CAPE COD CANAL & SANDWICH BEACHES
SANDWICH, MASSACHUSETTS

SECTION 111
SHORE DAMAGE MITIGATION STUDY
DRAFT DECISION DOCUMENT

March 2021

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Cape Cod Canal and Sandwich Beaches
Section 111 Shore Damage Mitigation Study
Detailed Project Report

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Cape Cod Canal and Sandwich Beaches
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1. Introduction

1.1 Background Information

The Cape Cod Canal (Canal) is a 17.5-mile manmade waterway separating Cape Cod from the mainland of Massachusetts. The Canal is a Federal Navigation Project (FNP), owned and operated by the U.S. Army Corps of Engineers (USACE) that was constructed in the early 20th century. It provides a shorter, more protected route to mariners who would otherwise travel an additional 135 miles around Cape Cod and the Islands of Martha's Vineyard and Nantucket. The alternative route leaves mariners fully exposed to the open ocean and its associated navigational hazards, which was particularly dangerous in 1909, when construction of the Canal first began. In order to maintain safe navigation into and out of the Canal, jetties were constructed at the east entrance that reduce wave energy and prevent shoaling of the channel itself. The jetties have served their intended purpose very well but as an unintended consequence, they also interrupt longshore sediment transport that prevents sediment from reaching the downdrift shoreline in Sandwich, Massachusetts. Erosion of the shoreline downdrift of the Canal, specifically at Town Neck Beach and Springhill Beach, has taken place since the Canal was constructed and has presumably been the result of a sand-starved littoral zone created by the jetties. The erosion has continued and progressed to the point where public and private infrastructure and resources are now imminently threatened by coastal storm hazards and are expected to sustain significant and even catastrophic damages if the problem is left unaddressed. Due to the presumed cause-and-effect relationship between the jetties and the downdrift erosion, the town of Sandwich has sought the USACE's assistance in mitigating damages caused by the Canal FNP. A formal letter from the Town was signed and sent to the Corps on March 2nd 2006 and can be found in Appendix G.

> *Additional information pertaining to the history and purpose of the Canal can be found at the New England District's website.*
>
> *https://www.nae.usace.army.mil/Missions/Recreation/Cape-Cod-Canal/History/*

1.2 National Environmental Policy Act Requirements

This Detailed Project Report (DPR) and integrated environmental assessment (EA) was prepared in compliance of the National Environmental Policy Act (NEPA), the Council on Environmental Quality's (CEQ) Guidance Regarding NEPA Regulations, and the USACE's Procedures for Implementing NEPA (33 CFR part 230).

The EA is a concise public document prepared by the USACE for the purpose of determining whether the proposed action has the potential to cause significant environmental effects (40 Code of Federal Regulations (CFR) 1508.9(a)).

Specific objectives of the EA are to:

- provide evidence and analysis sufficient to determine whether an Environmental Impact Statement (EIS) is required;
- aid the Federal agency's compliance with NEPA when no EIS is necessary;
- facilitate preparation of an EIS when one is necessary; and serve to justify a finding of no significant impact (FONSI).

The EA must discuss:

- the need for the proposed action;
- the proposed action and alternatives;
- the probable environmental impacts of the proposed action and alternatives;
- and the agencies and persons consulted during preparation of the EA.

NEPA requires Federal agencies to integrate the environmental review into their planning and decision-making process. This DPR/EA is consistent with NEPA statutory requirements. The report reflects an integrated planning process, which avoids, minimizes, and mitigates adverse project impacts associated with the proposed action(s).

1.3 Study Authority

This report was prepared under authority contained in Section 111 of the River and Harbor Act of 1968 (Public Law 90-483), as amended. Section 111 of the Continuing Authorities Program (CAP) authorizes the USACE to study, plan and implement structural and/or nonstructural measures to prevent or mitigate damage to public and privately-owned shorelines to the extent that such damages can be directly attributed to an FNP. The Federal expenditure limit for a project implemented under this authority is $12,5 million as most recently modified by the Water

Resources Development Act (WRDA) of 2018. Additionally, the costs of studies, design and implementation for Section 111 projects must be shared in the same proportion as the cost sharing provisions applicable to the project causing the shore damage. When the USACE took ownership of the Canal FNP and completed construction, including the jetties and their modification, the work was 100% federally funded. Therefore, this study and initial design and construction of any resulting project would also be 100% Federally funded.

