters along the Atlantic and Gulf Coasts from Massachusetts through Texas; however, Atlantic Coast sightings north of Florida are rare.

4.6.3.1 Status of Sea Turtles in the Study Area

Nesting

The sea turtle nesting and hatching season in NC generally extends from May 1 through November 15 (Holloman and Godfrey 2008). Loggerheads account for the majority of sea turtle nests in NC. Green sea turtles nest consistently in small numbers along the NC coast and leatherback nesting is rare. Kemp's ridley and hawksbill nesting are extremely rare in NC. A total of 605 sea turtle nests were recorded in the study from 2000-2023; including 350 nests (348 loggerhead and 2 green) on the north end of NTB and 255 nests (249 loggerhead and 6 green) on the south end of Onslow Beach (Table 4-14). On average, 14.6 and 10.6 nests were recorded annually on NTB and Onslow Beach, respectively.

Loggerhead Critical Habitat

The entire oceanfront dry beach on Topsail Island from the MHW line landward to the toe of the secondary dune or the first developed structure is designated as nesting critical habitat for the loggerhead sea turtle (Unit LOGG-T-NC-03-Topsail Island). Furthermore, nearshore ocean waters along the designated nesting beach from the MHW line out to 1.6 km from shore are designated as nearshore reproductive critical habitat for the loggerhead sea turtle (Unit LOGG-N-4-Topsail Island and Lea-Hutaff Island). Terrestrial critical habitat units represent beaches that are capable of supporting a high density of nests or those that are potential expansion areas for beaches with high nest densities. The Primary Constituent Elements (PCEs) of terrestrial critical habitat include: 1) unimpeded ocean-to-beach access for adult females and unimpeded nest-to-ocean access for hatchlings, 2) substrates that are suitable for nest construction and embryonic development, 3) a sufficiently dark nighttime environment to ensure that adult females are not deterred from nesting and that hatchlings are not disoriented and delayed or prevented from reaching the ocean, and 4) natural coastal processes that maintain suitable nesting habitat or artificially maintained habitats that mimic those associated with natural processes (79 FR 39756). The corresponding nearshore marine critical habitat units represent reproductive habitat along nesting beaches that is used by hatchlings for egress to the open ocean and by nesting females for movements between beaches and the open ocean during the nesting season. The PCEs of nearshore reproductive critical habitat include: 1) nearshore waters directly off the highest density nesting beaches and their adjacent beaches, 2) waters sufficiently free of obstructions and artificial lighting to allow transit through the surf zone to open water, and 3) waters with minimal manmade structures that could promote predators, disrupt wave patterns necessary for orientation, and/or create excessive longshore currents (79 FR 39855).

Table 4-14. Study Area Sea Turtle Nesting Data 2000-2023

Year	North Topsail Beach		Onslow Beach	
	Loggerhead	Green	Loggerhead	Green
2000	5	2	2	
2001	22		27	
2002	14		14	
2003	4		4	
2004	8		4	
2005	4		38	3
2006	24		4	
2007	7		12	2
2008	11		4	
2009	6		13	
2010	6		5	
2011	18		7	
2012	11		8	
2013	15		1	1
2014	11		4	
2015	14		10	
2016	26		4	
2017	17		7	
2018	4		2	
2019	37		26	
2020	23		21	
2021	20		9	
2022	11		14	
2023	30		9	
Species Total	**348**	**2**	**249**	**6**
Combined Total	**350**		**255**	
Avg nests/yr	**14.6**		**10.6**	

In-water Distribution and Habitat Use

North Carolina's sounds and estuaries provide important developmental and foraging habitats for post-pelagic juvenile loggerhead, green, and Kemp's ridley sea turtles. Most of the information regarding the inshore distribution of sea turtles in NC has been generated by studies in the Pamlico-Albemarle estuarine complex. Large numbers of loggerhead, green, and Kemp's ridley sea turtles are incidentally captured each year during commercial fishing operations in the Pamlico-Albemarle estuarine complex. All three species are represented primarily by juveniles, with few reported captures of older juveniles and adults (Epperly et al. 2007). All three species move inshore during the spring and disperse throughout the sounds during the summer. All three species leave the sounds and move offshore during the late fall and early winter. Epperly et al. (1995a) reported the presence of sea turtles in inshore waters from April through December. Goodman et al. (2007) reported inshore and nearshore ocean occurrences from April through November.

Leatherbacks are primarily a pelagic species preferring deep, offshore waters. Leatherbacks may be present in nearshore ocean waters during certain times of the year; however, they rarely enter inshore waters. Epperly (1995b) reported the appearance of significant numbers of leatherback turtles in nearshore ocean waters during May, coincident with the appearance of jellyfish prey. Sightings declined sharply after four weeks and only a few sightings were reported after late June. Leatherbacks were infrequently observed in inshore waters during this period. The surveys conducted by Goodman et al. (2007) recorded only one leatherback observation, during the summer in the nearshore ocean south of Cape Hatteras. Epperly et al. (1995a) reported the occurrence of three leatherbacks in Core and Pamlico Sounds during December 1989. Hawksbill sea turtles are very rare in NC waters, and they rarely enter inshore waters (Epperly et al. 1995a). A total of nine hawksbill stranding incidents were reported along NC beaches between 1998 and 2009 (Seaturtle.org 2011). Strandings were reported during the months of January, March, April, and November. Epperly et al. (1995b) reported the incidental capture of one hawksbill in Pamlico Sound.

Several studies have reported a strong relationship between sea turtle distribution and sea surface temperature. Goodman et al. (2007) conducted aerial sea turtle surveys and sea surface temperature monitoring in Core Sound, Pamlico Sound, and adjacent nearshore ocean waters from July 2004 to April 2006. All but one of the 92 sea turtle observations occurred in waters where sea surface temperatures were above 11°C. All sightings in the sounds occurred between 16 April and 20 November, and all sightings in the nearshore ocean occurred between 23 April and 27 November. The winter distribution of sea turtles offshore of Cape Hatteras was also correlated with sea surface temperatures above 11°C (Epperly et al. 1995c). In a similar study by Coles and Musick (2000), sea turtle distribution offshore of Cape Hatteras was restricted to sea surface temperatures ≥13.3°C.

4.6.4 North Atlantic Right Whale

Right whale populations in the North Atlantic and North Pacific were originally listed as a single endangered species in 1970 (35 FR 8495), but were reclassified in 2008 as two separate endangered species: the North Atlantic right whale (*Eubalaena glacialis*) and the North Pacific right whale (*E. japonica*) (73 FR 12024). The estimated size of the North Atlantic right whale population in 2020 was 336 individuals (Pettis et al. 2022). Ship collisions and fishing gear entanglements are the principal threats to North Atlantic right whales. Of 82 right whale mortalities that were observed in the U.S. and Canada between 1999 and 2018, researchers were able to identify a cause of death in 59.7% (n=49) of cases, with 10.2% dying from natural causes, 38.8% from vessel collisions, and 51.0% from entanglement (Moore et al. 2021). Analyses of whale-vessel interactions indicate that the probability of vessel strikes and serious injuries from vessel strikes increase with ship speed (NMFS 2008). In an effort to reduce ship strikes, NMFS published the Right Whale Ship Strike Reduction Rule in 2014 (50 CFR 224.105). The Ship Strike Reduction Rule established Seasonal Management Areas (SMAs) with mandatory large vessel (≥65 ft) speed restrictions. Additional federal regulations (62 FR 6729) prohibit vessel approaches within 500 yards of North Atlantic right whales.

The majority of the western North Atlantic population ranges from wintering and calving areas in coastal waters along the southeastern US Atlantic Coast to summer feeding grounds in coastal waters off New England and Canada. Waters along the southeastern US coast from Cape Fear, NC to Cape Canaveral, FL constitute the only known calving habitat for North Atlantic right whales (Kraus et al. 1986, Knowlton et al. 1994). Reproductive females typically arrive in the calving areas during late November and early December after migrating south from the northern feeding grounds (Fujiwara and Caswell 2001, Garrison 2007, and Hamilton et al. 2007). Mothers and newborn calves reside within the southeast through winter and generally depart the calving grounds by the end of March or early April (Reeves et al. 2001). Other members of the population spend the winter on the northern feeding grounds in areas such as the Gulf of Maine and Cape Cod Bay (Cole et al. 2013, Clark et al. 2010). Designated critical habitats for the North Atlantic right whale include northeastern feeding grounds in the Gulf of Maine/Georges Bank region and southeastern nearshore ocean calving habitat from Cape Fear, NC to Cape Canaveral, FL (81 FR 4838).

In an effort to better define the geographic and temporal extent of the right whale mid-Atlantic migratory corridor, Knowlton et al. (2002) analyzed 489 right whale sightings that occurred between 1974 and 2002. The largest number of sightings (34.4%) occurred within zero to five nautical miles (nm) of land, and well over half of the sightings (63.8%) occurred within zero to ten nm of land. Nearly all of the sightings (94.1%) were within zero to 30 nm of land. A total of 17 sightings occurred within a 35 nm radius of the Port of Morehead City, and 15 of these sightings were within a 20 nm radius of the Port of Morehead City. Sightings in the vicinity of the Port of Morehead City occurred from October through April, with a peak during February and March. Sightings to the south in the vicinity of the Port of Wilmington flowed a similar pattern. The sightings data indicate that right whales may be present in nearshore ocean waters of the study area from October through April as they migrate between summer feeding/nursery areas and winter calving grounds.

4.6.5 Florida Manatee

The Florida manatee (*Trichechus manatus latitostris*), a subspecies of the West Indian manatee, was originally listed as endangered in 1967 (32 FR 4001). In 1969, the endangered listing was expanded to encompass the species throughout its range, including the Antillean manatee (*Trichechus manatus manatus*), a subspecies occurring in the Caribbean and South America. In 2017, both subspecies were reclassified from endangered to threatened throughout their ranges (82 FR 16668). The most recent abundance estimate for the Florida subspecies within the southeastern US was 6,350 individuals (Martin et al. 2015). The principal anthropogenic threats to manatees include watercraft strikes, entrapment and/or crushing in water control structures, ingestion of marine debris, and entanglement in fishing gear. Of 2,372 human-caused manatee deaths that occurred from 1978-2012; 84% (n=1,980) were attributed to watercraft strikes, 9%

(n=204) to water control structures, and the remaining 8% (n=188) to ingestion of marine debris, entanglement in fishing gear, and other human causes.

Manatees are intolerant of cold water temperatures and consequently are generally restricted to warm water sites of peninsular Florida during the winter. As water temperatures reach 68°F in the spring, manatees disperse from winter sites, with some individuals undertaking extensive northward movements along the southeastern US Atlantic Coast (USFWS 2001). Summer sightings are most common in Florida and Georgia. Sightings decline rapidly north of Georgia, and sightings north of Cape Hatteras are rare. Manatees inhabit marine, brackish, and freshwater environments where they are associated with seagrass beds, salt marshes, freshwater bottom areas, and many other habitat types. Manatees feed on a wide variety of submerged, floating, and emergent vegetation. Seagrasses are a staple in coastal habitats, and preferred foraging habitats consist of shallow seagrass beds with access to deep water. Although manatees tolerate a wide range of salinities, they prefer areas where osmotic stress is minimal or areas that have a natural or artificial source of fresh water (USFWS 2001). Cummings et al. (2014) described the temporal and spatial distribution of manatees in NC based on analysis of sighting and stranding records from 1991-2012. Although sightings were reported along the entire NC coast, most were concentrated around the densely populated areas of Wilmington and Beaufort, NC. Sightings were most common in the Atlantic Intracoastal Waterway; however, manatees were also observed in sounds, bays, rivers, creeks, marinas, and the open ocean. Manatee occurrences in NC are primarily restricted to the months of June through October. Nearly all (93%) of the NC sighting (n=99) and stranding (n=9) records that were analyzed by Cummings et al. (2014) occurred between June and October when water temperatures were above 68°F [20 degrees Centigrade (°C)].

4.6.6 Other Marine Mammals

In addition to the protections afforded to threatened and endangered marine mammals under the ESA, all marine mammals are protected under the Marine Mammal Protection Act. A number of marine mammals that are not listed under the ESA have been reported from coastal waters between Cape Hatteras and NRI; including 28 cetaceans (whales, dolphins, and porpoises) and four pennipeds (seals, sea lions, and fur seals) (Department of the Navy 2008). The majority of these additional species are generally not expected to occur in the nearshore waters of the study area. Many are typically found in offshore waters near the continental shelf break or beyond, while a number of others are known only from stranding records or rare sightings that are considered extralimital to their normal distributions. Marine mammal occurrence data compiled by the Department of the Navy (2003 and 2008) for the Cherry Point Military Operations Area indicate that only the bottlenose dolphin (*Tursiops truncates*) and Atlantic spotted dolphin (*Stenella frontalis*) are likely to occur regularly in the study area. Bottlenose dolphins may occur in both estuarine and nearshore marine waters throughout the year, although estuarine occurrences peak during summer and most winter sightings are from the nearshore ocean (Department of the Navy 2003 and 2008). Bottlenose dolphins along the South Atlantic coast include both resident and migratory populations. A resident bottlenose dolphin population northeast of the project area in the vicinity of Beaufort, NC, is the northernmost documented site of year-round bottlenose dolphin residency in the western North Atlantic (Koster et al. 2000). Atlantic spotted dolphins occur regularly in nearshore waters south of Chesapeake Bay (Mullin and Fulling 2003). Nearshore sightings of Atlantic spotted dolphins have been recorded in the vicinity of the study area during winter, spring, and summer (Department of the Navy 2008).

4.6.7 Atlantic Sturgeon

The Atlantic sturgeon was listed under the ESA in 2012 as five separate DPSs including the New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs that were listed as endangered and the Gulf of Maine DPS that was listed as threatened (77 FR 5914, 77 FR 5880). The southernmost South Atlantic DPS encompasses Atlantic sturgeon that spawn in river systems from the Edisto River, SC to the St Johns River, FL. The Atlantic sturgeon is an anadromous, estuarine-dependent species that historically occurred in large estuarine and riverine systems from Newfoundland and Labrador to the St. Johns River, FL (ASSRT 2007). Historical overharvesting contributed to drastic declines in Atlantic sturgeon populations, with commercial exploitation continuing throughout most of the 20th century (ASSRT 2007). Although directed commercial harvest is no longer permitted, by-catch mortality associated with other fisheries remains a threat. By-catch mortality in the shad and shrimp fisheries and water quality degradation in nursery habitats are currently considered to be the primary threats to southeastern sturgeon populations (Collins et al. 2000). Dams that block access to spawning grounds are also a factor in some southern river systems. Additional stressors include ship strikes and interactions with dredges.

Adults spend most of their lives in the marine environment, but migrate to the upper freshwater reaches of large rivers to spawn. Spawning adults generally migrate upriver in the spring/early summer to spawning grounds in the vicinity of the fall line. Spawning occurs over hard substrates to which the eggs rapidly adhere. Post-larval juveniles move downriver to the vicinity of the freshwater-saltwater boundary, and eventually move to estuarine waters in the lower reaches of rivers where they reside for a period of months or years (Moser and Ross 1995). Subadult and adult Atlantic sturgeon emigrate from rivers into coastal marine waters where they undertake long range migrations. Migratory subadult and adult sturgeon in the marine environment are typically found in shallow nearshore coastal waters over gravel or sand substrates at depths of less than 60 ft (Collins and Smith 1997, Stein et al. 2004, Laney et al. 2007). Although extensive mixing of sturgeon from all DPSs occurs in coastal waters, migratory adults return to their natal river to spawn. Atlantic sturgeon are benthic omnivores that filter quantities of mud along with their food. Adults consume mollusks, gastropods, amphipods, isopods, and fish, while juveniles feed on aquatic insects and other invertebrates (ASSRT 2007).

In NC, spawning occurs in the Roanoke, Tar-Pamlico, and Cape Fear River systems and possibly in the Neuse River (ASSRT 2007). Based on analysis of tagging data collected between 1988 and 2006, Laney et al. (2007) concluded that shallow nearshore coastal waters over gravel or sand substrates along the NC coast represent a winter (January-February) aggregation site and an important area of winter habitat for migratory adult and subadult Atlantic sturgeon. In 1974 and 1975, anadromous fishery surveys in the New River captured four adult Atlantic sturgeon (Sholar 1975). Based on the work by Laney et al. (2007), it is assumed that migratory adult and subadult Atlantic sturgeon may be present in nearshore and estuarine waters of the study area during the winter months. Rulifson et al. (2020) reached a similar conclusion based on detections of acoustically tagged Atlantic sturgeon in coastal waters off the southern flank of Cape Hatteras. The study recorded 653 detections of 24 individuals during a 2008–2011 deployment of acoustic receivers and 854 detections of 67 individuals during a 2012–2014 deployment. Atlantic sturgeon detections included individuals from four of the five DPSs (New York Bight DPS, Chesapeake Bay DPS, Carolina DPS, and South Atlantic DPS). The presence likelihood for Atlantic sturgeon was highest during the winter, with some predicted presence during the late fall and early spring.

4.6.8 Shortnose Sturgeon

Adult shortnose sturgeon in southern rivers are estuarine anadromous, foraging at the saltwater-freshwater interface and moving upstream to spawn in the early spring [Shortnose Sturgeon Status Review Team (SSSRT) 2010]. Shortnose sturgeon spend most of their lives in their natal river systems and rarely migrate to marine environments. Juveniles occupy the saltwater-freshwater interface, moving back and forth with the low salinity portion of the salt wedge during summer. Juveniles typically move upstream during the spring and summer and downstream during the winter, with movements occurring above the saltwater-freshwater interface. In southern rivers, both adults and juveniles are known to congregate in cool, deep thermal refugia during the summer. The shortnose sturgeon is a benthic omnivore that feeds on crustaceans, insect larvae, worms, and mollusks. Juveniles randomly vacuum the bottom and consume mostly insect larvae and small crustaceans; whereas adults are more selective feeders, feeding primarily on small mollusks.

Shortnose sturgeon were thought to be extirpated from NC waters until an individual was captured in the Brunswick River in 1987 (Ross et al. 1988). Subsequent gill-net studies (1989-1993) confirmed the presence of a small population in the lower Cape Fear River (Moser and Ross 1995). Surveys in the Neuse River during 2001 and 2002 failed to capture any shortnose sturgeon (Oakley and Hightower 2007). The current distribution of the shortnose sturgeon in NC is thought to include only the Cape Fear and Pee Dee Rivers, and no spawning populations have been confirmed in the state (SSSRT 2010). The NCDMF Observer Program has documented only two shortnose sturgeon interactions with NC's estuarine anchored gill net fisheries, both of which occurred in the Cape Fear River. The NCDMF independent gill net survey captured a single shortnose sturgeon in western Albemarle Sound in 1998 (Armstrong and Hightower 1999). Based on the lack of reported occurrences in the vicinity of the action area its restriction primarily to the portions of large rivers above the saltwater-freshwater interface, shortnose sturgeon occurrences within the high salinity waters of the action area are considered unlikely. However, the occurrence of a transient individual within the action area cannot be entirely discounted, as genetic studies indicate that some individuals move between the various river spawning populations (Quattro et al. 2002, Wirgin et al. 2005).

4.6.9 Seabeach Amaranth

Seabeach amaranth was listed under the ESA as threatened throughout its range in 1993 (58 FR 18035 18042). No critical habitat has been designated for this species. Historically, this species occurred on coastal barrier island beaches from Massachusetts to South Carolina. Extant populations are currently known from South Carolina, North Carolina, Virginia, Delaware, Maryland, New Jersey, and New York. Although the historical range included Rhode Island and Massachusetts, seabeach amaranth has not been found in these states for over a century. Range-wide population numbers increased substantially during the 1990s, reaching a record high population estimate of 244,608 plants in 2000. Range-wide numbers subsequently underwent a rapid decline, reaching a low just 1,308 plants in 2013 (USFWS 2023). Numbers have remained low since 2013, with a range-wide total of just 8,168 plants reported for 2021. Primary habitats for seabeach amaranth include overwash flats on the accreting ends of islands, lower foredunes, and the upper dry beach on non-eroding barrier islands. Seabeach amaranth is an annual species, meaning that the presence of plants in any given year is dependent on seed production and dispersal during previous years. Seeds germinate from April through July, and flowering begins as early as June. Seed production begins in July or August, and both flowering and seed production continue until the end of the growing season. Seabeach amaranth is intolerant of competition; consequently, its survival depends on a continuous supply of newly disturbed habitats. Prolific seed production and dispersal via wind and water enable the colonization of new habitats as they become available.

Although variable from year to year, the distribution of seabeach amaranth encompasses the entire barrier island coast of NC. The largest numbers of plants have been found along the southern NC coast, with concentrations occurring along Topsail Island and Bogue Banks. Long-term population trends in NC have been similar to those of the overall range-wide population. After a record high annual count of 39,933 plants in 1995, annual state-wide numbers fluctuated between approximately 200 and 14,000 plants through 2002. Beginning in 2003, the NC population increased substantially over three consecutive years, reaching 25,885 plants in 2005. The NC population has since been in rapid decline, reaching a record low annual total of 154 plants in 2012. Numbers have remained relatively low since 2012, with a state-wide total of just 98 plants reported for 2021. On Onslow Beach, seabeach amaranth has typically been most abundant on the south end of the island on overwash flats and the accretional inlet sand spit (MCBCL 2015). On the north end of NTB, seabeach amaranth has typically been most abundant at NRI in the vicinity of the inlet shoulder. Long term trends on Onslow Beach and the north end of NTB have been similar to the state-wide trend. Relatively high counts during the mid-1990s and mid-2000s were followed by rapid and long-term declines (Figure 4-6).