It should also be noted that although Federal participation is limited to addressing only those damages directly attributable to the FNP under Section 111 authority, if there are multiple causes for the damages, the non-Federal sponsor would be responsible for all costs associated with correcting shore damage not attributed to the FNP.

1.4 Non-Federal Sponsor

The town of Sandwich, Massachusetts is the non-Federal sponsor for this study. The Town initially requested USACE assistance under Section 111 authority in their letter of March 2nd, 2006. The Town has partnered with the USACE in the past on cost-shared studies on expanding the East Boat Basin of the Canal, and funded beach placement actions in association with maintenance dredging of the Canal. The Town has also contracted with regional firms on geomorphological and coastal processes studies of its shoreline, some of which were used to inform this study process.

1.5 Prior Studies, Reports, and Existing Water Projects

Both the Town and the USACE have a history of investigating and/or attempting to address erosion of the shoreline downdrift of the Canal over the past 25-50 years. In addition to USACE's direct involvement with those efforts, the Town has worked with Woods Hole Group, Inc. on their own accord to investigate the problem, develop plans and apply for beach nourishment permit. The most recent USACE related efforts include the following:

- <u>2015: Section 204 Feasibility Study</u>
  In 2014-2015, the USACE conducted a Feasibility Study under Section 204 of the CAP program, aimed at beneficially reusing material to be dredged from the Canal as part of a routine maintenance dredging effort. This study considered a cost-shared project that would place approximately 120,000 cubic yards of a sand on Town Neck Beach. A Federal Interest Determination was completed in 2014, but the feasibility study was ultimately abandoned in 2015 due to several policy compliance concerns that could not be resolved prior to the separately scheduled dredging effort commencing.

- 2016: Sand Placement on Town Neck Beach
  In 2015, following the abandonment of the abovementioned Section 204 study, the town of Sandwich was able to procure enough funding, with contributions from the Commonwealth of Massachusetts, to pay for the material in full, without Federal participation. Consequently, a Memorandum of Agreement was signed between the USACE and the Town of Sandwich on September 22, 2015 and 120,000 cubic yards of sand was placed on Town Neck Beach in January of 2016.

- 2019: Scusset Borrow Area Permitted
  The town of Sandwich has been working with Woods Hole Group, Inc. (WHG) for over a decade investigating the nature of the erosion problem downdrift of the Canal and any opportunities to address it. These efforts have been separate but parallel to the USACE's efforts. In 2019, the Town obtained permits to dredge approximately 224,000 cubic yards of material from the nearshore of Scusset Beach for the specific purpose of nourishing Town Neck Beach. Those permits are currently valid, but funding is a limiting factor for the Town, who cannot currently conduct the work through their own means.

1.6 Study Area

The study area is located on the north shore of Cape Cod in the town of Sandwich, Massachusetts, approximately 50 miles southeast of Boston and 18 miles south of Plymouth (Figure 1-1). The study area is the approximately 2.5 miles of directly impacted shoreline, including Scusset Beach, the east entrance to the Canal, Town Neck Beach, Old Sandwich Harbor and Springhill Beach. The study area also includes the neighboring areas of Great Marsh, Route 6A and downtown Sandwich, which have not yet been directly impacted by the problem but can reasonably be expected to be impacted if the problem is left unaddressed. The study was primarily focused on the Canal jetties maintaining the east entrance of the Canal, accretion of material along the updrift shoreline at Scusset Beach and erosion along the downdrift shoreline at Town Neck Beach and Springhill Beach (Figures 1-2 and 1-3). The study area can more explicitly be divided into several distinct focus areas, which are described below.

Figure 1-1: Study Location

Figure 1-2: Study Area

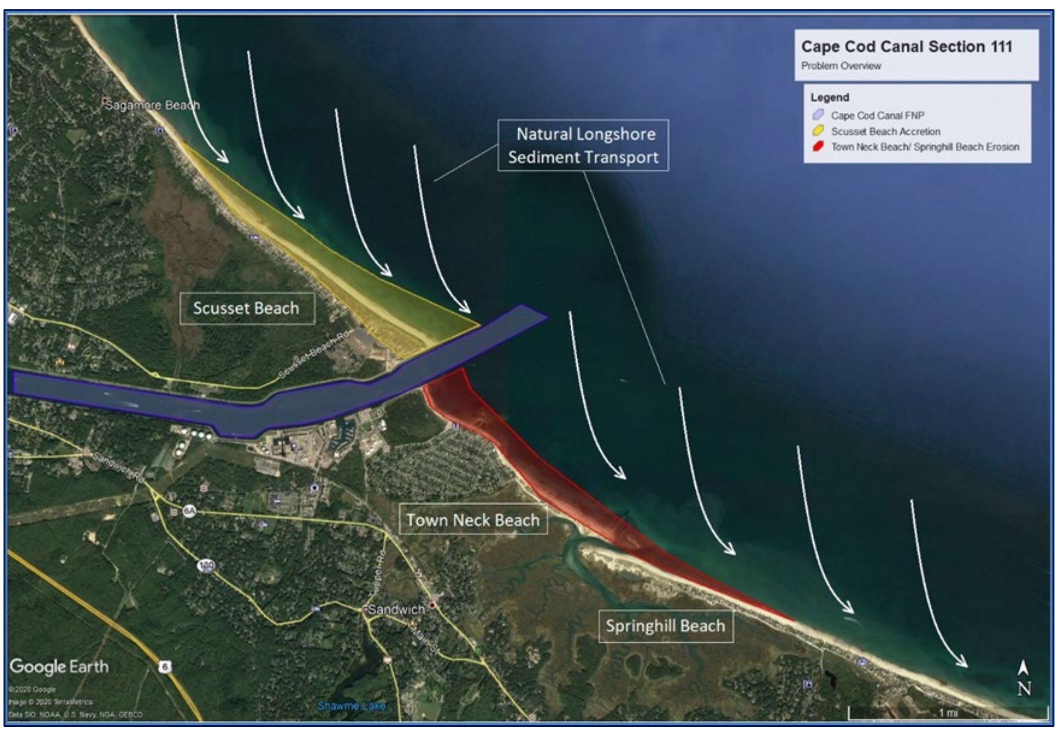

Figure 1-3: Problem Overview

Cape Cod Canal/East End Jetties

The Canal is a 17.5-mile navigable waterway bisecting the "arm" of Cape Cod, with entrances at Buzzards Bay to the west, and Cape Cod Bay to the east. Two jetties located at the eastern entrance maintain safe navigation into and out of the Canal by reducing wave energy and shoaling of the channel, but also interrupt natural longshore sediment transport along the Sandwich Shoreline.

Town Neck Beach

Town Neck Beach is the roughly 1.25-mile stretch of shoreline immediately downdrift of the Canal, where acute and long-term erosion are most prominent. There is a ¼ mile section of that shoreline between the Canal and Town Neck Beach proper (town-owned beach) that is owned by a nearby power supply company but for the purpose of this study Town Neck Beach refers to the entire shoreline from the Canal to the Old Sandwich Harbor inlet (tidal inlet to Great Marsh).

Springhill Beach

Springhill Beach is the continuation of the Sandwich shoreline immediately downdrift of Town Neck Beach and Old Sandwich Harbor Inlet. Springhill Beach was the presumed lateral extent of the Canal's influence on the problem (i.e. the point beyond which erosion occurs naturally).

Great Marsh

Immediately behind the barrier dunes at Town Neck Beach and Springhill Beach is a large salt marsh system known as Great Marsh. Great Marsh provides 600+ acres of contiguous healthy salt marsh habitat to local wildlife, and a 1,100 linear foot boardwalk running through the system that serves as a recreational feature and primary public access point to Town Neck Beach. Great Marsh also serves as a buffer between the open-ocean and the Route 6A/Downtown Sandwich area. The dunes at Town Neck Beach and Springhill Beach protect the entire marsh from the threat of coastal storm damage.