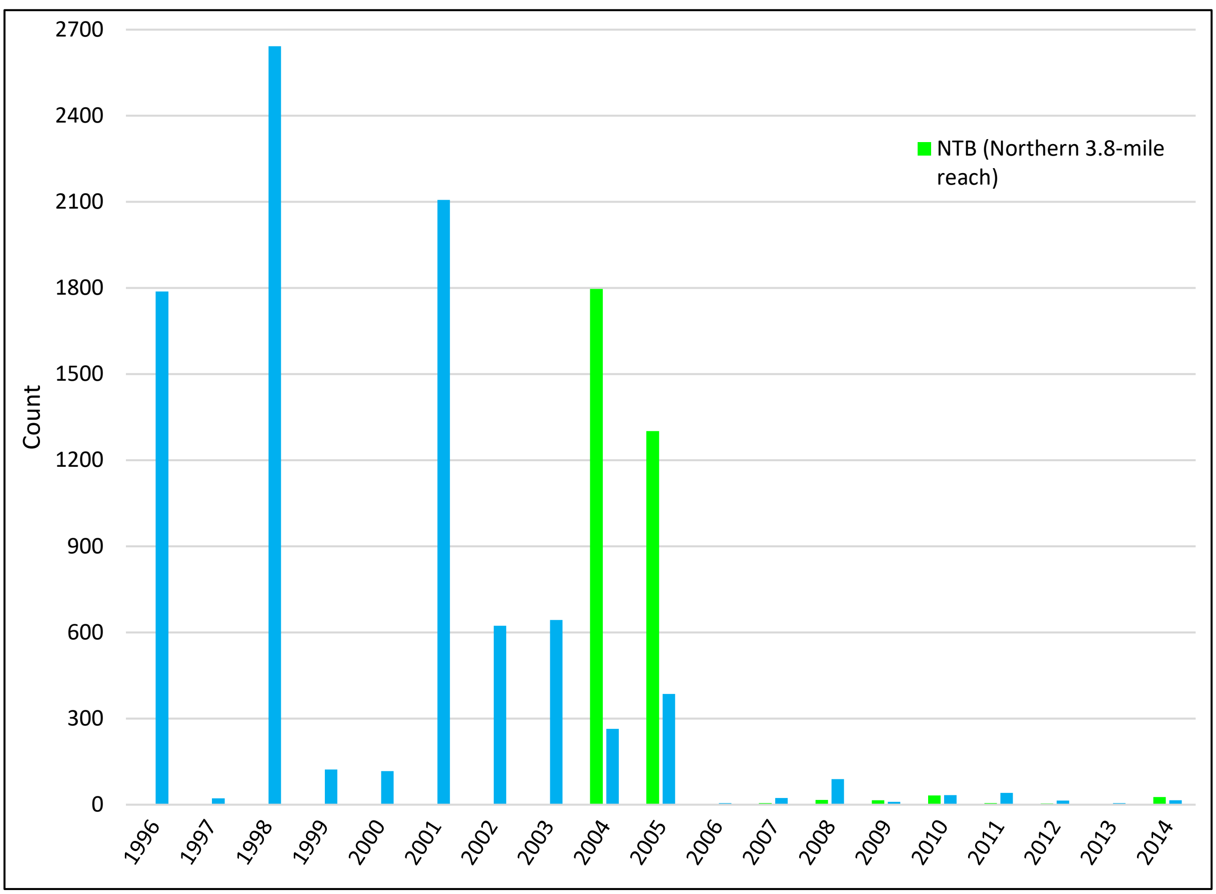


Figure 4-6. Annual seabeach amaranth counts 1996-2014

4.7 Cultural Resources

As a consequence of nearly 400 years of sustained maritime activity, coastal waters along Onslow County contain the remains of numerous historical shipwrecks. At least 25 shipwrecks have been recorded in the general vicinity of NRI (Table 4-15). None of the known shipwrecks are currently listed or proposed for listing in the National Register of Historic Places (NRHP). A number of submerged cultural resource investigations have been undertaken in the study area in support of the federal Surf City and NTB CSDR project and the non-federal NTB Shore Protection Project. Several remote sensing surveys were conducted in support of the original NRI realignment ebb channel design and subsequent pivot channel redesign processes. An initial investigation of the preliminary design channel in 2004 identified anomalies that were considered to have a moderate to high potential association with shipwrecks and/or other submerged cultural resources (TAR 2005). The channel design was subsequently modified to avoid these features, and an additional remote sensing survey of the final design channel footprint was performed in 2007 (TAR 2008). In support of the Town's subsequent proposal to modify the originally constructed ebb channel alignment, a third remote sensing survey of the proposed "pivot channel" was performed in 2016 (TAR 2016). No anomalies were detected in the pivot channel footprint. Additional remote sensing surveys covering the Town's offshore borrow site were performed by the USACE (MATER 2005) and the Town (TAR 2008). Neither of these surveys detected any anomalies within the offshore borrow site.

Table 4-15. Reported shipwrecks in the vicinity of NRI (TAR 2016)

Name	Type	Date Lost	Cause and Location
Unknown	Unknown	July 1737	Sank near mouth of New River
Sarah	Sloop	Dec 1747	Bear Inlet
Unknown	Sloop	July 1752	Bear Inlet
Henrietta	Sloop	Dec 1764	Bear Inlet
Unknown	Schooner	Apr 1765	Below Bear Inlet
Unknown	Sloop	Dec 1765	Near New River
Sally	Schooner	Mar 1799	East side of New River Bar
Seaman	Schooner	Mar 1837	Cast away at New River Inlet
Unknown	Schooner	Sept 1815	Mouth of New River
Pulaski	Side Wheel Steamer	June 1838	Exploded at New River Inlet
Marchioness of Bute	Ship	Jan 1853	Near Bear Inlet
Albion	Schooner	Mar 1858	Inside New River Bar
Multiple Unknown	Unknown	Sept 1861	Scuttled at Bear Inlet to prevent Union capture
USS Ellis	Side Wheel Steamer	Nov 1862	Burned near mouth of New River; Salvaged 1867
Nutfield	Side Wheel Steamer	Feb 1864	Burned at New River Inlet
Unknown	Schooner	Mar 1864	Burned at Bear Creek by Union forces
G.O. Bigelow	Schooner	Dec 1864	Destroyed at Bear Inlet by Union forces
Unknown	Unknown	1880	Stranded at mouth of New River
Lorenzo	Schooner	Aug 1880	New River Bar
Unknown	Unknown	1881	Stranded at mouth of New River
Unknown	Unknown	1884	Stranded at mouth of New River
Unknown	Unknown	1890	Stranded at Bear Inlet
Unknown	Unknown	1890	Stranded at New River Inlet
Unknown	Unknown	1894	Stranded at New River Inlet
Morris and Cliff	Schooner	Jan 1926	Lost ~1 mile west of Brown's Inlet

4.8 Public Interest Factors

4.8.1 Socioeconomic Resources

The Town of NTB is primarily a residential and resort community with a population comprised of permanent residents and seasonal inhabitants. The 2020 US Census reported a total of 1,005 permanent residents within the Town. In contrast, the estimated peak day population during the summer months is 28,844 individuals based on the number of seasonal housing units, campground sites, and public access parking spaces (Table 4-16). According to the NC Department of Revenue, the total value of taxable real property in NTB for fiscal year 2021-2022 was $961.8 million, which accounted for 15 percent of the overall Onslow County real property tax base of $6.6 billion (NCDOR 2022). Visitor spending is a major contributor to the economies of both the County and the Town. Direct visitor expenditures in Onslow County during 2021 totaled $338.5 million. Additional economic impacts in Onslow County directly attributable to visitor spending included 2,197 jobs, an $84 million payroll, and $27.1 million in state and local tax revenues (Tourism Economics 2022). Beach recreation in NTB generated an estimated $25.1 million in direct traveler expenditures during fiscal year 2013-2014 (Table 4-17). The total estimated impact on sales and business activity due to direct beach recreation expenditures and economic multiplier effects was over $38.1 million for 2013-2014. Furthermore, direct beach recreation expenditures in NTB supported an estimated 493 jobs within Onslow County (NCDEQ 2016). The Town collects a three percent accommodation tax on all hotel, motel, and condominium rentals. Accommodation tax revenues are allocated to the Town's shoreline protection fund for beach nourishment projects. Annual accommodation tax revenues for fiscal year 2015/2016 totaled $466,041. NRI provides an economically important connection between soundside harbors and ocean fishing waters. In 2015, the estimated total economic impact of recreational fishing charters through New River Inlet was 2.4 million (Table 4-18). Commercial landings attributable to trips through New River Inlet had a total economic impact of $7.3 million in 2015 (Table 4-19) (NCDEQ 2016).

Table 4-16. Town of NTB - Estimated Peak Day Population

Occupancy Type	Number of Units	Persons Per Unit	Seasonal Population Estimate
Campground Sites	577	3.5	2,020
Public Access Parking Spaces	1,212	4	9,696
Seasonal Housing Units	2,003	8	16,024
Permanent Residents			1,104
Total			**28,844**

Source: Town of North Topsail Beach 2019 CAMA Land Use Plan Update

Table 4-17. Town of NTB - Economic Impact of Beach Recreation 2013-2014

Direct Impact Expenditures	Total Impact Output/Sales/ Business Activity	Total Impact Employment	Total Local Tax Revenue	Total State Tax Revenue	Total Federal Tax Revenue	Annual Consumer Surplus
$25,103,828	$38,129,598	493	$1,921,311	$1,649,488	$2,734,575	$2,429,707

Source: NCDEQ 2016

Table 4-18. New River Inlet - Economic Impact of For-hire (Charter/Head Boat) Fishing 2015

Direct Impact Expenditures	Total Impact Output/Sales/ Business Activity	Total Impact Employment	Total Local Tax Revenue	Total State Tax Revenue	Total Federal Tax Revenue	Annual Consumer Surplus
$1,778,442	$2,379,549	84	$71,332	$68,514	$117,184	$2,848,193

Source: NCDEQ 2016

Table 4-19. New River Inlet - Economic Impact of Commercial Fishing 2015

Direct Impact Landings Value at Dockside	Total Impact Output/Sales/ Business Activity	Total Impact Employment	Total Local Tax Revenue	Total State Tax Revenue	Total Federal Tax Revenue
$5,475,273	$7,342,059	462	$90,820	$122,561	$241,061

Source: NCDEQ 2016

4.8.2 Land Use

Figure 4-7 depicts the existing land use classification of properties on the north end of NTB as presented in the Town's most recent (2019) CAMA Land Use Plan Update. Vacant land use accounts for 76% of the total municipal land area, followed by residential (14%) and rights-of-way (9%) (Table 4-20). Additional land uses, including commercial, office/institutional, and recreation, account for less than 1% of the total municipal land area. Residential land use is comprised predominantly of single family homes, although oceanfront development on the north end includes a number of high rise condominium structures. The 2020 US Census reported a total of 2,675 housing units within the Town of NTB including 545 permanently occupied units and 2,130 seasonal units (Table 4-21). Approximately 80 percent of the housing units are secondary vacation homes that are occupied or rented out on a seasonal basis. A non-conforming parcel analysis determined that the majority of the vacant parcels are suitable for residential development (CAMA Land Use Plan). Onslow Beach is part of Marine Corps Base Camp Lejeune and is divided into four principal land use zones. The south end study area reach of the island is managed primarily for conservation, but also supports low impact military training and seasonal recreational off-road vehicle use. The remainder of the island to the north is divided among amphibious military training, recreation, and impact area land use zones.

The majority of the study area is encompassed by designated System Units within the John H. Chafee Coastal Barrier Resources System (CBRS). The CBRS was established under the Coastal Barrier Resources Act (CBRA) of 1982 to discourage the development of hurricane prone, biologically sensitive coastal barrier islands. The CBRA prohibits most new federal expenditures that encourage or subsidize barrier island development. The CBRA established the John H. Chafee Coastal Barrier Resources System (CBRS) consisting of barrier islands that are either undeveloped or predominantly undeveloped. The CBRS includes two types of designated units; System Units and Otherwise Protected Areas (OPAs). CBRS System Units L06 (Topsail) and L05 (Onslow Beach) encompass the majority of the study area (Figure 4-8). The only exception is the northernmost ~3,000-ft subaerial reach of NTB, which is excluded from Unit L06. In System Units, new development and projects that involve substantial improvements of existing structures are not eligible for most types of federal funding and assistance; including the National Flood Insurance Program (NFIP) and subsidies for road construction, channel dredging, and other coastal engineering projects.

Table 4-20. Existing Land Use - Town of North Topsail Beach

Class	Area (acres)	Percent of Land Area
Vacant	3,299.91	75.48%
Residential	614.89	14.06%
Right-of-way	388.18	8.88%
Commercial	41.94	0.96%
Multi-Family Residential	6.67	0.15%
Office & Institutional	6.55	0.15%
Recreational	13.86	0.32%
Total	**4372.0**	**100%**

Source: Town of NTB CAMA Land Use Plan 2019 Update

Table 4-21. Town of North Topsail Beach - Housing Characteristics

Bedrooms	Percent of Housing
No Bedroom	0.9
1 Bedroom	4.5
2 or 3 Bedrooms	70.8
4 or more bedrooms	23.8

Source: 2020 US Census

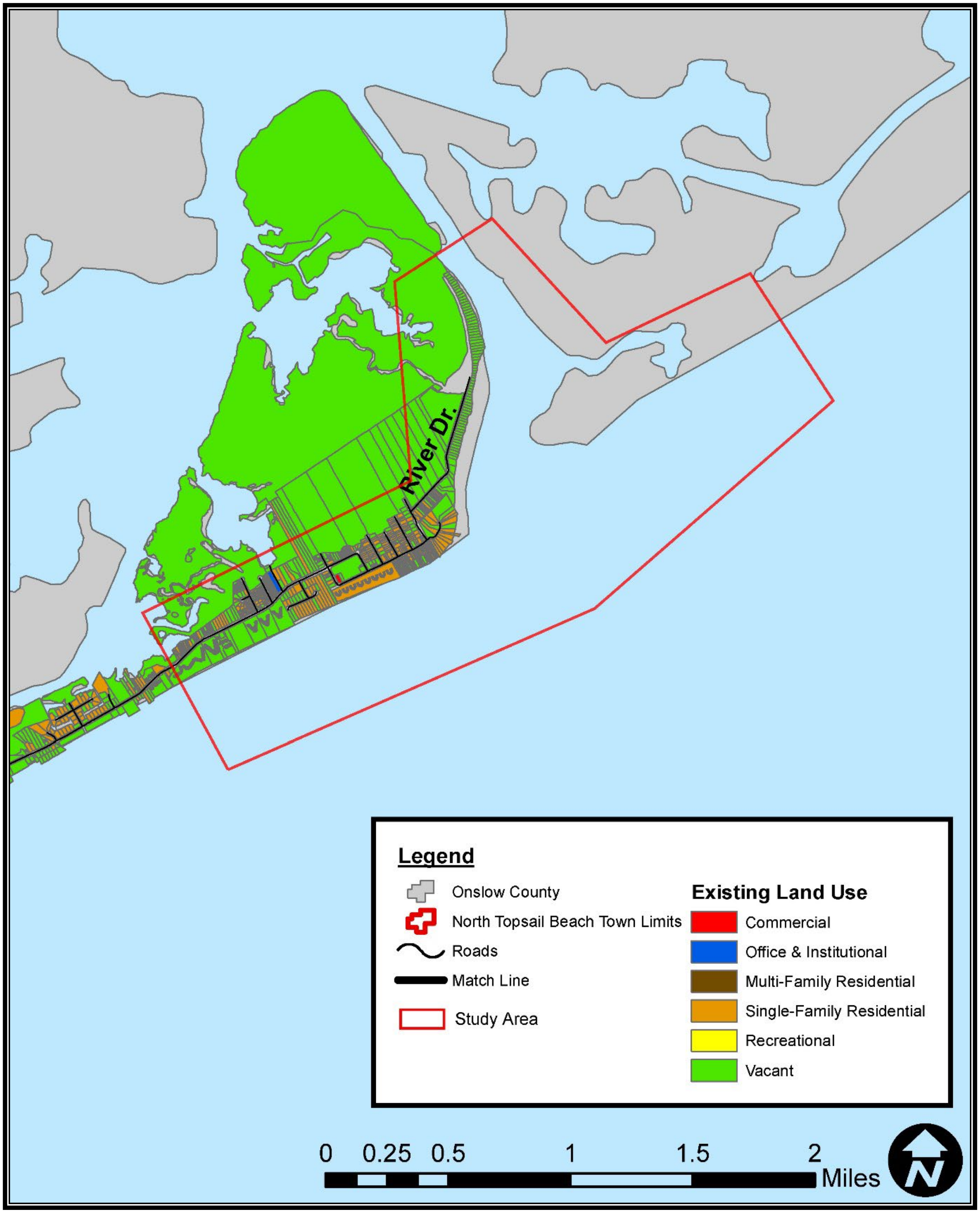


Figure 4-7. NTB Existing Land Use (Town of NTB CAMA Land Use Plan 2019 Update)

May 1, 2023

CBRS Buffer Zone   System Unit

CBRS Units

Otherwise Protected Area

Figure 4-8. Coastal Barrier Resources System - System Units

4.8.3 Aesthetic Resources

Aesthetic resources include the physical, biological and cultural landscape elements that contribute to perceptions of scenic beauty. North Carolina's barrier islands are highly valued for their natural beauty. Important natural landscape elements of these islands include marine and estuarine water resources, sandy beaches, dunes, maritime forests, saltmarshes, and associated wildlife. Cultural elements, such as historic coastal structures, contribute to a sense of place and the perception of barrier islands as a unique scenic resource. The scenic beauty of NC's barrier islands is reflected in their popularity as a tourist destination. Surveys of beach visitors in NC indicate that tourists and residents consider natural beauty, wide sandy beaches, visible wildlife, and historical structures to be important elements of a positive beach experience (Ellis and Vogelsong 2005). The dune/beach/ocean system is a highly visible public resource that is readily accessible to the general public via numerous access points along the entire island.

4.8.4 Recreation

The north end of NTB encompasses approximately 1.8 miles of publicly accessible oceanfront and inlet beaches that provide visitors with a wide range of recreational opportunities; including relaxing, sunbathing, beach combing, wildlife viewing, swimming, surfing, fishing, and beach driving. The adjoining ocean, inlet and estuarine waters provide additional recreational opportunities for water-based activities such as recreational boating, kayaking, and paddleboarding. Public access to the north end beaches is provided through a system of Town- and County-maintained facilities and accessways; including three access sites that include parking areas and amenities and numerous additional dune crosswalks. Beach access #3 at NRI provides vehicular access to a designated public beach driving area (4x4 Drive-On Area) along the NRI shoreline. NTB is a popular tourist destination with an estimated peak day population of 28,844 individuals during the summer (Insight 2021). As previously described, visitor spending on beach recreation is a major contributor to the economies of both the Town and Onslow County, with an estimated economic impact of over $2.4 M annually. As part of Marine Corps Base Camp Lejeune (MCBCL), Onslow Beach is off-limits to the general public. The south end of Onslow Beach is managed primarily for conservation and low-impact military training, but provides limited recreational opportunities for military personnel and their families in the form of seasonal recreational off-road vehicle use and surf fishing.

4.8.5 Infrastructure

Water and Wastewater

The Onslow Water and Sewer Authority (ONWASA) provides central water service throughout the Town of NTB and serves ~2,690 accounts (Insight 2021). As of 2019, the ONWASA system was operating at 90 percent capacity. Town water usage accounts for ~4.3 percent of the system's capacity during the peak summer months and ~1.8 percent during the winter off-season months. All of the ONWASA system water supply wells are located on the mainland. There are ~3.5 miles of water mains on the north end of NTB. Existing north end water mains totaling ~3.5 miles are distributed along the entirety of New River Inlet Road and all of the local subdivision roads. Pluris, LLC provides central sewer service throughout the majority of the Town. A few properties continue to be served by private on-site septic systems or private package treatment plants. Pluris has a total permitted operating capacity of 1,542,635 gallons per day (gpd) and is currently operating at 75 percent capacity. Existing north end sewer mains totaling ~3.5 miles are distributed along the entirety of New River Inlet Road and the majority of the local subdivision roads. There is no water or wastewater infrastructure on the south end of Onslow Beach.

Transportation

Transportation infrastructure on the north end of NTB includes 1.4 miles of state-maintained roadway (New River Inlet Road) and ~2.0 miles of local subdivision roads that are maintained by the Town. New River Inlet Road (SR 1568) is the main thoroughfare providing access to the north end of NTB. New River Inlet Road originates at the NC Highway 210 Bridge in central NTB and extends north ~5.3 miles to New River Inlet. Access to Topsail Island across the AIWW is provided by two high rise bridges, including the NC Highway 210 Bridge in central NTB and the NC Highway 210 Bridge in Surf City. As of the 2019 CAMA Land Use Plan Update, there were no proposed transportation projects within the Town of NTB (Insight 2021). Roads are absent from the south end of Onslow Beach.