Route 6A/Downtown Sandwich

Immediately landward of Great Marsh is Route 6A and Downtown Sandwich. Route 6A is a low-lying main road that serves as one of the primary access routes to and from Cape Cod and consequently serves as a primary evacuation route for the entire region. Several public facilities, including the local fire station, police station and post office are located along Route 6A. Downtown Sandwich, which is built around and generally accessed via Route 6A is an Historic District that serves as the economic hub for the Town. This area includes many local business and registered historic buildings, including Town Hall. Both areas will become significantly more at risk to coastal storm hazards if the dune system at Town Neck Beach were to fail.

Scusset Beach
Scusset Beach is located immediate updrift (north) of Canal's east entrance, where material has steadily accreted since the construction of the Canal and has the potential to be used as a source of beach nourishment material.

1.7 Problem Statement/Purpose and Need

Over the past 100 years, and most noticeably in the last 20 years, erosion along the Sandwich shoreline has resulted in a dwindling beach profile that subsequently and significantly threatens public and private property and infrastructure within the coastal community of Sandwich, Massachusetts. Several shoreline homes have already succumbed to the erosion in recent years, and continued loss of the dune has created an imminent threat of catastrophic damage to additional shorefront structures, Great Marsh and the Route 6A/Downtown Sandwich area.

Erosion of the Sandwich shoreline and its threat to both the shorefront and interior coastal community has reached what effectively amounts to 'critical mass'; a tipping point where what once served as a naturally wide buffer to coastal storm energy has little to no remaining capacity to absorb that energy and serve as a protective feature. Instead, each coastal storm in the area now has a high likelihood of undermining shorefront structures and/or breaching the dune; the consequences of which would be significant and felt by the entire community.

The following are examples of how that impact has already been experienced in recent years. During Winter Storm Juno in 2015, at least one home was undermined and condemned along Springhill Beach (Figure 1-4). During that same storm, the dune along Town Neck Beach was partially breached, completely filling and blocking the main inlet channel. Emergency action was then taken in order to excavate the channel, restore the dune and prevent more significant damage to the marsh from occurring (Figure 1-5). In March of 2018, Winter Storm Riley resulted in significant damage to several structures along Town Neck Beach including the total loss of the home at 103 Wood Avenue (Figure 1-6). During both Winter Storm Juno in 2015 and Winter Storm Riley in 2018, Route 6A was closed due to coastal flooding of the roadway, and local businesses within the Downtown Sandwich area were closed as well (Figures 1-7, 1-8 and 1-9).

Note: Coastal flooding in the area is a natural occurring phenomenon and it is not necessarily caused by erosion of the shoreline. However, if the dune were to breach and/or erode completely, the interior infrastructure would be exposed to wave run-up and wave attack, which would exacerbate flooding impacts.

Figure 1-4: Property located along Springhill Beach, undermined during Winter Storm Juno in 2015

Figure 1-5: Emergency excavation of the Great Marsh inlet channel following Winter Storm Juno in 2015

Figure 1-6: 103 Wood Ave undermined and destroyed following Winter Storm Riley in 2018 (photo credit NBC 10 News/David Curran/Satellite News Service)

Figure 1-7: Local business located along Route 6A, closed during Winter Storm Riley in 2018 (photo credit NPR/Rick Anderson)

Figure 1-8: Flooding of Route 6A and the Sandwich Fire Department during Winter Storm Riley in 2018 (photo credit CapeCod.com)

Figure 1-9: Route 6A flooded during Winter Storm Riley in 2018 (photo credit CapeCod.com)

1.8 Opportunities

For decades, it has been presumed locally that the jetties at the east end of the Canal have been the predominant cause of erosion in Sandwich since they interrupt natural longshore sediment transport by design. Section 111 of the CAP program authorizes the USACE to specifically investigate the cause-and-effect relationship between Federal Navigation Projects and adjacent shorelines. For the Cape Cod Canal and Sandwich Beaches, this study examined the Canal's east jetties and erosion of the downdrift shoreline. Below is an outline of some of the specific opportunities associated with this study.

<u>Reduce Coastal Storm Damage to Shoreline Structures</u>
The most obvious opportunity to mitigate impacts of continued erosion of the Sandwich shoreline is the opportunity to reduce the likelihood of shoreline structures being undermined and destroyed. Although most of the shoreline structures that stand to benefit from this study are privately owned, their vulnerability to erosion would not be nearly as imminent but for the Canal FNP. The Section 111 authority provides an opportunity to mitigate that increased vulnerability.