4.8.6 Public Safety

Boating and Water Safety

Recreational vessel operations in study area are subject to concurrent state and federal safety regulations under Title 46 of the US Code and the North Carolina Boating Safety Act. The NCWRC Division of Enforcement has assumed the primary responsibility for enforcing both federal and state safety regulations under a cooperative agreement with the USCG. Since 2015, the NCWRC has reported a total of 39 boating accidents in Onslow County, including four accidents that resulted in fatalities (Table 4-22). The vast majority of accidents (>90%) in NC waters occur during the months of April through October. Collision with vessel is the leading cause of boating accidents in NC. Shoaling of the NRI ocean bar channel has been an ongoing navigation safety concern. Although the USACE has historically conducted frequent maintenance dredging of the NRI and AIWW Crossing navigation channels, recent cuts to the USACE budget for shallow draft inlet dredging have resulted in unsafe or impassable conditions for commercial and recreational vessels. In 2016, Onslow County took action to address ongoing navigation safety concerns by funding and performing maintenance dredging of the NRI and AIWW Crossing channels. The NTB Fire Department provides water rescue services for beach-goers and conducts regular patrols of the beach strand on ATVs during the peak visitor season.

Table 4-22. Boating accidents in Onslow County 2016-2022

Year	Total Fatal	Alcohol-Related Fatal	Total Non-Fatal	Alcohol-Related Non-Fatal	Total Accidents
2022	0	0	6	0	6
2021	1	0	5	0	6
2020	1	0	4	0	5
2019	1	1	3	1	4
2018	1	0	5	0	6
2017	0	0	4	0	4
2016	0	0	8	1	8
Total	**4**	**1**	**35**	**2**	**39**

Hazardous, Toxic, and Radioactive Wastes (HTRW)

In 1989, the United States Environmental Protection Agency (USEPA) placed Camp Lejeune on the National Priorities List (NPL) of sites that are federally regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); informally known as the Superfund program. The inclusion of Camp Lejeune on the NPL was based on soil and groundwater contamination caused by historical disposal, storage, and handling of hazardous materials; including unexploded ordnance (UXO). Camp Lejeune has since conducted a series of environmental studies and cleanup activities under the US Department of Defense (DoD) Environmental Restoration Program (ERP). Currently, there are numerous hazardous waste and UXO sites [Operational Units (OUs)] on Camp Lejeune that are in various phases of the CERCLA process. There are no OUs within the study area, and the only OU on the island of Onslow Beach is a former water tower site ~5 miles north of NRI where the historical use of lead based paint resulted in soil contamination. The only in-water OU is a UXO site in the New River ~9 river miles above NRI. Based on a review of NCDEQ Division of Waste Management GIS data[3] there are no additional active or inactive hazardous sites in the vicinity of the study area.

4.8.7 Water Quality

All water bodies in NC are assigned a surface water classification that defines the best uses to be protected (e.g., water supply, swimming, fishing). Each classification is subject to a specific set of water quality standards that are designed to protect the designated uses. All ocean waters within the study area are Class SB tidal salt waters that are protected for primary recreational activities involving full body contact (e.g., frequent or organized swimming). Class SB waters are subject to water quality standards for fecal coliform bacteria. All inshore waters of the study area are Class SA tidal salt waters that are protected for commercial shellfishing as well as all Class SB uses. Class SA waters are subject to fecal coliform bacteria standards, restrictions on domestic wastewater discharges, and specific stormwater control measures. All SA waters in the action area are also assigned the supplementary classification of High Quality Waters (HQW), which are waters having excellent water quality and/or important functions such as those associated with PNAs. Class SA commercial shellfishing waters are assigned a Shellfish Growing Area Status of Approved, Conditional, or Prohibited based on NCDMF Shellfish Sanitation and Recreational Water Quality Section fecal coliform criteria. The 2022 NC 303d list identifies the majority of the Class SA estuarine waters to the west of NRI as Prohibited based on exceedances of the fecal coliform standard for SA waters.

4.8.8 Navigation

The Wilmington District USACE maintains a number of federal navigation channels in the vicinity of the study area that are used by recreational, commercial, and military vessels, including NRI, the AIWW, and the Channels to Jacksonville. The NRI federal navigation project consists of a 6-ft-deep by 90-ft-wide channel extending seaward from the AIWW through the inlet throat and across the ebb tidal delta to the natural 6-ft depth contour in the Atlantic Ocean. The AIWW consists of a 12-ft-deep by 90-ft-wide channel extending through the back-barrier estuaries behind NTB and Onslow Beach and across NRI at the mouth of the New River Estuary. The AIWW channel segment across NRI is known as the AIWW NRI Crossing. The Channels to Jacksonville navigation project consists of a 12-ft-deep by 90-ft-wide channel extending north from the AIWW

[3]https://www.deq.nc.gov/about/divisions/waste-management/science-data-and-reports/waste-management-gis-data-and-maps

NRI Crossing through the New River Estuary to a point just south of NC HWY 24 in Jacksonville, NC. The federal channels are maintained either by USACE dredges or private dredges under contract to the federal government. The outer NRI channel across the ocean bar is maintained by sidecaster dredges, which discharge the dredged material to open waters adjacent to the navigation channel. Maintenance dredging of the ocean bar channel follows the existing deepwater ebb channel, with no attempt being made to maintain a fixed channel alignment. The remainder of the NRI channel along with the AIWW Crossing and Channels to Jacksonville are maintained by hydraulic cutterhead dredges, with dredged material placement via direct pipeline delivery to the NTB north end oceanfront beach and/or DA-143.

4.8.9 Hydrodynamics

Ocean currents on the inner continental shelf of Onslow Bay are controlled primarily by tides and local wind stress, with tides being the principal driver of cross-shelf currents and wind stress the principal driver of alongshore currents (Pietrafesa et al. 1985a, 1985b). Mean annual alongshore tidal flow is to the northeast, as are monthly mean flows with the exception of reversals during February, July, and October. Mean cross-shelf flow is offshore during the winter and onshore during the summer. USACE Wave Information Studies (WIS) wave hindcast data for Station 63284 located approximately nine miles offshore of NRI indicate that the study area wave climate is dominated by small (0.5-1.5 m), short period (predominantly 7-10 seconds) wind waves out of the south to southeast quadrant (https://wisportal.erdc.dren.mil/). During the spring and summer, prevailing winds are out of the southwest, and the wave climate is dominated by relatively small waves that approach from the south. As the prevailing winds shift to the northeast in the fall, the predominant direction of wave approach shifts to the southeast and wave heights increase. During the winter, relatively strong winds from the southwest, northwest, and northeast predominate, and the wave climate is dominated by relatively large waves that approach from the southeast.

NRI drains the New River Estuary and connects the back-barrier lagoonal estuaries with the Atlantic Ocean. Various navigation improvements since the 1930s have resulted in significant changes to the hydrodynamics of NRI (Cleary 2014). Construction of the AIWW in the 1930s and construction of a connecting channel (Cedar Bush Cut) between the AIWW and NRI in 1940 increased inlet hydraulic connectivity with the New River and back barrier estuaries. The increases in hydraulic connectivity in turn caused widening of the inlet throat and enlargement of the ebb tidal delta. Over the 20-year period from 1938 to 1958, the area of the ebb-tidal delta is estimated to have increased from 1.63 million ft^2 to 9.53 million ft^2, with a corresponding increase in the ebb tidal delta sediment volume from 1.5 MCY to 8.8 MCY (Jarrett 2002). Based on the increase in the ebb-tidal delta sediment volume, the ebb tidal prism (i.e., the total volume of water flowing through the inlet over the course of a single ebb tide event) is estimated to have increased by a factor of four from 180 million cubic feet to 750 million cubic feet. CPE (2010) used the Advance Circulation Model for Shelves, Coasts, and Estuaries (ADCIRC) to model the ebb and flood tidal prisms through NRI, resulting in a similar predicted ebb tidal prism water volume of 784 million cubic feet and a predicted flood tidal prism volume of 598 million cubic feet.

4.8.10 Shoreline Change

Erosional and accretional oceanfront shoreline trends along the north end of NTB are largely dictated by inlet ebb channel migration patterns and associated changes in ebb-tidal delta symmetry (CPE 2010, Cleary 2014). The ebb tidal delta has a wave sheltering effect on the north end shoreline that varies according to the ebb channel alignment and ebb tidal delta configuration. Analyses of historical shoreline and inlet ebb tidal delta changes indicate that the north end shoreline has experienced periods of accretion when the outer ebb channel was aligned towards the southwest, whereas northeasterly ebb channel alignments have produced erosional conditions. Calculated long term (1949-2016) average annual erosion rates for the inlet-influenced north end oceanfront shoreline range from 1 to 17 ft/yr (NCDCM 2019). However, the north end shoreline has experienced relatively high rates of background erosion since the early 1990s, with annual erosion rates as high as 100 ft/yr occurring in the vicinity of the Topsail Reef condominium complex. The current erosional trend along the north end of NTB was initiated by a northeastward shift in the NRI ebb channel alignment that began in the early 1990s. The northeastward shift in the channel alignment initiated a corresponding northeastward shift in the inlet ebb tidal delta, which in turn exposed the north end shoreline to increased onshore wave energy. Since 1996, the 5,100-ft north end shoreline has experienced net recession ranging from 70 to 240 ft. Currently, the north end shoreline is largely maintained in a fixed position by ~3,600 lf of sandbag revetments.

The south end of Onslow Beach has experienced high long-term erosion rates that are primarily the result of historical navigation improvements that modified inlet hydrodynamics, including construction of the AIWW in the 1930s and construction of a connecting channel (Cedar Bush Cut) between the AIWW and NRI in 1940 (Cleary et al. 2001, Cleary 2014). As previously described (see Section 4.8.10), resulting inlet changes from 1938 to 1958 included a six-fold increase in the area of the ebb-tidal delta and a fourfold increase in the ebb tidal prism. Although the estimated average annual erosion rate from 1857 to 1933 was less than 1.1 ft/year (USACE 1989), the estimated average annual erosion rate from 1938 to 1980 increased to 6.6 ft/year, with localized rates as high as 26 ft/year (Benton et al. 1993). The most recent NCDCM calculated long term (1949-2017) average annual erosion rates for the south end of Onslow Beach range from 8 to 12 ft/yr (NCDCM 2019).

4.8.11 Non-Relevant Public Interest Factors

4.8.11.1 Air Quality

Pursuant to the Clean Air Act (CAA) [42 United States Code (USC) 7401 et. seq.], the USEPA has set National Ambient Air Quality Standards (NAAQS) for commonly occurring “criteria pollutants” that may harm public health or the environment. National Ambient Air Quality Standards have been established for seven criteria pollutants: nitrogen dioxide (NO2), carbon monoxide (CO), particulate matter less than ten microns in diameter (PM10), particulate matter less than 2.5 microns in diameter (PM2.5), sulfur dioxide (SO2), lead (Pb), and ozone (O3). All US counties are assigned a designation of either “attainment,” “maintenance,” or “non-attainment” for each individual criteria pollutant. The North Carolina Division of Air Quality (NCDAQ) maintains an ambient air monitoring network for those criteria pollutants requiring monitoring by the Environmental Protection Agency (EPA). Areas that exceed EPA national ambient air quality standards based on regional ambient air monitoring are designated as non-attainment areas. Onslow County is currently designated as an attainment area for all criteria pollutants (USEPA 2023). Marine Corps Base Camp Lejeune is regulated under Title V of the CAA as a major stationary source of air emissions. Stationary source air emissions are generated on the mainland portion of the installation by oil and fuel-fired generators, engine testing facilities, painting facilities, and a solid waste landfill.

4.8.11.2 Noise

Sources of ambient subaerial noise in the study area include breaking waves in the surf zone, beach recreational activities, commercial and recreational vessel traffic, and vehicular traffic. The Town of NTB noise ordinance (Article VII Noise Control) prohibits daytime noise emissions that exceed 70 decibels (dB) and nighttime noise emissions that exceed 50 dB. There are no major noise sources such as airports or industrial facilities that would produce sound levels that are incompatible with existing land use in the study area.

4.8.11.3 Light

Existing sources of artificial nighttime light in the study area include residential and commercial exterior lighting, street lights, lighted signs, public parks, lighted docks and piers, and vehicular headlights. Artificial nighttime lighting has been implicated in the disruption of animal behavior. Responses of organisms to artificial nighttime light; including attraction, repulsion, and disorientation; can affect foraging behavior, reproduction, and migration (Longcore and Rich 2004). Artificial lighting on the ocean beach can deter nesting sea turtles from emerging onto the nesting beach and impair the ability of sea turtle hatchlings to properly orient to the ocean (Witherington 1992, Witherington and Martin 2003). Upward light spill from unshielded fixtures can attract or disorient migrating birds, leading to collisions with lighted structures or causing birds to continuously circle lighted platforms (Nightingale et al. 2006). The Town of NTB lighting ordinance [§6.02.02 (C) Outdoor Lighting] is designed to control light spillage and ensure that excessive lighting and glare are not directed at the beachfront and/or sound front. Outdoor lighting on the ocean side of oceanfront dwellings must consist of low voltage indirect or full cut-off fixtures and must not illuminate any part of the dune or public beach area.

5.0 ENVIRONMENTAL CONSEQUENCES

Analyses of the environmental consequences of the alternatives are organized into four main components: Section 5.1 describes the impact analysis methodology that was used to evaluate the effects of the five alternatives, Section 5.2 describes and compares projected shoreline and habitat changes under the alternatives based on morphological modeling, and Section 5.3 describes the general effects of similar dredging and beach fill placement activities under the with-project alternatives (i.e., Alternatives 1, 3, 4, and 5). More detailed analyses that address the effects of each alternative on each environmental resource category are presented in Appendix D.

5.1 Impact Analysis Methodology

This section describes the methods that were used to evaluate the environmental consequences (hereinafter referred to synonymously as effects and impacts) of the five alternatives in accordance with the CEQ regulations for implementing the NEPA (40 CFR 1500 *et. seq.*). The analysis of each alternative considers the direct, indirect, and cumulative effects on the natural and human environment. As defined by CEQ regulations, direct impacts are those occurring at the same time and place as the proposed action while indirect impacts are those occurring later in time or at a greater distance from the proposed action. Cumulative impacts are those caused by the effects of the proposed action when added to the effects of other separate past, present, and reasonably foreseeable future actions regardless of the agency or person that undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. The projected direct, indirect, and cumulative impacts of the three action alternatives (Alternatives 3, 4, and 5) are evaluated against the projected impacts of two no action alternatives (Alternatives 1 and 2) (Table 5.1). The Alternative 1 no action scenario represents the continuation of current beach and inlet management practices without modification; including periodic nourishment of the north end shoreline and periodic dredging to maintain the currently authorized NRI ebb channel alignment (i.e. pivot channel). Alternative 2 represents a “no management” scenario without any federally authorized beach and inlet management activities being undertaken by the Town. Alternatives 3, 4, and 5 represent alternative management plans for maintaining a 5,100-ft-long dune and berm beach fill project along the north end shoreline over the next 30 years.

Table 5-1. Alternatives

<table>
<tr><td rowspan="2">No Action Alternatives</td><td>Alternative 1</td><td>No Action (Status Quo): Continue currently authorized beach and inlet management</td></tr>
<tr><td>Alternative 2</td><td>Abandon and Retreat: No federally authorized beach or inlet management by the Town of NTB</td></tr>
<tr><td rowspan="3">Action Alternatives</td><td>Alternative 3</td><td>Beach Nourishment Only</td></tr>
<tr><td>Alternative 4</td><td>Beach Nourishment and Terminal Groin</td></tr>
<tr><td>Alternative 5</td><td>Beach Nourishment, Terminal Groin, and Inlet Management (Applicant’s Preferred Alternative)</td></tr>
</table>

5.1.1 Direct and Indirect Impact Analysis

Direct and indirect impacts were analyzed through a combination of quantitative and qualitative methods. GIS spatial analysis was used to quantify the direct impacts of the alternatives on physical and biological habitats by superimposing the beach fill, dredging, and groin footprints of disturbance on baseline habitat maps. Morphological modeling was used to evaluate the effects of the alternatives on coastal processes and morphological change trends within the study area. As described in detail below, the model outputs include projected changes in bathymetry and topography that were used to quantify shoreline and habitat area changes under the various alternatives. Effects on species and biological communities were primarily assessed qualitatively based on direct habitat effects, indirect model-projected habitat changes, and review of the best available scientific information; including scientific literature, biological and physical monitoring studies, and government resource agency reports.

5.1.1.1 Morphological Modeling

The Delft3D modeling system was used to evaluate the effects of the five alternatives on coastal morphology (i.e. topography and bathymetry) within the study area. Delft3D is a process-based model that simulates hydrodynamic, sediment transport, and morphological processes and evaluates the responses of these processes to human interventions such as beach nourishment, dredging, and the construction of jetties and groins. In marine and coastal systems, morphological changes are ultimately the result of sediment redistribution via processes of erosion, transport, and deposition. The model inputs include baseline topographic and bathymetric data sets representing initial beach and seafloor morphological conditions. As the simulations run, the model calculates changes in sediment transport and continuously updates the initial topography and bathymetry in accordance with the calculated changes. Model simulations representing each of the five alternatives were run for a period of four years. The four-year model runs were developed to represent wave, current, and meteorological forcing conditions within the study area during the period of 2015-2018. Coastal model applications that reproduce prior conditions (hindcasting) allow for the use of existing measured data sets and the calibration of models under known forcing conditions, thereby increasing the robustness of model outputs. Selection of the 2015-2018 period was based on a number of factors; including the erosional condition of the initial 2015 shoreline, the projected renourishment intervals under the alternatives, and the occurrence of extreme storm events during the four-year period. The initial 2015 shoreline is in an eroded condition that is representative of anticipated shoreline conditions at the end of a typical four-year nourishment cycle. Erosion has removed all of the beach fill material from previous projects that might otherwise mask the effects of the alternatives. The duration of the model runs covers an entire four-year beach nourishment cycle; beginning with an initial nourishment event and ending at the point when the next renourishment event is expected to be required. In addition to the inclusion of forcing conditions that drive long-term background erosional processes, the inclusion of extreme storm events in the modeling runs is required to evaluate short-term storm-induced morphological changes. The 2015-2018 period captures the effects of an extreme storm event; Hurricane Matthew (2016).

As described above, the main model outputs are bathymetric and topographic data sets representing conditions at the end of the four-year model runs. For purposes of quantifying projected shoreline and habitat changes, the initial (input) and final (output) bathymetric/topographic data sets for the alternatives were converted to depth/elevation contour layers. GIS analysis of the contour layers was then used to calculate average beach widths and habitat acreages for both initial and final conditions. The initial values were then subtracted from the final values to generate projected beach width and habitat area changes. Beach width and habitat area calculations were based on the positions of the MHW and MLW contours. The MHW and MLW contours represent the boundaries between supratidal (above MHW), intertidal (between MHW and MLW), and subtidal (below MLW) habitats. Projected changes in the positions of the MHW/MLW contours over the four-year model runs result in conversions between these habitat types. To allow for discrete assessments of habitat changes within the oceanfront, inlet, and estuarine systems; the study area was divided into six habitat compartments. Projected habitat area changes were calculated for the individual compartments. Beach width measurements represent the cross-shore distance between the MLW contour and the toe of the primary dune or sandbag revetment, as applicable. Beach width measurements at 200-ft intervals (n=26) along the north end project shoreline were used to calculate average beach widths for the alternatives. The calculations described thus far yield the absolute beach width and habitat area changes under the individual alternatives. However, pursuant to NEPA, the projected changes under Alternatives 1, 3, 4, and 5 are ultimately evaluated against the projected changes under Alternative 2. Model-projected changes under Alternative 2 (Abandon and Retreat) are primarily driven by interactions between forcing conditions (e.g., waves, currents, and storms) and natural coastal processes (e.g., hydrodynamics and sediment transport); whereas projected changes under Alternatives 1, 3, 4, and 5 are driven by interactions between forcing conditions, natural coastal processes, and various engineered shore protection measures (i.e. beach nourishment, dredging, terminal groin construction).

GIS analysis of the projected MHW contour changes was also used to assess changes in the erosional hazard risk to properties on the north end of NTB. Properties at-risk were defined as those having a parcel boundary within 25 ft of the projected MHW contour. Determinations of at-risk parcels under Alternatives 1, 3, 4, and 5 were based on the Delft3D model-projected MHW contour positions at the end of the four-year model runs. The projected MHW contour positions under 1, 3, 4, and 5 are representative of conditions at the end of a nourishment cycle just prior to the next scheduled renourishment event. Thus, based on recurring nourishment events at two- or four-year intervals, the model-projected MHW contour positions represent the anticipated maximum landward extent of MHW recession over the 30-year project life. In the case of Alternative 2, the four-year model-projected MHW line would continue to recede over the remainder of the 30-year period, progressively placing more properties at-risk of erosional damage. In order to capture the full extent of potential erosional impacts, the USGS Digital Shoreline Analysis System (DSAS) was used to project the 30-year position of the MHW line under Alternative 2. The DSAS is an add-in to ArcGIS that enables the calculation of rate-of-change statistics from multiple historical shoreline positions. Application of the DSAS utilized historical shorelines that predate the sandbag revetment, and only those representing conditions without beach fill on the north end. Properties at-risk were determined for all alternatives by overlaying the projected MHW contours on the Town of NTB tax parcel GIS layer. The potential economic impacts associated with erosion risk were estimated as the total assessed tax value of the at-risk properties.

Morphological modeling provides valuable information for understanding coastal change, evaluating the likely outcomes of alternative coastal management scenarios, and supporting informed decision-making. Delft3D is a highly robust process-based model that was developed and calibrated for the study area using high quality, local measured data sets that are derived from a long history of coastal engineering studies and monitoring programs; including USACE CSRM Feasibility Studies, supporting investigations for the NTB Shoreline Protection Project, the Town of NTB beach profile monitoring program, oceanographic monitoring programs, and USACE hydrographic surveys. However, regardless of the model employed and the quality of the input data, there are always considerable uncertainties and limitations associated with the prediction of morphological change in highly complex and variable coastal systems. Accordingly, coastal models are neither intended nor expected to provide accurate absolute predictions of future conditions. When applied to coastal engineering design, modeling results are interpreted as indicators of the relative performance of design alternatives. Quantitative metrics (e.g., beach width and habitat area changes) and graphic outputs (e.g., bathymetric plots) that are used to represent the model output data are important tools for understanding the modeling results and comparing projected changes under the various alternatives. However, these metrics are intended for use as aids to help visualize broader morphological change trends and should not be interpreted as absolute predictions of future conditions under the alternatives.

5.1.2 Cumulative Effects Analysis

As defined by the CEQ regulations, cumulative effects are those caused by the effects of a proposed action when added to the effects of other separate past, present, and reasonably foreseeable future actions regardless of the agency or person that undertakes such actions. The potential cumulative effects of the alternatives were evaluated at local and regional geographic scales. Analyses of local-scale cumulative effects, which are included with the analyses of direct and indirect effects, consider the effects of the alternatives in combination with the effects of similar coastal engineering activities in the general vicinity of the study area. The more comprehensive regional-scale cumulative effects analysis, which is provided as a stand-alone document in Appendix E, considers the effects of the proposed action in combination with the effects of similar coastal engineering activities along the southern NC coast between Cape Lookout and the NC/SC border. Cape Lookout divides the NC coast into northern and southern regions that are distinct in terms of geological framework, beach and inlet management activity, and coastal development; whereas the NC/SC border represents the southern limit of Wilmington District regulatory authority over coastal engineering activities.

The local and regional-scale analyses focus on separate actions that are similar to the proposed action, including beach nourishment, the construction of groins and jetties, navigation dredging, and ocean borrow site dredging activities. Analyses emphasize the potential for temporal and spatial overlap between the effects of the alternatives and those of separate actions. Cumulative effects can occur when the time required for resources to recover from a single impact event is greater than the time between repeated impact events. Cumulative effects can also occur when the proximity and timing of spatially separate actions are such that their impacts overlap. The timeframe of the analysis encompasses the 64-year period from 1995 through 2058. This timeframe encompasses all of the past locally-funded non-federal nourishment activities on NTB, the trend of increasing beach nourishment activity along the southern NC coast that has been ongoing since the mid-1990s, and the future 30-year project life of the proposed action.

The geographic scope of the local-scale cumulative effects assessment encompasses the study area, the adjoining oceanfront beaches along Topsail Island between the study area and New Topsail Inlet, and the nearshore ocean waters and offshore borrow sites along the adjoining beaches of Topsail Island. Separate beach fill actions considered in the analyses of local-scale cumulative effects include USACE north end beach placement of dredged material from the NRI and AIWW Crossing navigation channels, the NTB Shoreline Protection Project, the Surf City CSRM Project, the Topsail Beach CSRM Project, and the Town of Topsail Beach 30-year Beach Management Plan (Table 5-2). Separate navigation dredging actions considered include USACE maintenance activities in the NRI and AIWW NRI Crossing channels (Table 5-3), and separate offshore borrow site dredging activities include those associated with the NTB Shoreline Protection Project, Surf City CSRM Project, and Topsail Beach CSRM Project (Table 5-4). Separate actions that are considered in the regional-scale cumulative effects assessment are described in Appendix E.

Table 5-2. Separate beach fill actions in the vicinity of the study area

Shoreline Reach	Renourishment Interval	Project Length (miles)
USACE Beach Placement of Navigation Dredged Material	variable	1.0
NTB Shoreline Protection Project - Phase 2	≥4 yrs	1.9
NTB Shoreline Protection Project - Phase 3	≥4 yrs	2.2
NTB Shoreline Protection Project - Phase 4	≥4 yrs	1.3
NTB Shoreline Protection Project - Phase 5	≥4 yrs	3.9
Surf City CSRM	6 yrs	6.0
Topsail Beach CSRM	4 yrs	5.0
Topsail Beach 30-yr Beach Management Plan	5 yrs	4.7
Total Length		**20.4**

Table 5-3. Separate navigation dredging actions in the vicinity of the study area

Channel Reach	Width	Depth	Length (miles)
NRI - Ocean Bar Channel and Cedar Bush Cut	90	6	2.6 mi
AIWW NRI Crossing	90	12	2.6 mi
NRI - Channels to Jacksonville	90	12	20.0 mi
Total Length			**25.2**

Table 5-4. Separate offshore borrow site dredging actions

Borrow Site	Distance (miles)	Number of Sites[1]
NTB Shoreline Protection Project	0.4 - 1.6	1
Surf City CSRM	1.0 - 6.0	Multiple sites off Topsail Island
Topsail Beach CSRM	1.0 - 6.0	Multiple sites off Topsail Island

5.2 Effects of the Alternatives on Shoreline Change

This section describes the Delft3D model-projected shoreline, habitat, and sediment volume changes under the alternatives and compares the projected changes under Alternatives 1, 3, 4, and 5 to the baseline projected changes under Alternative 2. The discussion of projected changes is divided among three sections covering the NTB north end oceanfront shoreline, the NRI complex, and the Onslow Beach south end oceanfront shoreline. As previously described, for impact analysis purposes, the shoreline is defined as the MSL (0-m NAVD88) contour and beach width is defined as the cross-shore distance between the MSL contour and the toe of the primary dune or sandbag revetment. Projected habitat losses and gains were derived from model-projected changes in the MHW and MLW contours. Sediment volume changes represent the difference between initial (Year-0) and model-projected final (Year-4) volumes above the seaward limit of the north end equilibrium beach profile (26-ft contour).

5.2.1 NTB North End Oceanfront Shoreline

Under Alternative 2, the starting position of the north end shoreline at the beginning of the model run is representative of eroded conditions at the end of a nourishment cycle when all previously placed beach fill has been removed by erosion. The initial eroded north end beach under Alternative 2 is comprised of narrow dry and intertidal beach zones that are proximal to the sandbag revetment/dune toe. In contrast, the initial shorelines under Alternatives 1, 3, 4, and 5 are representative of conditions at the completion of a beach nourishment event when the shorelines have been reestablished along the seaward margins of the beach fill construction templates. Constructed beach fills initially consist of a wide flat supratidal (dry beach) berm and a narrow transitional intertidal beach that is represented in the initial model bathymetry by a pair of closely-spaced parallel MHW and MLW contours. As sediments comprising the flat berm are reworked and transported seaward as part of the initial post-construction beach profile equilibration process, the width of the supratidal dry beach berm is rapidly reduced and the position of the MHW contour rapidly recedes. Initial reductions in dry beach width are accompanied by corresponding increases in intertidal beach width. The initial beach profile equilibration process is followed by more gradual shoreline changes that are driven by background process of erosion and accretion and storm events.

The north end shoreline responses under the five alternatives are characterized by similar alongshore variability in erosion and accretion, with a transition zone in the vicinity of Station 1150+00 dividing the shoreline into southern erosional and northern accretional subreaches. Under Alternative 2, the southern shoreline subreach recedes by an average of 81 ft over the course of the four-year model run; reducing average beach width along the southern subreach to 24 ft (Table 5-5, Figure 5-1). MHW contour recession along the ~1,400-linear-ft Topsail Reefs complex is halted by the sandbag revetment, and the MHW contour along the remainder of the southern subreach to the south is proximal to the toe of the frontal dune at the end of the model run (Figure 5-2). As landward migration of the MHW contour is impeded by the revetment and dune, continuing recession of the MLW contour (Figure 5-3) reduces the width of the intertidal beach. At the end of the model run, the southern subreach is comprised of extremely narrow intertidal and dry beach zones. As eroded sediments from the southern subreach are transported northeastward along the shoreline, a portion of the material is deposited along the northern subreach, resulting in minor net shoreline accretion under Alternative 2 (Figure 5-1). As a result, average beach width along the northern subreach increases to 118 ft over the course of the model run (Table 5-5). Average beach width for the northern and southern subreaches combined is 53 ft at the end of the model run (Table 5-5). Corresponding effects on habitat quantities within the NTB oceanfront compartment include a decrease in intertidal beach habitat of 1 acre and a decrease in dry beach and dune habitat of 11 acres (Figure 5-4).

Table 5-5. North end oceanfront shoreline projected Year-4 average beach widths under Alternatives 1, 3, 4, and 5 compared to Alternative 2

Project Shoreline Reach	Reach Length	Average Beach Width (ft)[2]					Avg Beach Width (ft) Change[3] Compared to Alternative 2			
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 1	Alt 3	Alt 4	Alt 5
Southern Subreach	3,400 ft	68	24	74	87	105	+44	+50	+63	+81
Northern Subreach	1,700 ft	225	118	307	433	354	+107	+189	+315	+236
Combined	5,100 ft	116	53	145	193	182	+63	+92	+140	+129

[1]Beach width = distance from model-projected Year-4 ending MSL (0-m) contour to toe of dune or revetment
[2]Average of beach widths measured at 200-ft intervals alongshore
[3]Change for each alternative = average beach width minus average beach under Alt 2

Under Alternative 1, average beach width along the southern subreach at the end of the four-year model run is increased by 44 ft in comparison to Alternative 2 (Table 5-5, Figure 5-5). MHW contour recession along the ~1,400-linear-ft Topsail Reefs complex is halted by the sandbag revetment (Figure 5-2). The MHW contour along the ~800-linear-ft project reach to the south is positioned along the dune toe, and the MHW contour along the remaining ~1,000-linear-ft project reach to the south has receded ~40 ft landward of the dune toe (Figure 5-2). The MLW contour along the Topsail Reefs complex is positioned ~30 to 80 ft seaward of the revetment and the Alternative 2 MLW contour, and the MLW contour along the majority of the remaining ~1,800-linear-ft project reach to the south is positioned ~20 ft seaward of the Alternative 2 MLW contour (Figure 5-3). As in the case of Alternative 2, northeastward transport of eroded oceanfront beach sediments contributes to minor net accretion along the northern shoreline subreach (Figure 5-5). At the end of the model run, average beach width along the northern subreach is increased by 107 ft in comparison to Alternative 2 (Table 5-5). Average beach width for the northern and southern subreaches combined is increased by 63 ft in comparison to Alternative 2 (Table 5-5). The projected effects of Alternative 1 on habitat quantities within the NTB oceanfront compartment include an intertidal beach habitat increase of 1 acre and a dry beach/dune habitat increase of 2 acres compared to Alternative 2 (Table 5-6, Figure 5-6). The north end equilibrium beach profile sediment volume at Year-4 is increased by ~289,000 cy compared to Alternative 2 (Table 5-7).

Under Alternative 3, average beach width along the southern subreach at the end of the four-year modeling run is increased by 50 ft in comparison to Alternative 2 (Table 5-5, Figure 5-7). The MHW contour response along the southern subreach is essentially the same as that of Alternative 1 (Figure 5-2). The MLW contour position along the northern half of the Topsail Reefs complex is similar to that of Alternative 2, whereas the MLW position along the southern half of the complex is ~75 ft seaward of the revetment and the Alternative 2 MLW contour (Figure 5-3). The MLW contour along the remaining ~1,800-linear-ft project reach to the south is positioned ~20 to 70 ft seaward of the Alternative 2 MLW contour (Figure 5-3). The northern subreach response under Alternative 3 includes extensive deposition of eroded beach fill along the inlet shoulder and associated sand spit development from the inlet shoulder. As a result, accretion along the northernmost section of the northern subreach is substantially increased in relation to Alternatives 1 and 2 (Figure 5-7). At the end of the model run, average beach width along the northern subreach is increased by 189 ft in comparison to Alternative 2 (Table 5-5). Average beach width for the northern and southern subreaches combined is increased by 92 ft compared to Alternative 2 (Table 5-5). The projected effects of Alternative 3 on habitat quantities within the NTB oceanfront compartment include an increase in intertidal beach habitat of 2 acres and an increase in dry beach and dune habitat of 3 acres in comparison to Alternative 2 (Table 5-6, Figure 5-8). The north end beach profile sediment volume at Year-4 is increased by ~50,000 cy compared to Alternative 2 (Table 5-7).

Under Alternative 4, average beach width along the southern subreach at the end of the four-year modeling run is increased by 63 ft in comparison to Alternative 2 (Table 5-5, Figure 5-9). The position of the MHW contour along the southern subreach is similar to that of Alternative 2 (Figure 5-2). The MLW contour along the Topsail Reefs complex under Alternative 4 is positioned ~80 ft seaward of the revetment and the Alternative 2 MLW contour, whereas the MLW contour along the remaining ~1,800-linear-ft project reach to the south is positioned ~30 to 60 ft seaward of the Alternative 2 MLW contour (Figure 5-3). The northern subreach response involves shoreline accretion and reorientation in response to the terminal groin. At the end of the four-year model run, the northern subreach shoreline has prograded seaward and assumed a southwest-northeast orientation that is perpendicularly aligned with the seaward terminus of the terminal groin (Figure 5-9). As a result, average beach width along the northern subreach is increased by 315 ft in comparison to Alternative 2 (Table 5-5, Figure 5-9). Average beach width for the northern and southern subreaches combined is increased by 140 ft compared to Alternative 2 (Table 5-5). Corresponding effects on habitat quantities in the NTB oceanfront compartment include an increase in intertidal beach habitat of 4 acres and an increase in dry beach habitat of 10 acres compared to Alternative 2 (Table 5-6, Figure 5-10). The north end equilibrium beach profile sediment volume at Year-4 is increased by ~532,000 cy compared to Alternative 2 (Table 5-7).

Under Alternative 5, average beach width along the southern subreach at the end of the four-year modeling run is increased by 81 ft in comparison to Alternative 2 (Table 5-5, Figure 5-11). The position of the MHW contour along the southern subreach is similar to that of Alternative 2 (Figure 5-2). The MLW contour along the Topsail Reefs complex under Alternative 5 is positioned ~80 to 130 ft seaward of the revetment and the Alternative 2 MLW contour, whereas the MLW contour along the remaining ~1,800-linear-ft project reach to the south is positioned ~30 to 60 ft seaward of the Alternative 2 MLW contour (Figure 5-3). The northern subreach response involves shoreline accretion and reorientation in response to the terminal groin. At the end of the four-year model run, the northern subreach shoreline has prograded seaward and assumed a southwest-northeast orientation that is perpendicularly aligned with the seaward terminus of the terminal groin (Figure 5-11). As a result, average beach width along the northern subreach is increased by 236 ft in comparison to Alternative 2 (Table 5-5, Figure 5-11). Average beach width for the northern and southern subreaches combined is increased by 129 ft compared to Alternative 2 (Table 5-5). Corresponding effects on habitat quantities in the NTB oceanfront compartment include an intertidal beach habitat increase of 4 acres and a dry beach/dune habitat increase of 8 acres compared to Alternative 2 (Table 5-6, Figure 5-12). The north end beach equilibrium beach profile sediment volume at Year-4 is increased by ~521,000 cy compared to Alternative 2 (Table 5-7).

Table 5-6. North end oceanfront beach projected Year-4 habitat area changes under Alternatives 1, 3, 4, and 5 compared to Alternative 2

Habitat Compartment[1]	Habitat Type	Year-4 Habitat Area[2] (acres)					Year-4 Habitat Area Change[3] Compared to Alternative 2 (acres)			
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 1	Alt 3	Alt 4	Alt 5
NTB Oceanfront	Supratidal	60	58	61	68	66	2	3	10	8
	Intertidal	11	10	12	14	14	1	2	4	4
	Subtidal	469	471	466	458	460	-2	-5	-13	-11
NTB Inlet	Supratidal	57	56	68	60	55	1	12	4	-1
	Intertidal	84	85	97	84	83	-1	12	-1	-2
	Subtidal	268	257	245	265	272	1	-22	-2	5
NTB Estuarine	Supratidal	90	89	90	90	90	1	1	1	1
	Intertidal	125	126	125	125	125	-1	-1	-1	-1
	Subtidal	2	2	2	2	2	0	0	0	0
Onslow Oceanfront	Supratidal	24	34	31	30	25	-10	-3	-4	-9
	Intertidal	7	7	9	9	7	0	2	2	0
	Subtidal	230	220	221	223	229	10	1	3	9
Onslow Inlet	Supratidal	99	72	73	75	87	27	1	3	15
	Intertidal	88	91	92	90	105	-3	1	-1	14
	Subtidal	232	267	255	254	228	-25	-2	-3	-29
Onslow Estuarine	Supratidal	37	36	37	37	37	1	1	1	1
	Intertidal	42	43	42	42	42	-1	-1	-1	-1
	Subtidal	6	6	6	6	6	0	0	0	0

[1]Habitat compartment boundaries are depicted on the habitat change figures
[2]Absolute habitat acreages based on projected MHW and MLW contour positions at the end of the 4-year model runs
[3] Change for each alternative = absolute habitat area minus the absolute habitat area under Alt 2

Table 5-7. North end oceanfront beach projected sediment volume[1] changes under Alternatives 1, 3, 4, and 5 compared to Alternative 2

Alternative	Sediment Volume Change (Cubic Yards)		
	YEAR 0	YEAR 2	YEAR 4
Alt 1 (Nourishment + Pivot Channel)	+160,497	+303,934	+288,554
Alt 2 (No Management)	0	0	0
Alt 3 (Nourishment)	+282,852	+274,969	+49,437
Alt 4 (Nourishment + Groin)	+343,642	+464,763	+532,062
Alt 5 (Nourishment + Groin + Pivot Channel)	+327,439	+506,675	+521,038

[1]Sediment volume above the 26-ft depth contour (equilibrium beach profile)

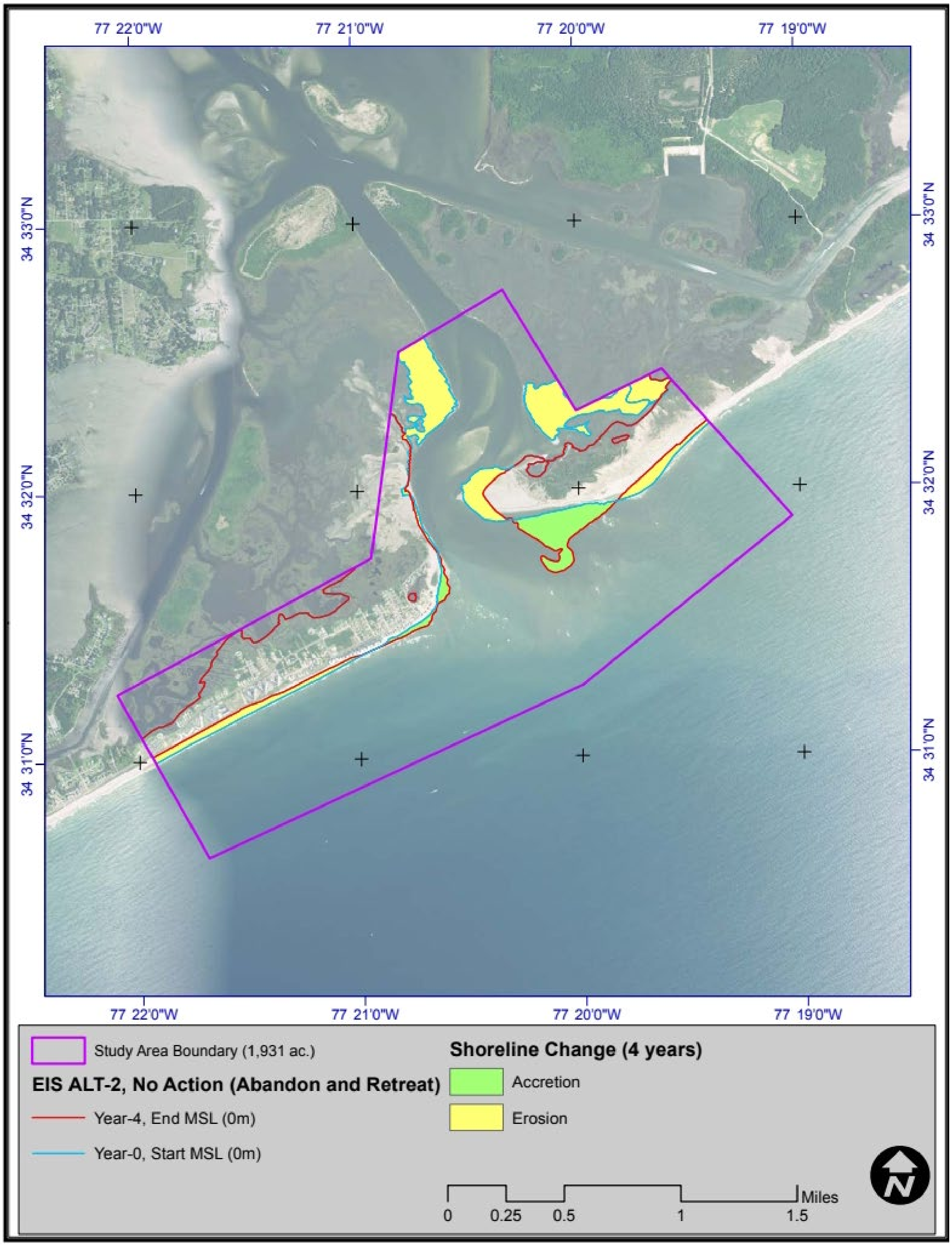


Figure 5-1. Alternative 2 - Model-projected Year-4 shoreline changes.