<u>Reduce Coastal Storm Damage to Great Marsh</u>
Great Marsh is a thriving 600+ acre salt marsh ecosystem located immediately landward of the barrier dune. Partial breaches of the dune have caused minor damage to the marsh in recent years and continued erosion of the shoreline will result in much more substantial breaches and potentially a complete loss of the dune. Without a barrier dune to protect it, the marsh will be exposed to direct wave energy that is likely to destroy significant portions, if not all of that natural system. This study provides an opportunity to substantially reduce the likelihood of catastrophic damages to the marsh occurring as a consequence of dune failure.

<u>Reduce Coastal Storm Damage to Route 6/A</u>
Route 6A is a low-lying main road immediately landward of Great Marsh that serves as a primary evacuation route for the entire Cape Cod region and is home to local critical infrastructure. It is currently vulnerable to flooding during low frequency storm surge but if the barrier dune were lost, then like Great Marsh, wave run-up and wave attack will increasingly threaten the road and critical infrastructure. Reducing erosion along the Sandwich shoreline is an opportunity to reduce the likelihood and consequence of increased flooding to the Route 6A.

Reduce Coastal Storm Risk to Historic District and Local Economy

The town of Sandwich is a small coastal community founded in 1639 whose economy is largely driven by tourism, recreation and an historic identity. All three of these economic drivers were established by taking advantage of the town's proximity to the ocean and as such, they are threatened by continued erosion and encroachment of the ocean. Reducing coastal storm risk and subsequent damage to historic structures and commercial infrastructure inherently benefits the local economy. Additionally, recreational beach usage is a key component of the tourism that drives the local economy, and Town Neck Beach is the only public beach in Sandwich that is located on the Cape Cod side of the Canal (Scusset Beach is a state park in the town of Sandwich but it is located on the mainland side of the Canal). Mitigating the erosion of the shoreline caused by the Canal FNP will help stabilize and improve recreational usage of Town Neck Beach. Reducing the threat of continued erosion along the Sandwich shoreline inherently improves the sustainability of these key local economic drivers.

Improve Relationship Between Community and the USACE

Although Town leadership has been developing a strong working relationship with the USACE through recent and ongoing efforts to address the erosion problem in question, the community at large has a more strained relationship with the USACE. For many in the community, the Canal is viewed as the obvious cause of the erosion problem, and the USACE has been viewed locally as remiss in addressing their concerns until very recently. That may be a generalization, but it stands to reason that the USACE has an opportunity through this study to improve its relationship with the community, which is a worthwhile pursuit through the lens of public service.

1.9 Constraints

Several key constraints were identified at the beginning of the study and were instrumental in the development of alternatives as well as the selection of a recommended plan. Those constraints are outlined below.

1.9.1. Federal Expenditure Limit

Section 111 of the CAP program limits Federal participation to $12.5 million, including the cost of studies, design and implementation, and participation in any future renourishment. The federal expenditure limit significantly constrains the size and scope of a project that can be implemented through this study, particularly when considering the perpetual nature of the problem being investigated.

1.9.2. Environmental Impacts

Previous efforts to address erosion along the Sandwich shoreline have resulted in a well-established understanding of environmental concerns associated with Essential Fish Habitat (EFH) and submerged aquatic vegetation (SAV) in the intertidal and subtidal zone within the study area. These concerns were a constraint in that they were a primary consideration in the development and evaluation of measures and alternatives during this study.

1.9.3. Direct Attribution

Erosion is a naturally occurring coastal process that is often exacerbated by anthropogenic alterations of the shoreline. Federal participation in a project through Section 111 authority is limited to mitigating those damages directly attributable to a FNP, which in this case is an exacerbation of shoreline erosion attributed to the jetties at the eastern entrance of the Canal. While this study presumed that erosion of the Sandwich shoreline has been influenced by the Canal FNP, the study had to consider the possibility that naturally occurring erosion also contributes to shoreline retreat and subsequent coastal storm risk/damage within the study area. Therefore, this study needed to identify the extent to which erosion of the Sandwich shoreline is directly attributable to the Canal FNP and alternatives needed to be developed and evaluated with that distinction in mind.

1.10 Planning Goals/Objectives

The following are the goals and objectives of this project over the period of analysis and as limited by the $12.5 million Federal project limit under Section 111.

Goals

- Establish a quantifiable understanding of the cause-and-effect relationship between the Canal FNP and erosion of the Sandwich shoreline.
- Identify a readily implementable plan for reducing erosion related damages directly attributable to the Canal FNP

Objectives

- Quantify shoreline change and sediment transport rates both updrift and downdrift of the Canal's eastern entrance
- Quantify the influence that naturally occurring erosion has on the erosion of the Sandwich shoreline
- Determine the extent to which the Canal FNP is contributing to erosion along the Sandwich shoreline, in order to determine the extent to which Federal participation in mitigating the damages is warranted
- Develop and evaluate measures and alternatives that have the potential to mitigate erosion related damages along the Sandwich shoreline
- Recommend a readily implementable plan for mitigating damages to Town Neck Beach, Springhill Beach, Great Marsh and the Route 6A/Downtown Sandwich areas caused by continued erosion of the shoreline

1.11 Permits, Approvals, and Regulatory Requirements

In addition to compliance with the NEPA, the USACE must ensure that projects completed under this authority comply with all applicable Federal laws. For example, compliance with the Endangered Species Act, the Fish and Wildlife Coordination Act, the National Historic Preservation Act, the Clean Water Act, etc., is always mandatory for Federal actions.

Table 1-1 outlines the major environmental permits and reviews (Federal and State) for the project; Section 8 *Compliance with Environmental Laws and Regulations* summarizes the project's compliance with applicable Federal laws, regulations, Executive Orders, and Executive Memoranda.

Table 1-1: Environmental permitting laws and compliance requirements

Major Environmental Permits and Reviews for the Cape Cod Canal and Sandwich Beaches Shore Damage Mitigation Project	
Agency	**Permit/Review**
Federal	
U.S. Department of the Army Corps of Engineers	Clean Water Act Section 404(b)(1) Evaluation
U.S. Department of the Interior Fish and Wildlife Service	Endangered Species Act Section 7 Consultation, Fish and Wildlife Coordination
U.S. Department of Commerce National Marine Fisheries Service	Essential Fish Habitat Consultation - Magnuson-Stevens Fishery Act (MSFCMA), Endangered Species Act Section 7 Consultation, and Fish and Wildlife Coordination Act
U.S. Environmental Protection Agency	Clean Air Act Compliance Evaluation, and NEPA Compliance Evaluation
Commonwealth of Massachusetts	
Dept. of Environmental Protection Division of Waterways and Wetlands Division of Marine Fisheries	Clean Water Act Section 401 Water Quality Certificate Fish and Wildlife Coordination
Massachusetts Coastal Zone Management Program	Coastal Zone Management Consistency Determination
Historic Preservation Commission and State Historic Preservation Office	Review/Comments on construction activities affecting cultural resources (Section 106, NHPA)
Section 10, *Compliance with Environmental Laws and Regulations*, summarizes the project's compliance with applicable Federal laws, regulations, Executive Orders, and Executive Memorandum	

2. Cause-and-Effect Relationship

2.1 Introduction

This study presumed that the Canal FNP has directly influenced and exacerbated erosion along the downdrift Sandwich shoreline, resulting in damages to public and private property and infrastructure. An erosion/accretion complex that is consistent with other typical shore-perpendicular structures is apparent within the study area, but in order for the USACE to implement a project through Section 111, that presumption needed to be more explicitly characterized. Consequently, this study aimed to confirm that a cause-and-effect relationship does exist between the Canal FNP and downdrift erosion, and it sought to quantify the extent to which that relationship negatively impacts public and private property and infrastructure. In order to do so, two key analyses were conducted: a shoreline change analysis and a sediment transport analysis. The shoreline change analysis focused on identifying the geospatial and volumetric changes to beach profile itself, while the sediment transport analysis focused on the capacity and direction of sediment transport within the study area. The USACE contracted WHG to conduct these analyses. This section of the report summarizes those efforts and additional information on both analyses can be found in Appendix B and Appendix C.