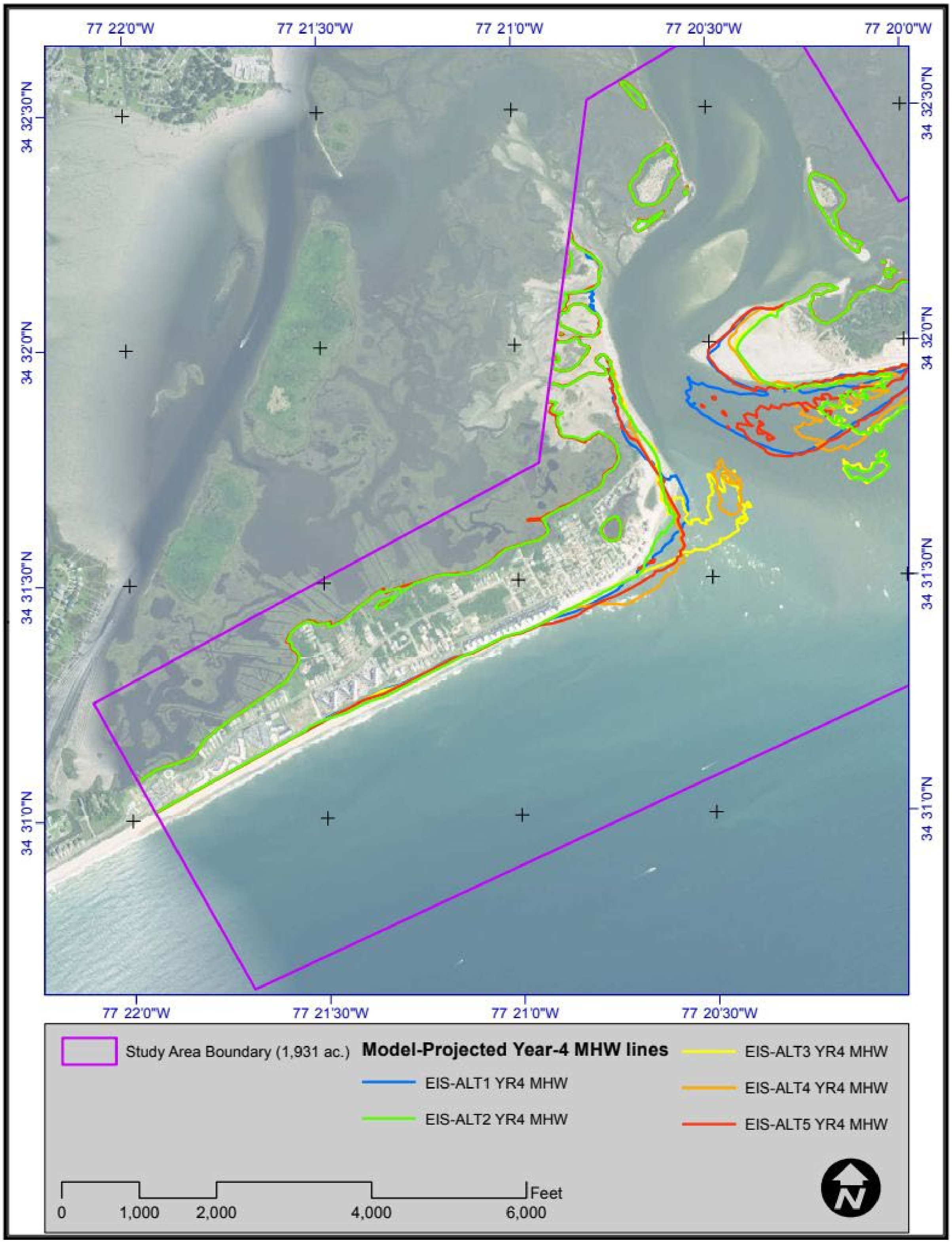


Figure 5-2. Model-projected Year-4 MHW contours for all alternatives on NTB.

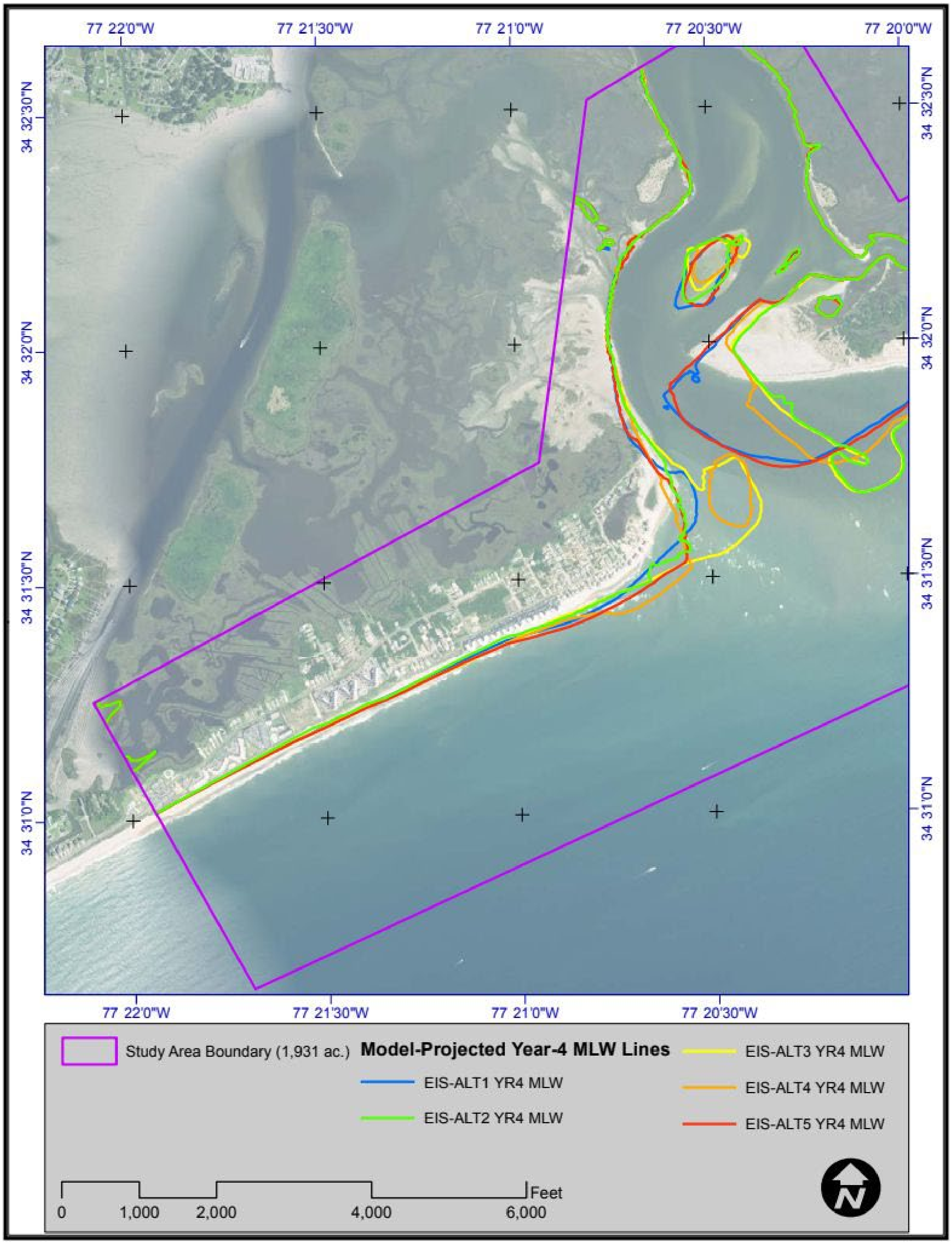


Figure 5-3. Model-projected Year-4 MLW contours for all alternatives on NTB.

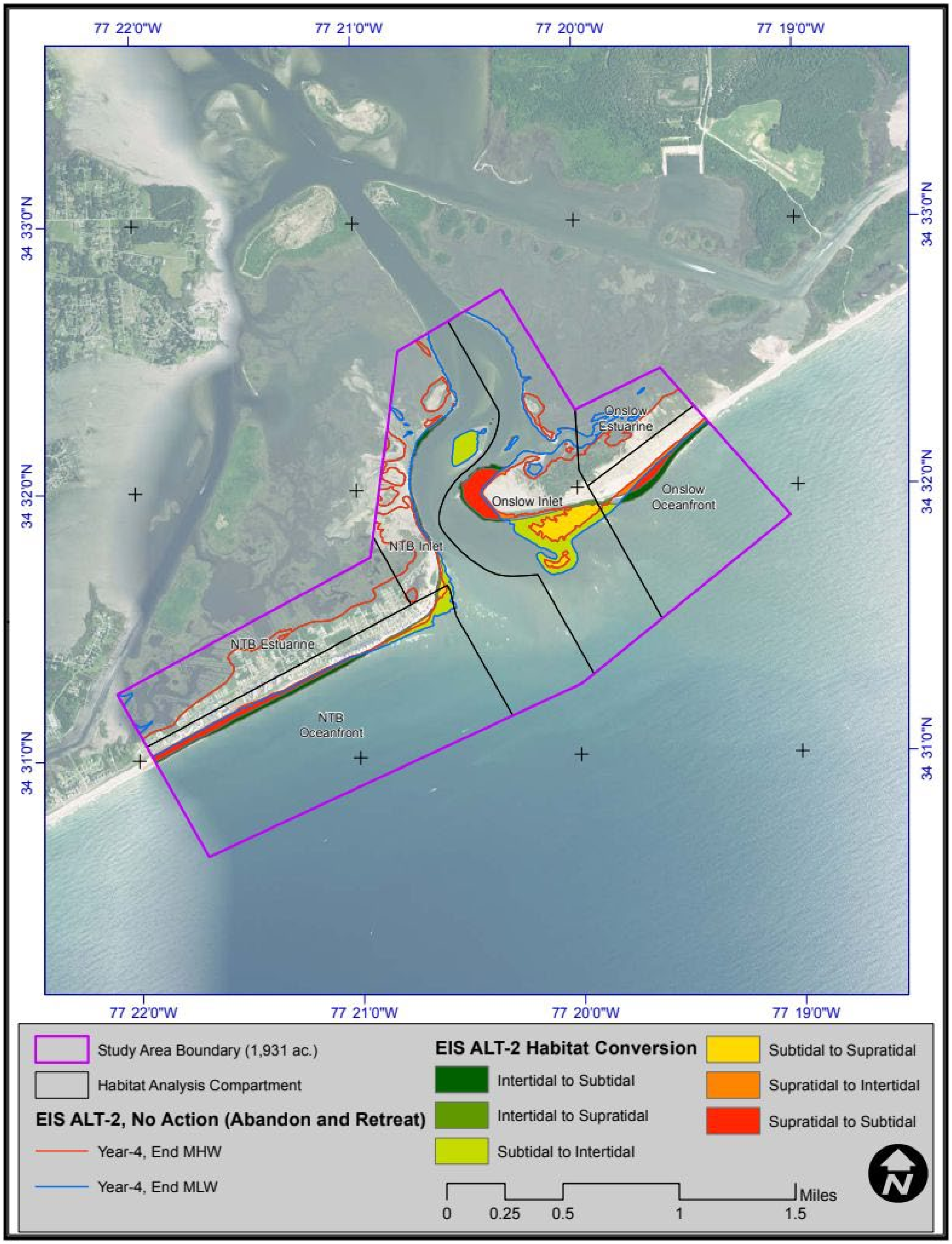


Figure 5-4. Alternative 2 - Model-projected Year-4 habitat changes.

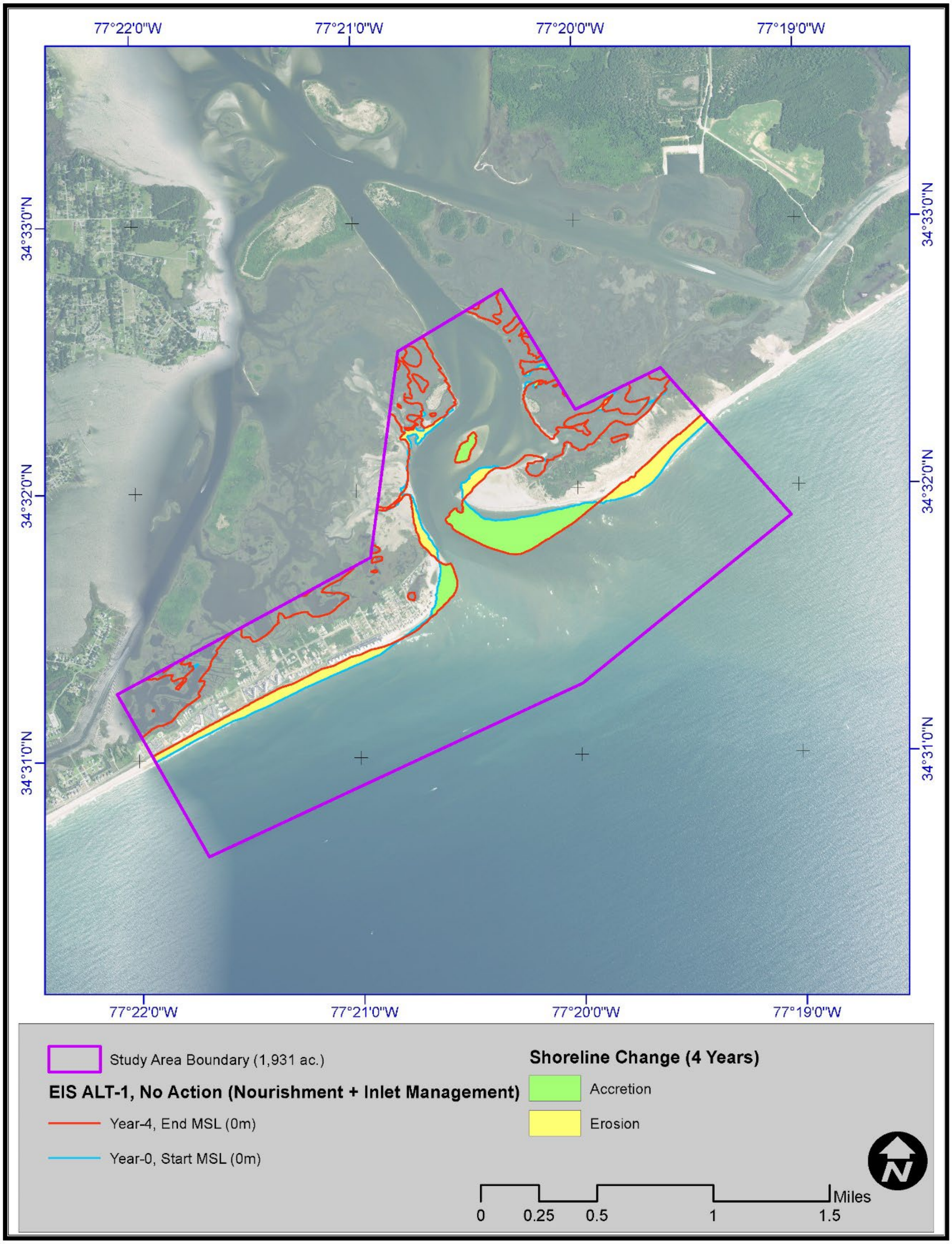


Figure 5-5. Alternative 1 - Model-projected Year-4 shoreline changes.

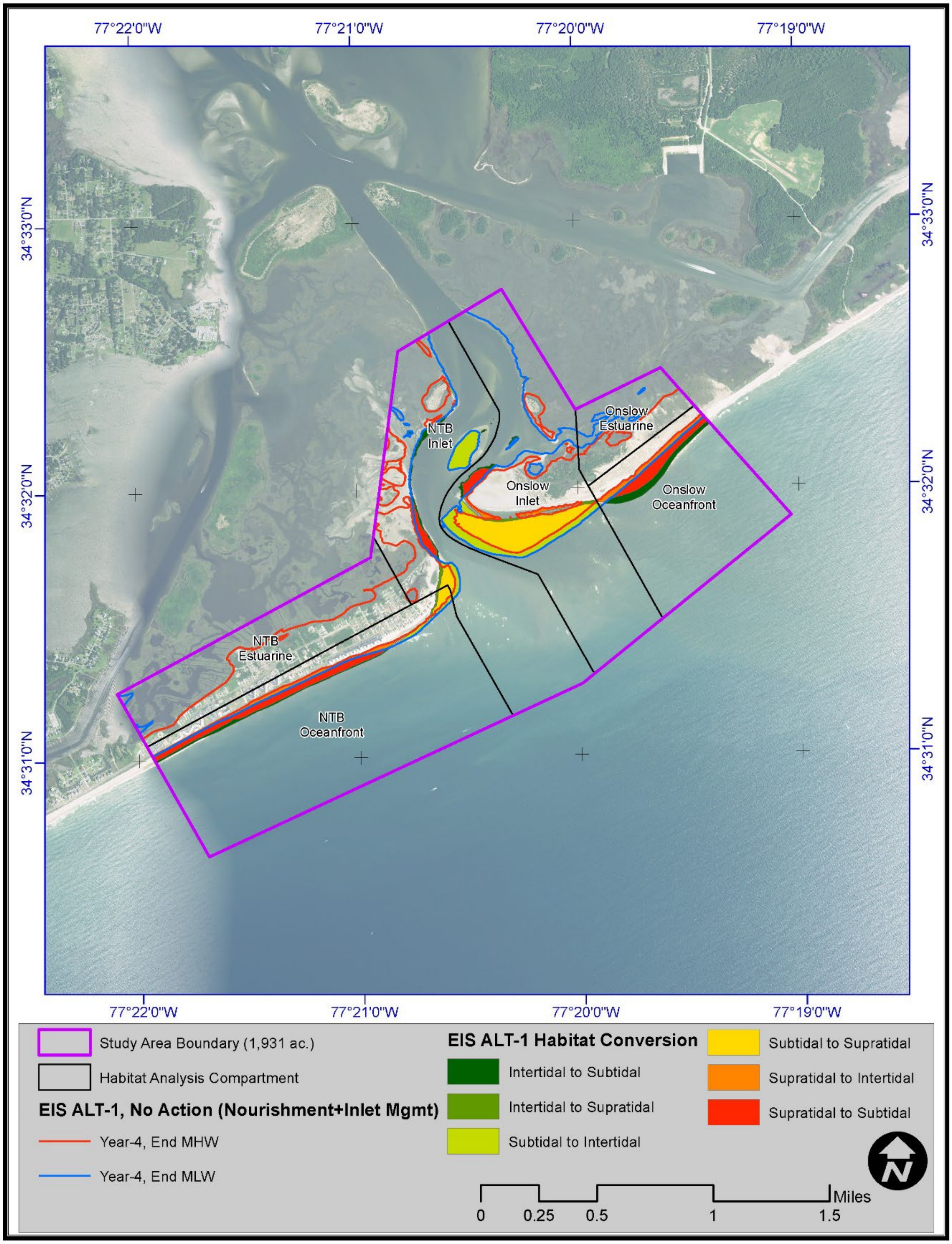


Figure 5-6. Alternative 1 - Model-projected Year-4 habitat changes.

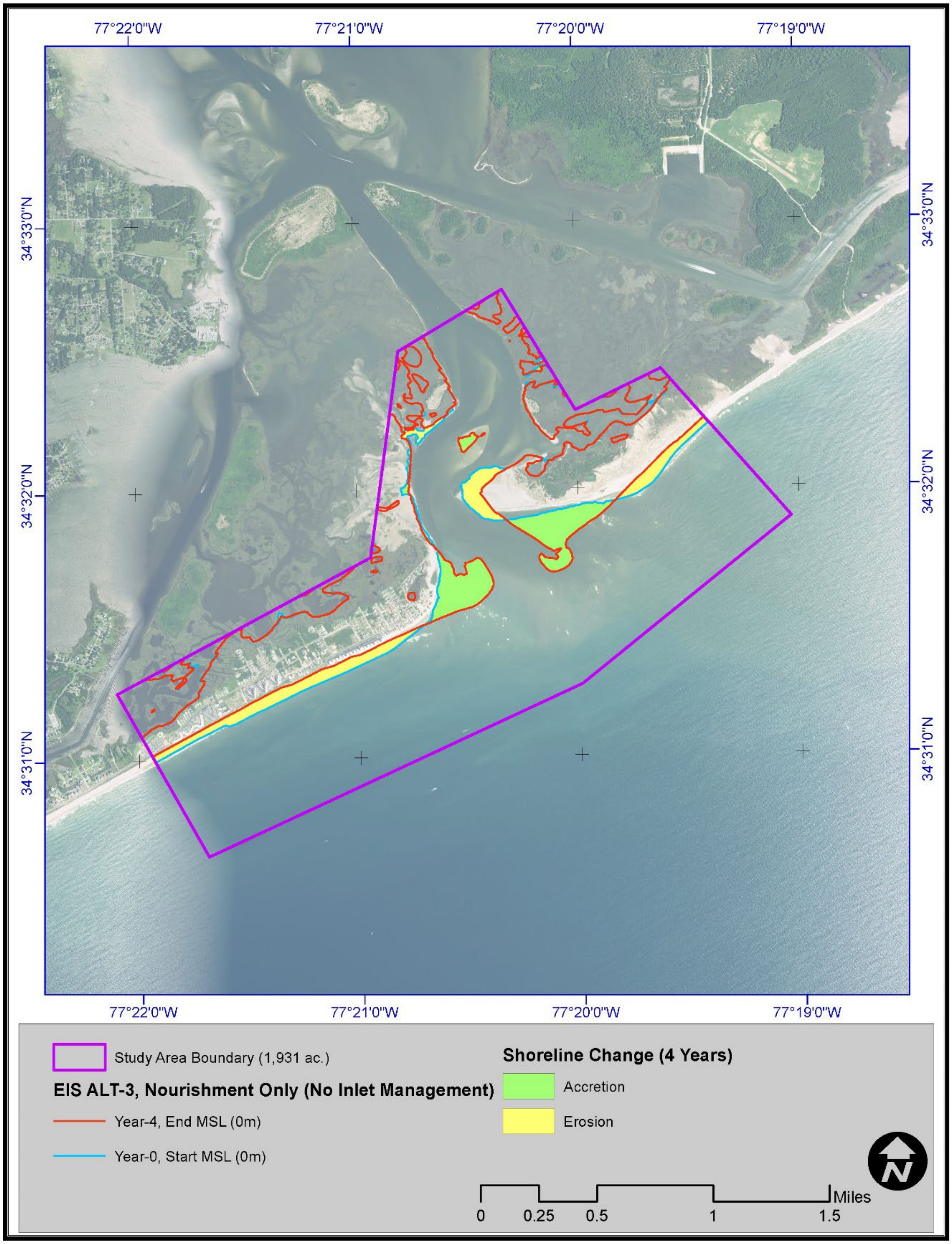


Figure 5-7. Alternative 3 - Model-projected Year-4 shoreline changes.

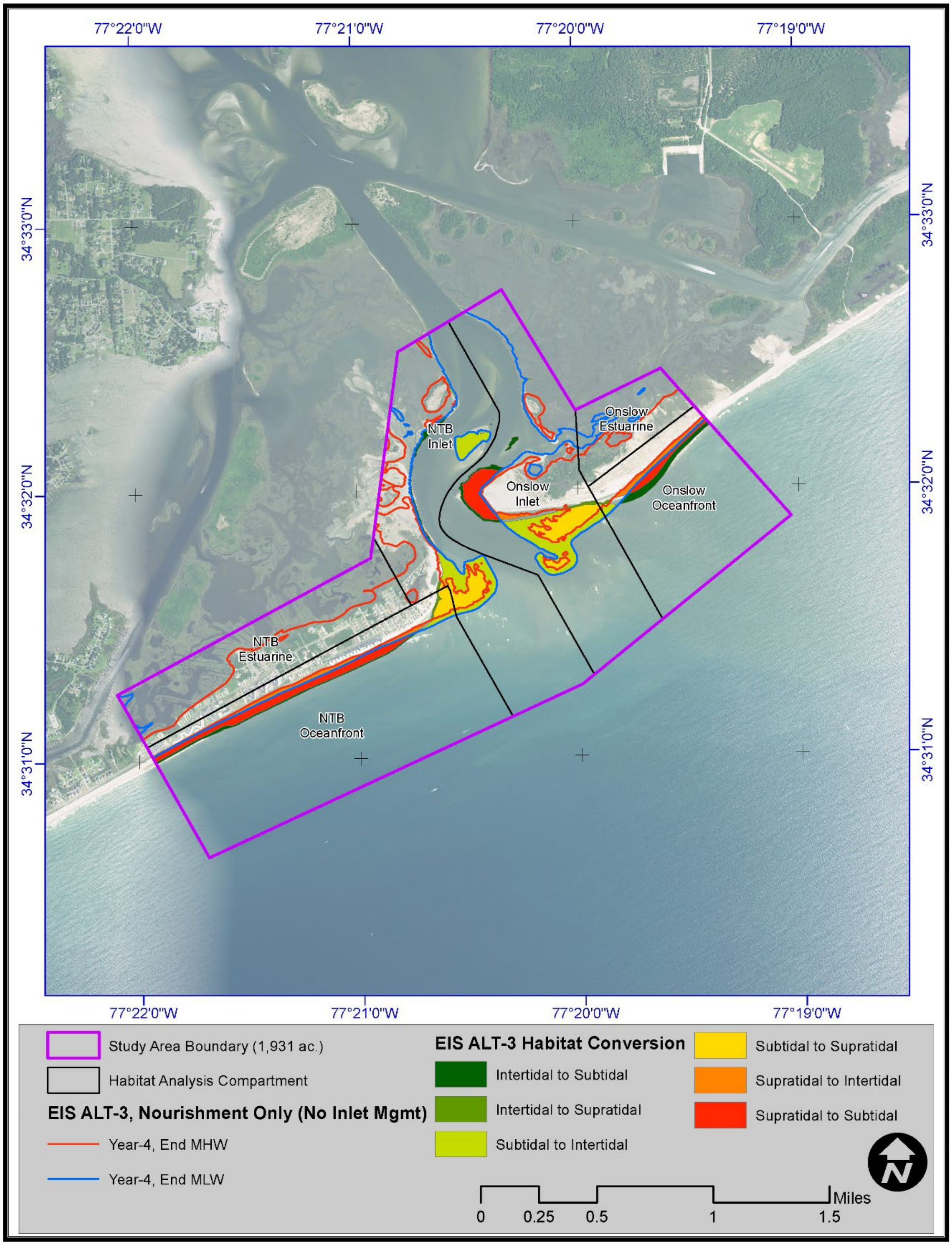


Figure 5-8. Alternative 3 - Model-projected Year-4 habitat changes.

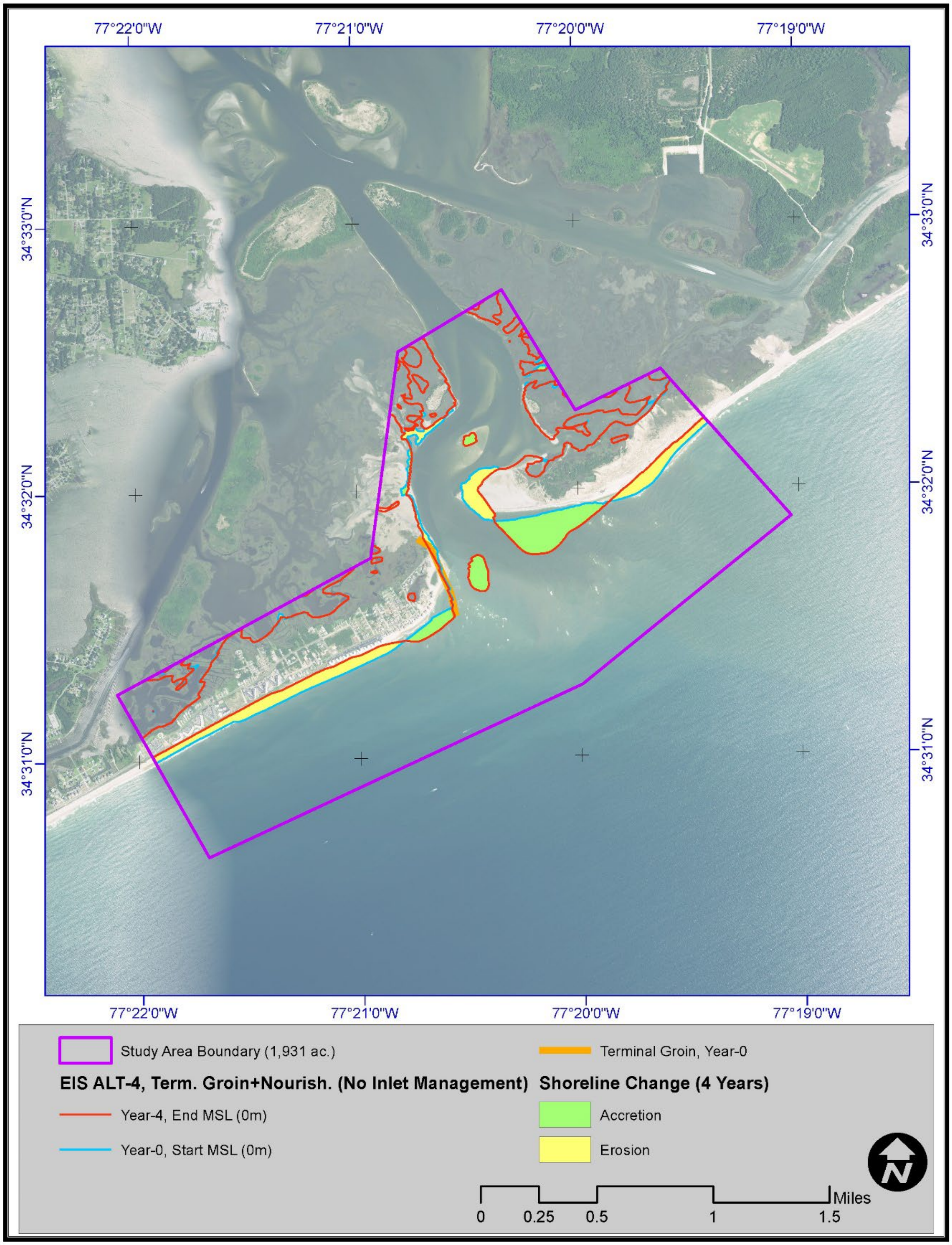


Figure 5-9. Alternative 4 - Model-projected Year-4 shoreline changes.

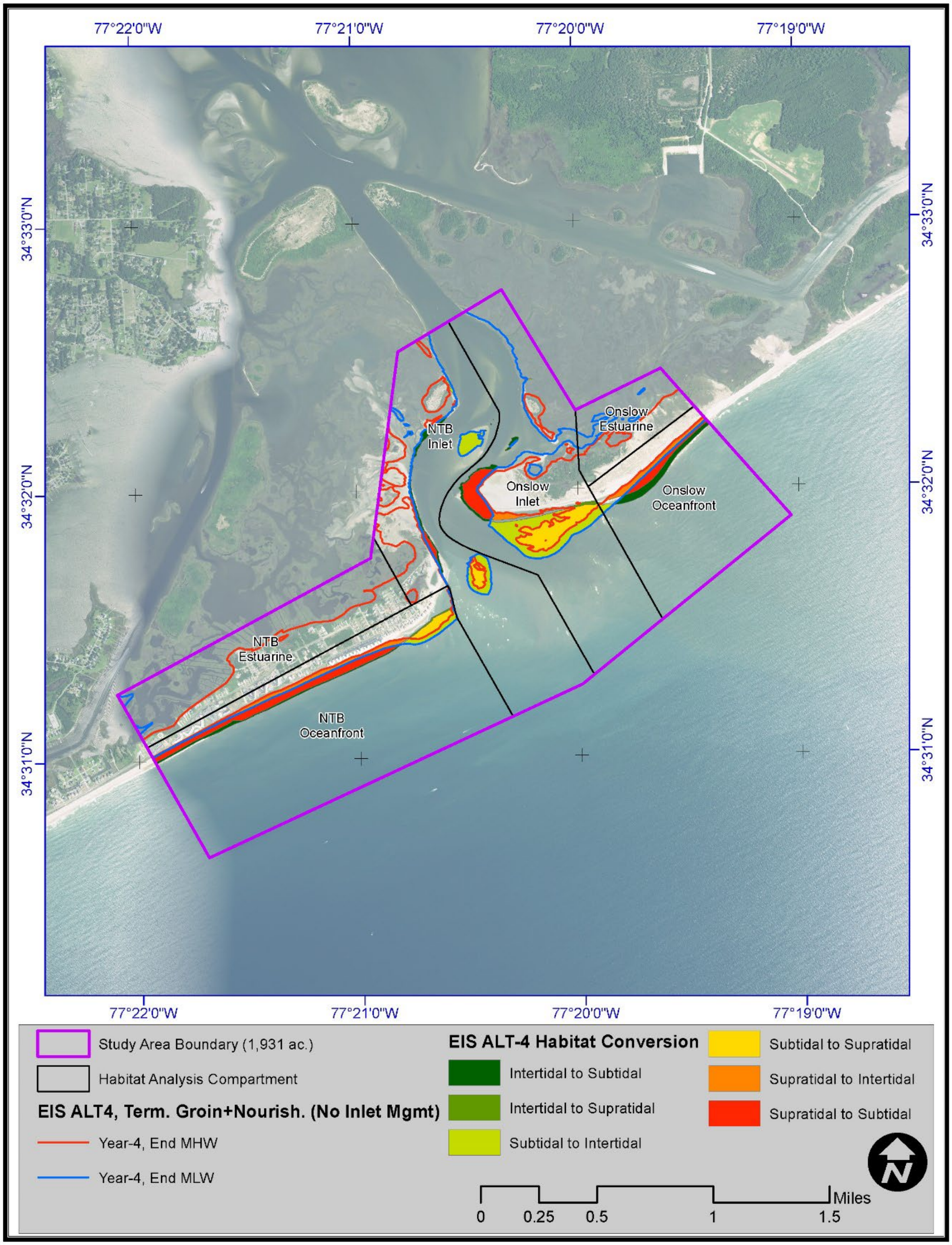


Figure 5-10. Alternative 4 - Model-projected Year-4 habitat changes.

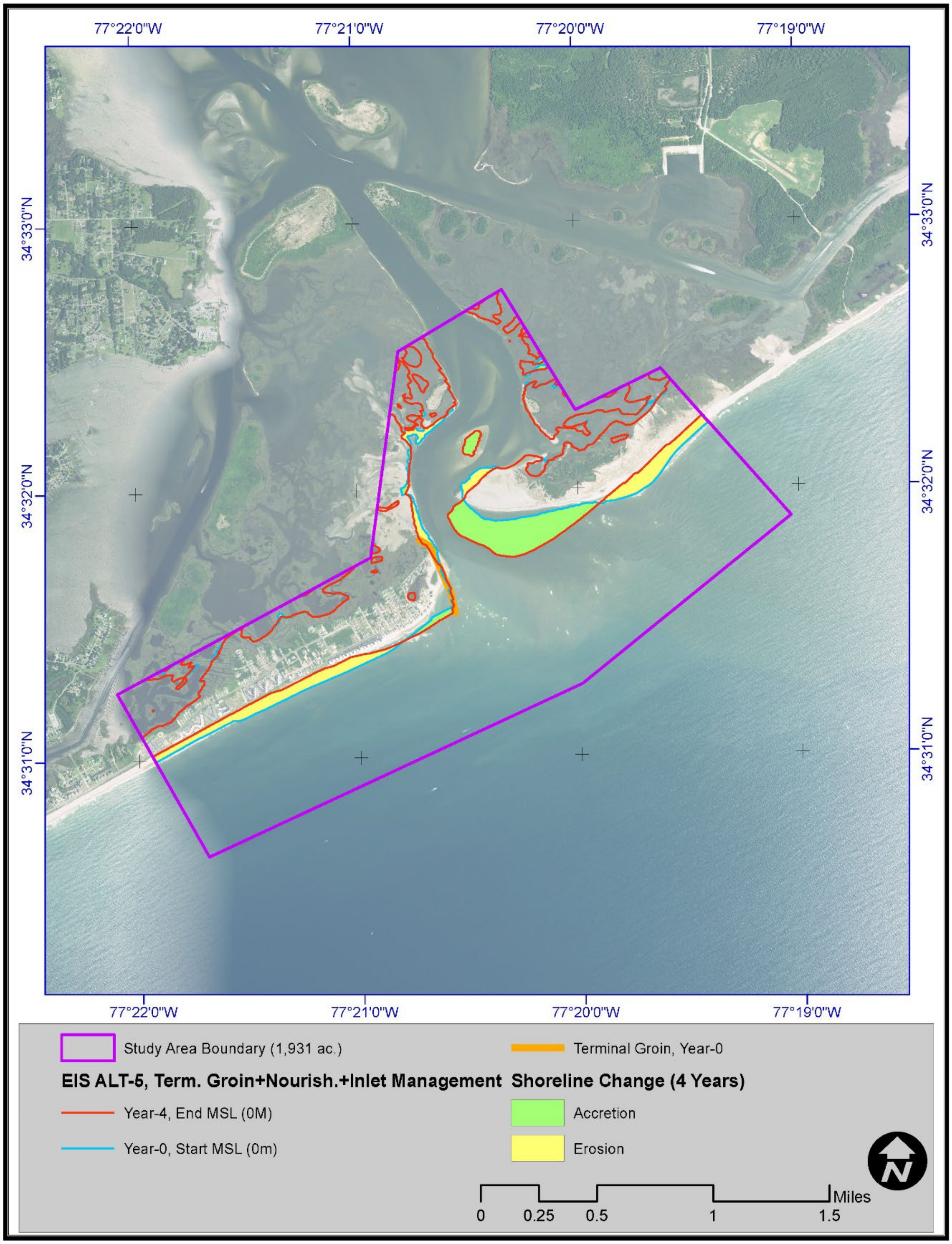


Figure 5-11. Alternative 5 - Model-projected Year-4 shoreline changes.

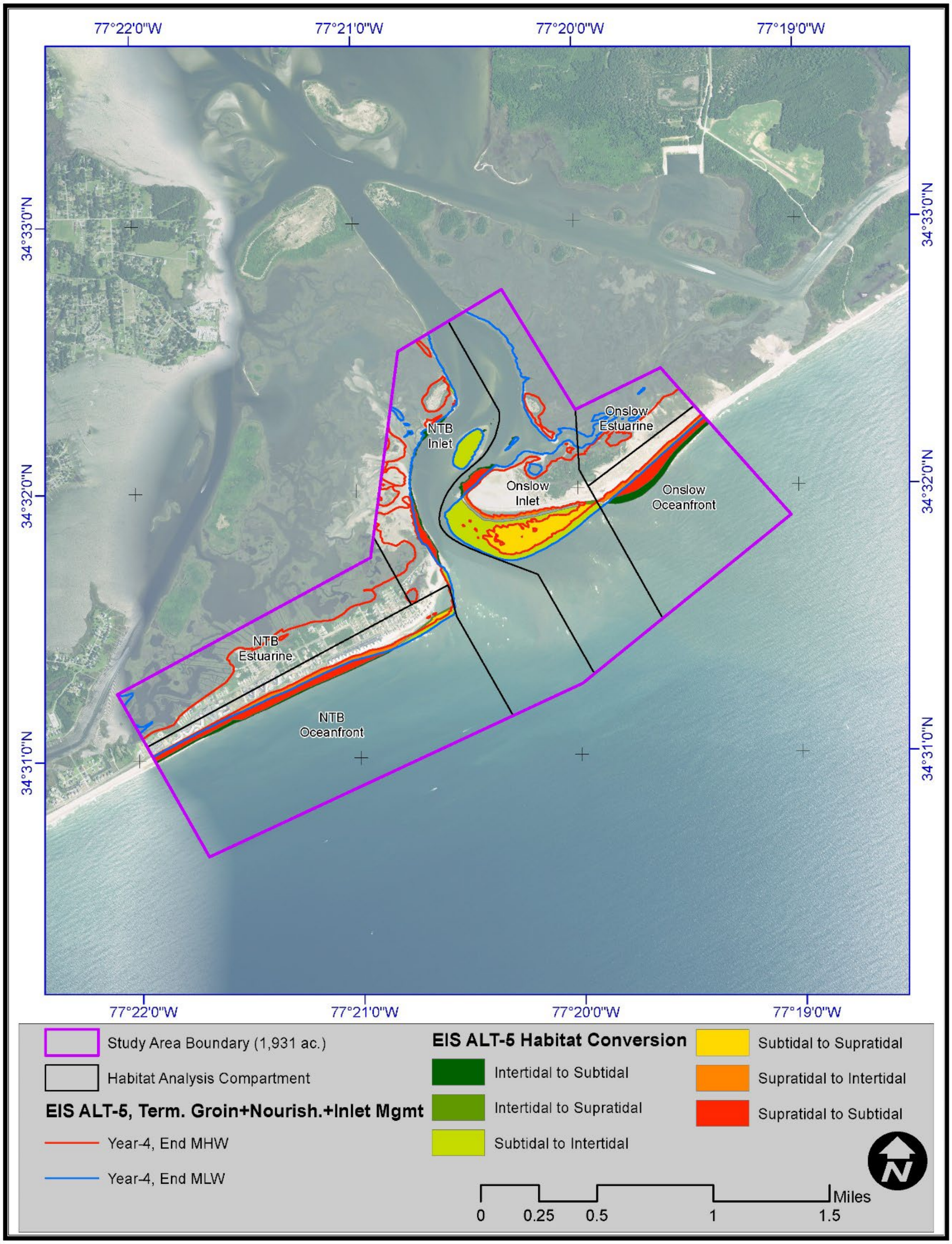


Figure 5-12. Alternative 5 - Model-projected Year-4 habitat changes.