2.2 Coastal Setting

The town of Sandwich is located on the northern shoreline of Cape Cod facing Cape Cod Bay and is bisected by the Cape Cod Canal. Sediments are generally transported in a northwest to southeast direction from Plymouth to Sandwich and further south/east towards Barnstable. Astronomical tides in Cape Cod Bay are semi-diurnal, with the mean tidal range at Sandwich being approximately 9.6 feet (2.9 m) and the diurnal tidal range being 10.3 feet (3.1 m). The coast is characterized by the Canal entrance and the Old Sandwich Harbor Inlet with predominantly sandy beaches backed by dunes, bluffs, and salt marsh. Cape Cod and the Sandwich shoreline was formed by glacial deposition of sediments. In addition to their geological source, sediments found in the Canal region are also the result of active coastal processes including winds, waves, tides and currents. Sediment has been supplied to Scusset Beach, and historically to Town Neck Beach, from the glacial cliffs located to the north in Plymouth (Fitzgerald, 1993). These cliffs are made up of sand-rich glacial outwash deposits and therefore represent an abundant source of sediment. Relative sea level has been rising since the last glacial maximum, which has eroded these cliffs and provided a steady supply of sediment to the beaches through longshore transport (Fitzgerald et al., 1994). The study area contains reworked sandy and gravelly glaciofluvial deposits and/or sandy and silty marine deposits. Complete details on the local geology can be found in Chapter 1.2 of Appendix C.

Grain size data from samples taken in 2016 at 24 stations on both Scusset and Town Neck Beaches indicate that the dominant sediment type is medium-to-coarse grained sand, with some gravel at Town Neck Beach. WHG also collected 11 sediment core samples from the nearshore at Scusset Beach to characterize the shore-parallel shoal and surrounding area. As with the beach grab samples, the offshore sediment is composed of poorly graded sand, but is fine to medium grained.

2.3 Erosion/Accretion Complex

Conceptually, littoral drift and sediment transport allow shorelines to naturally and cyclically erode and rebuild themselves, creating relatively stable conditions in an inherently dynamic environment. In this case however, jetties at the east entrance of the Canal interrupt the littoral drift and consequently interrupt natural sediment transport through the system. This is a typical geomorphological response to a large impermeable shore-perpendicular structure (e.g. groin or jetty) being built along a shoreline where there is a prevailing longshore current. Such interruptions result in sediment settling on the updrift side of the structure, where it accretes and builds a wider shoreline over time. That is generally viewed as a benefit for the updrift shoreline since it makes for a more robust beach, but for every action there is an equal and opposite reaction. When these structures collect material and create accretional conditions on the updrift side, they similarly starve the downdrift side of material, resulting in erosional conditions.

Shore-perpendicular structures of this ilk have been widely used for sediment retention purposes, historically, but as accretion/erosion complexes have become more readily understood, these structures have become much less popular and are generally discouraged by regulatory agencies for their negative impacts to the surrounding shoreline. Although these structures are more actively regulated now, many were built when less understanding and/or consideration was given to their cumulative impacts and many of them still exist today. The jetties at the east end of the Canal fall into this category. They were originally installed as “sandcatchers” when the Canal was first constructed by private interests, with the primary purpose of preventing material from filling in the channel itself. They have been very effective in retaining sediment and a very healthy beach profile exists on the updrift side of the Canal, but significant erosion exists on the downdrift side. It stands to reason that a cause-and-effect relationship exists between the Canal FNP and the downdrift erosion, consistent with the erosion/accretion complexes that typically coincide with similar shore-perpendicular structures. This study sought to confirm and quantify that relationship.

2.4 Shoreline Change Analysis

A shoreline change analysis of the problem area was conducted to better understand and quantify transformations of the Sandwich shoreline over time; both as they've historically been experienced and as they can reasonably be projected into the future. The analysis evaluated historical change in shoreline position, both locally and regionally, to understand how erosion immediately downdrift of the Canal, relates to erosion in the greater Sandwich area as a whole. The analysis of historical change in shoreline position was then used to project the future shoreline position downdrift of the Canal. In addition to the more geospatial analysis just described, a volumetric shoreline change analysis was conducted. The volumetric analysis was used to estimate the total amount of material that has been lost over the last 50 years as well as project the total amount of material that can reasonably be expected to erode over the next 50 years.