5.2.2 NRI Complex

The modeling results for NRI show several general morphological responses that are common to the five alternatives including southwestward reorientation and expansion of the Onslow Beach sand spit, deposition and shoreline accretion along the inlet shoulder of NTB, minor erosion of the NTB central inlet throat shoreline, and mid-inlet emergent flood shoal development in the back of the inlet throat. Under Alternative 2, the inlet ebb channel is relatively unstable and migrates northeastward towards the Onslow Beach inlet shoreline. Concurrently, the Onslow Beach sand spit undergoes a process of southwestward expansion that reorients the sand spit to a southwestward alignment that is in line with the adjoining updrift oceanfront shoreline on Onslow Beach (Figure 5-4). Although the northeast-migrating ebb channel eventually impedes the southwestward expansion process, the overall intertidal/supratidal sand spit area is increased by 22 acres at the end of the four-year modeling run. In the NTB inlet compartment, the deposition of eroded north end oceanfront beach sediments on the inlet shoulder contributes to minor accretion of the outer inlet throat shoreline, while the central inlet throat shoreline experiences minor erosion. Effects on habitat quantities in the NTB inlet compartment are predominantly associated with mid-inlet emergent flood shoal development of a in the back of the inlet throat, which adds 8 acres of intertidal habitat area (Figure 5-4).

Under Alternative 1, the dredged ebb (pivot) channel is relatively stable and is generally maintained in a southerly alignment along the north end of NTB. As a result, southwestward expansion of the Onslow Beach sand spit increases substantially compared to Alternative 2. The overall intertidal/supratidal sand spit area under Alternative 1 (Figure 5-6) is increased by ~24 acres in comparison to Alternative 2. Corresponding effects on habitat quantities in the Onslow Beach inlet compartment include a supratidal habitat increase of 27 acres and an intertidal habitat decrease of 3 acres compared to Alternative 2 (Table 5-6, Figure 5-6). Morphological responses in the NTB inlet compartment are generally similar to Alternative 2, with differences under Alternative 1 consisting of a minor increase in accretion along the inlet shoulder and a minor increase in erosion along the central inlet throat shoreline. Corresponding effects on habitat quantities in the NTB inlet compartment include a supratidal habitat increase of 1 acre and an intertidal habitat decrease of 1 acre compared to Alternative 2 (Table 5-6, Figure 5-6). Under Alternative 3, the projected responses of the inlet ebb channel and the Onslow Beach sand spit are similar to those described above for Alternative 2, with the ebb channel exhibiting a similar northeastward migration pattern that results in a similar southwestward sand spit expansion pattern. Effects on habitat quantities in the Onslow Beach inlet compartment include supratidal and intertidal habitat increases of 1 acre each compared to Alternative 2 (Table 5-6, Figure 5-8). On the north end of NTB, relatively large volumes of eroded beach fill from the oceanfront beach are deposited along the inlet shoulder; resulting in northeastward sand spit development from the NTB inlet shoreline. Corresponding effects on habitat quantities in the NTB inlet compartment include supratidal and intertidal habitat increases of 12 acres each compared to Alternative 2 (Table 5-6, Figure 5-8).

Model-projected inlet responses under Alternative 4 are indicative of significant effects on ebb channel dynamics. The formation of a large emergent shoal in the outermost (seaward) portion of the inlet throat along NTB splits the ebb channel into two branches that migrate towards the opposing inlet shorelines. The southwest-migrating branch erodes the NTB inlet throat shoreline and is positioned against the terminal groin at the end of the four-year model run. The northeast-migrating branch assumes a southeasterly alignment along the Onslow Beach inlet shoreline resulting in a southwestward sand spit expansion pattern that is similar to that of Alternative 2. Effects on habitat quantities in the Onslow Beach inlet compartment include a supratidal habitat increase of 3 acres and an intertidal habitat decrease of 1 acre compared to Alternative 2 (Table

5-6, Figure 5-10). In the NTB inlet compartment, the effects of increased inlet shoreline erosion on supratidal and intertidal habitat quantities include decreases of 2 and 3 acres compared to Alternative 2, respectively; however, 6 acres of supratidal habitat and 2 acres of intertidal habitat are added though emergent shoal development in the outer inlet throat. Net effects on habitat quantities in the NTB inlet compartment include a supratidal habitat increase of 4 acres and an intertidal habitat decrease of 1 acre compared to Alternative 2 (Table 5-6, Figure 5-10). Under Alternative 5, the projected responses of the inlet ebb channel and the Onslow Beach sand spit are similar to those described above for Alternative 1. The dredged ebb (pivot) channel is generally maintained in a southerly alignment along the north end of NTB, and southwestward expansion of the Onslow Beach sand spit is substantially increased compared to Alternative 2. The overall extent of intertidal/supratidal sand spit expansion is increased by 29 acres compared to Alternative 2. Corresponding effects on habitat quantities in the Onslow Beach inlet compartment include supratidal and intertidal habitat increases of 15 and 14 acres compared to Alternative 2, respectively (Table 5-6, Figure 5-12). Morphological responses in the NTB inlet compartment include a minor increase in erosion along the inlet throat shoreline but are otherwise similar to Alternative 2. Projected effects on habitat quantities in the NTB inlet compartment include supratidal and intertidal habitat decreases of 1 and 2 acres compared to Alternative 2, respectively (Table 5-6, Figure 5-12).

5.1.1 Onslow Beach Oceanfront Shoreline

The simulated south end oceanfront shoreline on Onslow Beach is erosional under all of the alternatives. The erosional oceanfront shoreline responses are part of an overall south end reorientation process that encompasses both the inlet sand spit and the oceanfront beach. Under all alternatives, expansion and seaward progradation of the sand spit to a southwestward orientation is accompanied by a corresponding landward shift in the adjoining updrift oceanfront shoreline. Differences among the alternatives in the extent of oceanfront shoreline recession are inversely related to differences in the extent of sand spit expansion and progradation in the adjoining Onslow Beach inlet compartment. Under Alternative 2, the MSL oceanfront shoreline recedes by an average of 162 ft over the course of the four-year model run (Figure 5-1). Under Alternatives 1, 3, 4, and 5; average shoreline recession is increased by 48 to 137 ft compared to Alternative 2 (Table 5-8, Figures 5-5, 5-7, 5-9, and 5-11). In the model runs for all alternatives, the spacing between the receding MHW and MLW contours is generally maintained, resulting in relatively small changes in intertidal beach habitat area. Alternatives 1 and 5 have no net effect on intertidal beach habitat quantities, whereas the projected effects of Alternatives 3 and 4 consist of minor increases of 2 acres compared to Alternative 2 (Table 5-6, Figures 5-6, 5-8, 5-10, and 5-12). Projected dry beach and dune habitat changes under Alternatives 3 and 4 include relatively small decreases of 3 and 4 acres compared to Alternative 2, respectively; whereas larger decreases of 10 and 9 acres are projected under Alternatives 1 and 5, respectively (Table 5-6, Figures 5-6, 5-8, 5-10, and 5-12).

As indicated above, projected shoreline and habitat changes in the Onslow Beach oceanfront compartment are part of an overall south end reconfiguration process encompassing both the inlet sand spit and the oceanfront beach. Under all alternatives, southwestward reorientation and expansion of the Onslow Beach sand spit effectively increases the length of the southeast-facing oceanfront beach by approximately 1,500 to 2,500 ft; however, the sand spit shoreline and habitat changes are included in the Onslow Beach inlet compartment calculations and are not accounted for in the analyses of oceanfront beach changes. In the specific case of Alternatives 1 and 5, projected habitat reductions in the oceanfront beach compartment are relatively small and inversely related to projected habitat changes in the inlet compartment. Detailed analysis of sand spit changes under the five alternatives was presented previously in Section 5.2.2 (NRI Complex).

Table 5-8. Projected oceanfront shoreline changes1 on Onslow Beach under Alternatives 1, 3, 4, and 5 compared to Alternative 2

	Alt 1	Alt 3	Alt 4	Alt 5
Average Shoreline Change (ft) Compared to Alternative 2	-137	-48	-58	-126
[1]Average of MSL (0-m) contour changes measured at 200-ft intervals alongshore.				

5.3 General Effects of Dredging and Beach Fill Placement

Alternatives 1, 3, 4, and 5 encompass similar dredging and beach fill placement activities that are projected to have similar effects on a number of habitats and biological communities, including marine soft bottom, marine water column, intertidal beach, and dry beach and dune habitats and communities. In order to reduce redundancy in the subsequent alternative-specific impact analysis sections, the detailed analyses of direct and indirect effects on these habitats and communities from dredging and beach fill placement under the four alternatives have been consolidated under this section. The effects described in this section are briefly summarized in the subsequent alternative-specific impact analysis sections.

5.3.1 Operational Characteristics of Dredging and Beach Fill Placement

Dredging activities under the four with-project alternatives would include the use of cutterhead dredges to maintain the pivot channel alignment of the NRI outer bar channel and/or extract beach fill from the Town's offshore borrow site. Hydraulic cutterhead dredges operate from barges that are towed to the dredging site and secured in place by two stern anchor pilings (spuds). Once in place, the dredge can be stepped forward into the cut or dredging area by alternately pivoting on the spuds, but the dredge is otherwise restricted to a relatively small dredging footprint. Sediment removal is accomplished by a pipeline with a rotating "cutterhead" mechanism at the suction end. The cutterhead is swung through the sediment in an arc-shaped motion as the two spuds are alternately lifted and returned to the seafloor. In making relatively deep cuts, the cutterhead mechanism generally remains buried in the sediment below the seafloor surface. Dislodged sediments are combined with water at the cutterhead, and the resulting slurry is pumped through a submerged pipeline that leads directly from the borrow site to the disposal site (e.g., beach). Sand is discharged onto the recipient beach in the form of a sediment-water slurry. Spreaders are attached to the discharge end of the pipeline to slow the velocity of the discharge, prevent erosion, and facilitate sediment settling. Temporary shore-parallel containment dikes are constructed in front of the onshore pipeline outfall to facilitate sediment settling and reduce turbidity in the nearshore environment. As placement activities progress, the onshore pipeline is extended along the beach by adding new sections of pipe. Pipelines are typically placed on the upper beach, but seaward of the dunes and any upper beach vegetation. Booster pumps may be required along the pipelines as they are extended along the beach. The location where the submerged pipeline emerges onto the beach may also shift incrementally as construction progresses. Front-end loaders or other heavy equipment are used to transport and position the onshore pipeline sections throughout the construction process. Bulldozers and other heavy equipment such as backhoes, front-end loaders, and tractors are used to redistribute and grade the discharged sediment as it falls out of suspension. A variety of supporting vehicles such as pick-up trucks and all-terrain vehicles are typically used to transport equipment and personnel along the beach throughout the construction process. Grade stakes are placed throughout the beach fill template to facilitate the construction of berms and dunes to design specifications. Constructed dunes are typically stabilized by planting native dune grasses. Post-construction tilling and/or escarpment leveling may be conducted as needed based on post-project monitoring results. Tilling and leveling are accomplished by heavy equipment similar to that employed in redistribution and grading operations. Compacted beach fill areas between the toe of the dune and the MHW line are typically tilled to a depth of 24-36 inches using a series of overlapping passes to ensure thorough decompaction. Chain-linked fencing or a similar apparatus may be dragged over the tilled areas as necessary to eliminate any ruts and furrows created by the tilling process. Escarpments are regraded according to the original berm design specifications.

5.3.2 Marine Soft Bottom Communities

5.3.2.1 Dredging

5.3.2.1.1 Direct Effects

New River Inlet

Pivot channel maintenance dredging events under Alternatives 1 and 5 would disturb ~40 acres of subtidal marine soft bottom habitat and remove the associated benthic invertebrate infaunal and epifaunal communities. Based on projected shoaling rates, benthic invertebrate communities in the pivot channel would experience recurring impacts from maintenance dredging every four years. Shallow soft bottom benthic invertebrate communities, such as those that occur on the ebb tidal delta, experience frequent natural disturbance from waves and currents; and consequently, are typically dominated by opportunistic species that recover rapidly from disturbance (Wilber and Clarke 2007). Studies of benthic community recovery in shallow navigation channels along the southeastern US coast have reported rapid recovery within two to six months (Van Dolah et al. 1984 and 1979, Stickney and Perlmutter 1975, and Stickney 1972). These studies indicate that recolonization via slumping of adjacent undisturbed sediments into the dredged channel is an important recovery mechanism. Van Dolah et al. (1984) also attributed relatively rapid recovery to rapid infilling by sediments that were similar in composition to the extracted material and avoidance of spring benthic invertebrate recruitment periods. The pivot channel extends across the shallow ebb tidal delta where soft bottom habitats and associated benthic invertebrate communities are continually disturbed by wave action and extreme tidal currents. Furthermore, pivot channel dredging would be conducted within the currently authorized environmental dredging window of 16 November - 31 March, thereby avoiding the peak benthic invertebrate recruitment period in NC. Therefore, it is expected that the direct effects of Alternatives 1 and 5 on benthic invertebrate communities in the pivot channel would be short term.

Offshore Borrow Site

Individual offshore borrow site dredging events under Alternatives 3, 4, and 5 would directly impact subtidal marine soft bottom habitat, resulting in removal of the associated benthic invertebrate infaunal and epifaunal communities. The areal extent of impact would vary according to site specific dredge cut depths; however, assuming a relatively shallow dredge cut depth of 6 ft, the maximum area of soft bottom habitat impact from an individual dredging event would be ~30 acres. Based on the proposed nourishment intervals, Alternatives 3 and 4 would require recurring offshore borrow site dredging events at intervals of two and four years, respectively. Alternative 5 would potentially use the offshore borrow site as a supplemental source of beach fill in the event that the pivot channel maintenance dredging triggers have not been met after four years. However, based on projected pivot channel shoaling rates, it is expected that any use of the offshore borrow site under Alternative 5 would be minimal.

Soft bottom communities at offshore borrow sites are periodically disturbed by storms and are generally dominated by opportunistic taxa that recover relatively rapidly from dredging-induced seafloor disturbance (Posey and Alphin 2002); however, recovery rates vary widely according to a number of project-related and environmental factors; including the type of dredge employed, the depth of the dredge cuts, hydrodynamic conditions at the borrow site, and the timing of dredging operations relative to benthic invertebrate recruitment periods (Wilber and Clarke 2007). Generally, reports of relatively long recovery periods (>1 year) have been associated with the accumulation of fine silt/clay sediments in deep borrow pits; whereas relatively short recovery periods (<1 year) have been associated with borrow pits that were rapidly infilled by sandy sediments that were similar in composition to the extracted material. At ocean borrow sites in New Jersey, Burlas et al. (2001) reported recovery of benthic communities in terms of abundance, diversity, and composition within one year; however, full recovery of biomass composition required longer periods ranging from 1.5 to 2.5 years. At ocean borrow sites in South Carolina, Crowe et al. 2013 reported persistent changes in both sediment composition and benthic community composition lasting six to eight years; however, long-term sediment changes were considered to be consistent with the large area of the borrow sites (1.5 km^2) and their proximity to the Charleston Harbor sediment plume. Conversely, Van Dolah (1998) reported that several years after dredging, surficial sediments in most ocean borrow sites in South Carolina consisted primarily of clean sand. These studies indicate that benthic community recovery rates at ocean borrow sites are dependent on a complex set of environmental variables.

5.3.2.1.2 Indirect Effects

Under Alternatives 1 and 5, direct impacts on benthic invertebrate communities in the pivot channel would indirectly affect demersal soft bottom fishes through temporary reductions in the availability of benthic invertebrate prey, potentially impacting foraging efficiency or inducing additional expenditures of energy in seeking out alternative foraging habitats. However, based on the anticipated short-term duration of direct effects on benthic invertebrate communities and the availability of expansive areas of undisturbed soft bottom foraging habitat adjacent to the dredged channel, it is expected that indirect effects on demersal fishes would be minor and short-term. Under Alternatives 3, 4, and 5, direct impacts on benthic invertebrate communities at the offshore borrow site would have similar indirect prey-loss effects on demersal soft bottom fishes. Benthic community recovery at the offshore borrow site would require longer periods, resulting in longer duration indirect effects on demersal fishes. However, it is expected that partial benthic community recovery would provide significant replacement prey resources within a relatively short time frame, and the area of disturbance at the offshore borrow site would constitute a small fraction of the available undisturbed soft bottom habitat along NTB. Therefore, it is expected that indirect prey-loss effects on demersal fish would be minor.

Sediments that are temporarily suspended during the dredging process may be dispersed and redeposited outside of the active pivot channel and offshore borrow site dredging footprints, potentially impacting adjacent soft bottom benthic communities through burial and/or adverse effects on the gill-breathing and filter-feeding functions of benthic organisms (Michel et al. 2013). Additionally, increases in suspended sediment concentrations and turbidity may reduce the ability of visually oriented demersal fishes to capture benthic prey (Manning et al. 2013). As previously described, the primary factors that influence the extent and duration of sediment suspension include sediment composition and hydrodynamic conditions within the dredging area and the type of dredge employed. In regard to pivot channel dredging under Alternatives 1 and 5, based on the composition of sediments in the pivot channel (coarse sand with minimal fines), the use of cutterhead pipeline dredges that have relatively low sediment suspension rates, and the anticipated rapid dispersal of suspended fine sediments by tidal currents, it is expected that the effects of dredging-induced sediment suspension and redeposition would be localized and short-term. Similarly, based on sediment composition, the use of cutterhead dredges, and rapid dispersal of suspended sediments by waves and currents, it is expected that dredging-induced sediment suspension and redeposition effects at the offshore borrow site under Alternatives 3, 4, and 5 would be localized and short-term.

5.3.2.2 Beach Fill Placement

5.3.2.2.1 Direct Effects

Beach fill placement under Alternatives 1, 3, 4, and 5 would directly impact shallow subtidal soft bottom habitats along the beach fill templates through the burial and mortality of benthic invertebrate communities. Shallow soft bottom benthic communities along the beach are continually disturbed by currents and wave action, and thus are dominated by opportunistic taxa that recover rapidly from disturbance (Wilber and Clarke 2007). Most studies of benthic community recovery from beach nourishment have focused on the intertidal beach rather than the shallow subtidal zone. However, Burlas et al. (2001) reported that the responses of nearshore subtidal soft bottom benthic communities to a beach nourishment project in New Jersey were limited to short-term (≤6.5 months) reductions in abundance, biomass, and taxa richness. Rakocinski et al. (1996) also reported relatively rapid recovery (≤1 year) of nearshore subtidal benthic communities following a beach nourishment project in Florida. Beach fill operations under the four alternatives would be conducted within a 16 Nov - 31 March environmental window, thereby avoiding the peak benthic invertebrate recruitment season in NC. Based on the use of compatible beach fill material and avoidance of the peak recruitment season, it is expected that direct beach fill effects on subtidal benthic communities would be short-term.

5.3.2.2.2 Indirect Effects

Direct impacts on shallow subtidal benthic invertebrate communities under Alternatives 1, 3, 4, and 5 would indirectly affect demersal surf zone fishes through temporary reductions in the availability of benthic invertebrate prey, potentially impacting foraging efficiency or inducing additional expenditures of energy in seeking out alternative foraging habitats. Sediments that are temporarily suspended during beach fill placement operations may be dispersed and redeposited outside of the immediate beach fill placement area, potentially impacting additional soft bottom communities through burial or adverse effects on the gill-breathing and filter-feeding functions of benthic invertebrates. When beach fill containing <10 percent fines has been used, monitoring studies have reported localized sediment suspension and turbidity effects that dissipate rapidly upon the cessation of beach fill placement operations (Van Dolah 1992, Wilber et al. 2006). Van Dolah (1992) reported that elevated turbidities during a beach nourishment project in South Carolina were confined to the immediate vicinity of the discharge sediment plume in close proximity to the shoreline. Turbidities approaching 200 NTU at a distance of 50 ft from shore extended 100 meters along the downdrift shoreline, began decreasing at 200 to 300 meters, and returned to background levels (25 - 50 NTU) at 500 meters. Turbidity measurements at 200 feet from shore indicated no effects from the sediment plume. Wilber et al. (2006) reported that elevated TSS concentrations during a beach nourishment project in New Jersey were limited to the swash zone within 400 m of the discharge location. Based on the use of compatible beach fill containing very small fine sediment fractions, it is anticipated that sediment suspension and redeposition effects under Alternatives 1, 3, 4, and 5 would be localized and short-term.

5.3.3 Marine Water Column

5.3.3.1 Sediment Suspension and Turbidity

5.3.3.1.1 <u>Dredging</u>

Pivot channel and offshore borrow site dredging operations would directly impact pelagic marine organisms through temporary sediment suspension and associated increases in turbidity. Increased sedimentation and turbidity during the dredging process can potentially affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of marine organisms. The primary factors that influence the extent and duration of sediment suspension include sediment composition and hydrodynamic conditions at the borrow site and the type of dredge employed (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities, whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge (Schroeder 2009). Sediment suspension by cutterhead dredges is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Based on sediment resuspension data collected during navigation dredging projects, Hayes et al. (2000) and Hayes and Wu (2001) reported average cutterhead dredge sediment resuspension rates ranging from 0.003 to 0.135% of the fine silt/clay fraction.

Tidal inlets along the southern NC coast are high energy environments where extreme tidal currents generally preclude the deposition of significant fine sediment quantities. Observed turbidity levels during dredging operations in Nixon Channel along the north end of Figure Eight Island did not exceed the state standard of 25 NTUs for tidal salt waters (Cleary and Knierim 2001). Similarly, observed turbidity levels during the 2005 Bogue Inlet ebb channel relocation project remained within the pre-project ambient range (9.7 to 35.2 NTUs) (CSE, unpublished data, 2005). Sediments within the pivot channel dredging footprint have a very small fine sediment fraction of 1.0 percent, thus indicating that turbidity increases and any associated effects on pelagic organisms from pivot channel dredging under Alternatives 1 and 5 would be short term and localized to the immediate vicinity of the active dredging area.

Offshore borrow site dredging operations under Alternatives 3, 4, and 5 would be conducted by cutterhead dredges, which have relatively low sediment suspension rates. Based on the use of cutterhead dredges, the small fine sediment fraction (6.4%) in the dredge cut sediments, and the location of the borrow site in the open ocean where suspended sediments would be rapidly dispersed by waves and currents, it is expected that sediment suspension and turbidity effects on pelagic communities would be minor, short-term, and localized to the immediate vicinity of the borrow site.

5.3.3.1.2 <u>Beach Fill Placement</u>

Temporary sediment suspension and associated increases in turbidity during beach fill placement operations may affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., photosynthesis, gill-breathing, filter-feeding) of pelagic marine organisms in the surf zone. According to Wilber et al. (2003), the effects of a beach nourishment project in New Jersey on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. According to Stull et al. (2016), beach nourishment projects along

Wrightsville Beach, Carolina Beach, and Kure Beach had no significant effects on zooplankton abundance in the surf zone. Total zooplankton abundances remained high throughout pre- and post-project sampling periods and were essentially constant across all nourishment sites (Stull et al. 2016). As previously described, when beach fill containing <10 percent fines has been used, monitoring studies have reported localized sediment suspension and turbidity effects that dissipate rapidly upon the cessation of beach fill placement operations (Van Dolah 1992, Wilber et al. 2006). Based on the use of compatible beach fill containing very small fine sediment fractions, it is anticipated that sediment suspension and redeposition effects under Alternatives 1, 3, 4, and 5 would be localized and short-term.

5.3.3.2 Hydraulic Entrainment

Cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). However, the planktonic larvae of marine fishes and invertebrates lack effective swimming capabilities, and thus are vulnerable to entrainment by dredges. Tidal inlets are critical conduits for the larvae of estuarine-dependent fish and invertebrates that spawn offshore on the continental shelf and use estuarine habitats for juvenile development. Successful larval recruitment to estuarine nursery areas is dependent on transport through tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by longshore currents and transported to inlets (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet (~40 miles northeast of NRI) indicate that larval densities within the inlet are highest from late May to early June and lowest in November (Hettler and Chester 1990). Pivot channel dredging operations under Alternatives 1 and 5 would be conducted within a 16 November - 31 March environmental nourishment window, thereby avoiding the peak larval ingress period. The results of a larval entrainment modeling study at Beaufort Inlet indicate that entrainment rates are likely to be very low regardless of larval concentrations and the distribution of larvae within the water column (Settle 2002). Even under worst case conditions when the dredge is operating 24 hours each day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the model-projected entrainment rate barely exceeds 0.1% of the daily (24-hour) larval flux through the inlet. Offshore borrow site dredging operations under Alternatives 3, 4, and 5 would also avoid the peak larval ingress period through adherence to a 16 November - 31 March environmental nourishment window. Based on the widespread dispersal of planktonic eggs and larvae in offshore waters, it is expected that entrainment rates at the offshore borrow site would be very low.

5.3.4 Oceanfront Beach and Dune Communities

5.3.4.1 Intertidal Beach Communities

5.3.4.1.1 Direct Effects

Beach fill placement events under Alternatives 1, 3, 4, and 5 would directly impact ~10 acres of intertidal beach habitat. Beach fill placement on top of the existing intertidal substrate would result in burial and mortality of the associated benthic infaunal invertebrate communities. Recolonization of the post-nourishment intertidal beach via larval settlement and adult recruitment from adjacent beaches would begin upon the cessation of beach fill operations. Intertidal beach benthic invertebrate communities are dominated by taxa that generally recover rapidly from disturbance; however, recovery rates are influenced by a number of factors, most importantly the compatibility of the beach fill sediments with those of the native beach and the timing of nourishment projects in relation to benthic invertebrate larval recruitment periods (Wilber et al. 2009, Peterson et al. 2006, and Hackney et al. 1996). Most benthic recovery studies have reported relatively rapid recovery within one year of the initial impact when highly compatible beach fill sediments were used and larval recruitment periods were avoided (Jutte et al. 1999a, Burlas et al. 2001, Van Dolah et al. 1994, Van Dolah et al. 1992, Gorzelany and Nelson 1987, Salomon and Naughton 1984, Parr et al. 1978, and Hayden and Dolan 1974). Conversely, longer recovery periods ranging from 15 months (Rakocinski et al. 1996) to 4 years (Peterson et al. 2014) have been reported when incompatible beach fill sediments containing large quantities of fine silt/clay or coarse shell hash material were used. NC has enacted regulatory technical standards for the compatibility of beach fill sediments with those of the native beach (15A NCAC 07H .0312). The Technical Standards require analyses of sediments from the recipient beaches and proposed borrow sites; including analyses of percent weight of fine-grained sediment, percent weight of granular sediment, percent weight of gravel, and percent weight of calcium carbonate. All beach fill placed on the north end project shoreline under Alternatives 1, 3, 4, and 5 would consist of compatible material in accordance with the NC Technical Standards. Furthermore, all beach fill operations under the four alternatives would be conducted within a 16 Nov-31 March environmental nourishment window, thereby avoiding the peak benthic invertebrate recruitment season in NC [May-September (Hackney et al. 1996, Diaz 1980, Reilly and Bellis 1978)]. Therefore, it is anticipated that benthic community recovery would occur relatively rapidly.

5.3.4.1.2 Indirect Effects

Direct impacts on intertidal benthic infaunal communities would indirectly affect shorebirds and demersal surf zone fishes through temporary reductions in benthic invertebrate prey availability; potentially reducing foraging efficiency and/or inducing shorebirds and demersal fishes to expend additional energy seeking out alternative foraging habitats. Peterson et al. (2006, 2014) reported a 70 to 90 percent decline in shorebird foraging activity on a beach at Bogue Banks following nourishment with incompatible beach fill containing large quantities of coarse shell material. The decline in shorebird activity was attributed primarily to depressed infaunal communities; however, high percent surface coverages of coarse shell material may have contributed to the decline by impeding the sediment-probing foraging technique of shorebirds. A study of beach nourishment effects on shorebirds and colonial waterbirds at Holden Beach and Oak Island detected no significant effects on shorebird or waterbird abundances (Grippo et al. 2007). However, the authors noted the possibility that abundances on nourished beaches could have been maintained by a continuous flux of arriving and departing migratory birds as opposed to extended residency by the same individuals. In terms of behavioral effects, the study detected a significant reduction in colonial waterbird feeding activity on nourished beaches; however, the feeding activities of shorebirds that are more heavily dependent on intertidal beach foraging habitats were not affected. According to Wilber et al. (2003), the effects of a beach nourishment project in New Jersey on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. Although the effects of temporary benthic prey loss on shorebirds and surf zone fishes potentially include adverse effects on energy reserves leading to reduced survivability or productivity, effects on survivability and productivity are not measurable or quantifiable. However, it is expected that relatively rapid benthic infaunal recruitment would provide substantial replacement prey resources within a relatively short period of time, and substantial undisturbed intertidal beach foraging habitat would be available along the adjacent beaches during benthic recovery periods.

5.3.4.2 Dry Beach and Dune Communities

5.3.4.2.1 Direct Effects

Beach fill placement events under Alternatives 1, 3, 4, and 5 would directly impact ~10 acres of dry beach and dune habitat. Sand placement on the upper dry beach would result in the burial and mortality of ghost crabs and other sand-dwelling invertebrate macrofauna. The reported effects of beach nourishment and beach scraping on ghost crabs range from no significant response (Bergquist et al. 2008) to significant long-term effects lasting approximately one year (Dixon 2007). The results of ghost crab recovery studies indicate that the primary project-related factors that influence post-nourishment recovery rates are similar to those previously described for intertidal benthic communities; including sediment compatibility, the timing of operations relative to recruitment periods, and the frequency of recurring impacts. Bergquist et al. (2008) attributed the absence of a clear response to a winter nourishment project at Folly Beach, South Carolina to the use of highly compatible beach fill. In contrast, a summer nourishment project at Folly Beach resulted in significant long-term (approximately one year) effects on local ghost crab population structure, including the loss of entire cohorts (Dixon 2007). Lindquist and Manning (2001) and Peterson et al. (2000) attributed significant reductions in ghost crab abundances lasting six to eight months to changes in sediment composition on newly constructed dune faces at Bogue Banks. Additionally, Peterson et al. (2006) reported that ghost crab recruitment on filled beaches appeared to be inhibited following a winter 2001/2002 nourishment project on Bogue Banks. Although sampling detected no statistically significant effects, Peterson et al. (2006) attributed the apparent effects on ghost crab recruitment to the placement of incompatible beach fill containing a high percentage of coarse shell material. Lindquist and Manning (2001) detected no response to an initial beach nourishment project at Topsail Beach; however, repeated annual nourishment projects resulted in significant reductions in ghost crab abundances.

All beach fill placed on the north end project shoreline under Alternatives 1, 3, 4, and 5 would consist of compatible material in accordance with the NC Technical Standards. Furthermore, all beach fill operations under the four alternatives would be conducted within a 16 Nov-31 March environmental window, thereby avoiding the ghost crab recruitment season in NC [July-September (Lucrezi and Schlacher 2014)]. Additionally, it is expected that the relatively short length of the project nourishment reach (5,100 ft) would facilitate rapid recovery via adult recruitment from adjacent beaches. Therefore, it is anticipated that ghost crab recovery would occur within a year of beach nourishment events. Beach fill placement operations would have additional short-term direct impacts on coastal waterbirds in the form of disturbance and temporary displacement from upper beach loafing and roosting habitats.. The completion of beach fill operations within a 16 Nov-31 March environmental nourishment window would avoid the 1 May to 15 November sea turtle nesting and hatching season in NC. Therefore, no direct beach fill impacts on nesting sea turtles or hatchlings would be expected under Alternatives 1, 3, 4, and 5.

5.3.4.2.2 Indirect Effects

Beach fill placement under Alternatives 1, 3, 4, and 5 may indirectly affect sea turtles, coastal waterbirds, and ghost crabs through physical modification of dry beach habitat. Sand placement can indirectly impact sea turtle nesting by altering dry beach nesting habitat in ways that deter nesting or reduce nesting and/or hatching success. Observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, substrate compaction, and escarpment formation (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). Loggerheads prefer steeply sloped beaches (Provancha and Ehrhart 1987) and typically select nest sites that correspond to the steepest slopes along a given beach (Wood and Bjorndal 2000). By design, sand placement projects construct a flat berm that gradually steepens to the natural equilibrium profile over time as the placed sediments are redistributed by natural transport processes. The initial post-construction reduction in slope may deter nesting females from emerging onto the beach or increase the likelihood of false crawls. The post-construction beach profile equilibration process may induce the formation of escarpments that prevent adult females from accessing upper dry beach nesting habitats. Furthermore, the compaction of sediments by construction activities may impede the ability of adult females to excavate nests. Studies that have documented declines in nesting success on nourished beaches have generally reported a return to normal nesting activity by the second or third post-project nesting season (Crain et al. 1995, Steinitz et al. 1998, Ernest and Martin 1999, Herren 1999, Rumbold et al. 2001, Byrd 2004, and Brock et al. 2009). In the case of severely eroded beaches, the restoration of a wider and higher dry beach may enhance the quality of sea turtle nesting habitats. Studies have reported immediate increases in nesting success following sand placement projects on chronically eroded beaches (Davis et al. 1999 and Byrd 2004).

Substrate modifications may have additional negative effects on the nest incubation environment and the ability of sea turtle hatchlings to emerge from the nest (Nelson and Dickerson 1988, and Crain et al. 1995). Compaction and the modification of substrate characteristics such as grain size, density, organic content, and color can alter the nest incubation 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, Ehrhart 1995, and Ackerman 1996). Nourished beaches often retain more water than natural beaches, thereby impeding gas exchange within the nest environment (Mrosovsky 1995, and Ackerman 1996). Warmer nest temperatures attributable to the placement of relatively dark sediments (Hays et al. 2001) may impede embryonic development (Matsuzawa et al. 2002) or increase the incidence of late-stage embryonic mortality (Ernest 2001). Sex determination in hatchlings is controlled by nest temperature, with warmer temperatures producing more females and cooler temperatures producing more males (Wibbels 2003). Thus, warmer nest temperatures attributable to sand placement may alter hatchling sex ratios. Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. The five-year study (2002-2007) included monitoring of nesting activity, hatching success, substrate compaction, and nest temperature. No significant beach nourishment effects on nesting success (i.e., nest/false crawl ratios) were detected, and there was no indication that nourishment adversely affected egg development or hatching success, with the exception of one nest on that apparently failed due to poor gas exchange. Nourishment had no significant effect on compaction; however, nests in nourished areas were on average 1.9°C warmer than nests laid at the same time on undisturbed beaches. Although sex ratios were not determined, Holloman and Godfrey concluded that the increase in nest temperature on nourished beaches probably increased the number of females produced. Measures employed under Alternatives 1, 3, 4, and 5 to minimize the extent and duration of adverse habitat modification effects would include the use of compatible beach fill sediments and the implementation of post-construction sediment compaction and escarpment monitoring with remediation as indicated. Based on these measures, it is expected that any indirect habitat modification effects on sea turtles would be minor and short-term.

6.0 AVOIDANCE AND MINIMIZATION

Pursuant to the CEQ regulations for implementing NEPA, environmental impact analyses must consider all relevant and reasonable measures to avoid and minimize the potential adverse effects of proposed actions. This section describes measures that would be implemented to avoid and minimize the environmental effects of dredging, beach fill placement, and terminal groin construction under the various alternatives.

6.1 Dredging

Environmental Dredging Window. All dredging operations will be completed between 16 November and 31 March, thereby avoiding peal larval ingress periods, peak benthic invertebrate recruitment periods, and periods when manatees and sea turtles are most likely to present in nearshore waters along the NC coast.

Protected Species Construction Conditions. All in-water construction activities would comply with NMFS-SERO's Protected Species Construction Conditions (NMFS 2021a).

- All personnel associated with the project will be instructed about the potential presence of species protected under the ESA and the Marine Mammal Protection Act (MMPA). All on-site project personnel will be responsible for observing water-related activities for the presence of protected species. All personnel shall be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals.

- Operations of moving equipment shall cease if a protected species is observed within 150 feet of operations.

- Activities shall not resume until the protected species has departed the project area of its own volition (e.g., species was observed departing or 20 minutes have passed since the animal was last seen in the area).

Vessel Strike Avoidance Measures. All vessel operations associated with the proposed action would comply with NMFS-SERO's Vessel Strike Avoidance Measures (NMFS 2021b).

- When a protected species is sighted, vessel operators will attempt to maintain a distance of 150 feet or greater between the animal and the vessel. Vessel operators will reduce speed and avoid abrupt changes in direction until the animal(s) has left the area.

- When dolphins are bow- or wake-riding, vessel operators will maintain course and speed as long as it is safe to do so or until the animal(s) leave the vicinity of the vessel.

- If a whale is sighted in the vessel's path or within 300 feet of the vessel, vessel operators will reduce speed and shift the engine to neutral. Vessel operators will not engage the engines until the animals are clear of the area.

- If a whale is sighted farther than 300 feet from the vessel, operators will maintain a distance of 300 feet or greater between the whale and the vessel and reduce speed to 10 knots or less.

Pipeline Routes. In the event that DA-143 is used as a supplemental source of beach fill, submerged pipelines will be routed to avoid SAV and shellfish beds. If submerged pipelines cannot be routed to avoid SAV and shellfish beds, floating pipelines will be used.

Pipeline Inspections. Dredging contracts would require routine inspections of dredging equipment and beach fill delivery pipelines, thereby minimizing the potential for pressurized leaks and associated turbidity and sedimentation effects.

Pollution Prevention. Dredging contracts would require routine inspections of dredging equipment and sand delivery pipelines, thereby minimizing the potential for pressurized leaks and associated turbidity and sedimentation effects.

6.2 Beach Fill Placement

Environmental Work Window. Beach fill placement operations will be completed between 16 November and 31 March, thereby avoiding the 1 May - 15 November sea turtle nesting and hatching season in NC, the April-August piping plover breeding season in NC, and the majority of the seabeach amaranth growing season.

Beach Fill Compatibility. All beach fill placed on the north end project shoreline will consist of compatible material in accordance with the NC Technical Standards for Beach Fill Projects (15A NCAC 07H .0312). All beach fill sediments will be compatible with those of the recipient beach based on analyses of percent weight of fine-grained sediment, percent weight of granular sediment, percent weight of gravel, and percent weight of calcium carbonate. Continuous visual monitoring of fill material will be conducted at the pipeline outfall before it is redistributed along the beach. If noticeable quantities of incompatible fill material are detected, the contractor will cease operations and immediately contact the Wilmington District Regulatory Branch and NCDCM to determine the appropriate course of corrective action.

Sediment Suspension and Turbidity. Beach fill placement operations will include the use of spreaders on pipelines to reduce effluent discharge velocities during sand-slurry placement on the beach. Temporary longitudinal sand dikes would be used to contain and direct the horizontal flow of the discharged sand-slurry along the beach. These measures would maximize sediment retention within the placement area and minimize potential surf zone turbidity effects.

Monitoring for Escarpments**.** Immediately after the completion of beach construction operations and prior to May 1, surveys for escarpments will be conducted within the limits of the construction area. Escarpments that are identified prior to or during the nesting season that interfere with sea turtle nesting (exceed 18 inches in height for a distance of 100 ft) would be leveled to the natural beach profile. If it is determined that escarpment leveling is required during the nesting or hatching season, leveling actions would be coordinated with the USFWS.

Monitoring for Sediment Compaction. Beginning immediately after the completion of beach construction operations and prior to 1 May, and for a subsequent period of one year, sand compaction will be monitored in the beach fill area. If required, the area will be tilled to a depth of 36 inches. All tilling activity shall be completed prior to May 1. A report on the results of compaction monitoring will be submitted to the USFWS prior to any tilling actions being taken.

Monitoring for Changes in Sea Turtle Nesting. Annual nest monitoring and nest protection will continue to be implemented by the Topsail Turtle Project Nesting Program under the NC Sea Turtle Project administered by the NCWRC.

6.3 Terminal Groin

Environmental Work Window. Terminal groin construction will be completed between 16 November and 31 March, thereby avoiding the 1 May - 15 November sea turtle nesting and hatching season in NC, the April-August piping plover breeding season in NC, and the majority of the seabeach amaranth growing season.

Protected Species Construction Conditions. All in-water construction activities would comply with NMFS-SERO's Protected Species Construction Conditions (NMFS 2021a).

- All personnel associated with the project will be instructed about the potential presence of species protected under the ESA and the Marine Mammal Protection Act (MMPA). All on-site project personnel will be responsible for observing water-related activities for the presence of protected species. All personnel shall be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals.

- Operations of moving equipment shall cease if a protected species is observed within 150 feet of operations.

- Activities shall not resume until the protected species has departed the project area of its own volition (e.g., species was observed departing or 20 minutes have passed since the animal was last seen in the area).

Monitoring for Shoreline and Beach Profile Changes. As required by the NC Coastal Policy Reform Act of 2013, the applicant will implement an approved Inlet Management Plan that provides for the following: 1) post-construction monitoring of oceanfront and adjacent estuarine shorelines for groin-related impacts, 2) establishment of a baseline for assessing impacts and the thresholds that will trigger mitigation, 3) provisions for the implementation of mitigation measures in the event that thresholds are reached, and 4) provisions for modification or removal of the groin in the event that impacts cannot be otherwise mitigated.

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