2.4.1. Historical Change in Shoreline Position – Local

A computer-based mapping methodology, within a Geographic Information System (GIS) framework, was used to compile and analyze changes in the historical shoreline position between 1952 and 2018 at Town Neck Beach and Springhill Beach. The purpose of this task was to quantify changes in shoreline position using the most accurate data sources and compilation procedures available, and to characterize areas of erosion and accretion. In order to evaluate trends in shoreline change at Sandwich, various graphical representations have been developed. Shoreline positions for each of the available dates between the period of 1952 and 2018 were developed and changes in shoreline position were evaluated along a series of 139 shore-perpendicular transects spaced at 100-foot intervals along 3.2 miles of the shoreline moving eastward from the Canal. At each shoreline change transect, distances of shoreline movement and annual rates of change were determined. Data from 1952 to 2018 was used to compute long-term rates of shoreline change while data from 2000 to 2018 was used to compute short-term rates of shoreline change. Figures 2-1 and 2-2 show the long-term and short-term rates of change, respectively, at the shoreline change transects along Town Neck and Springhill Beaches. Negative values (yellow-orange-red) correspond to shoreline erosion, whereas positive values (green) correspond to shoreline accretion. Both the long- and short-term rates of change are plotted by transect in Figure 2-3. Transects 1 to 74 cover Town Neck Beach from the Canal to Old Harbor Inlet while transects 75 to 139 define Springhill Beach east of Old Harbor Inlet.

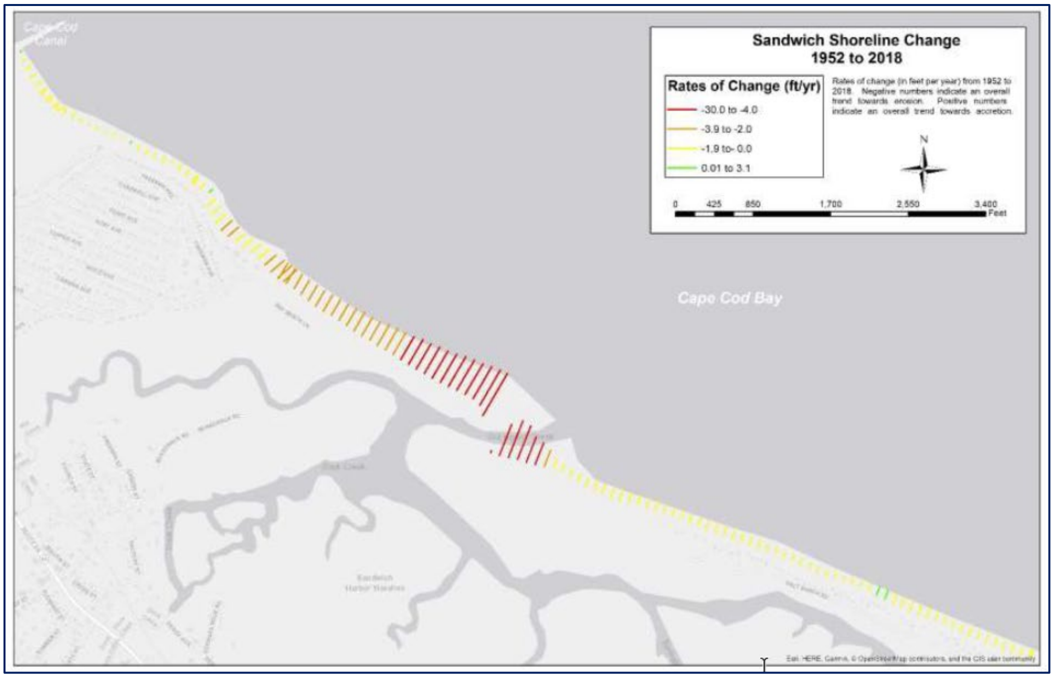

Figure 2-4: Long-term (1952-2018) shoreline change rates at Sandwich (WHG, 2020)

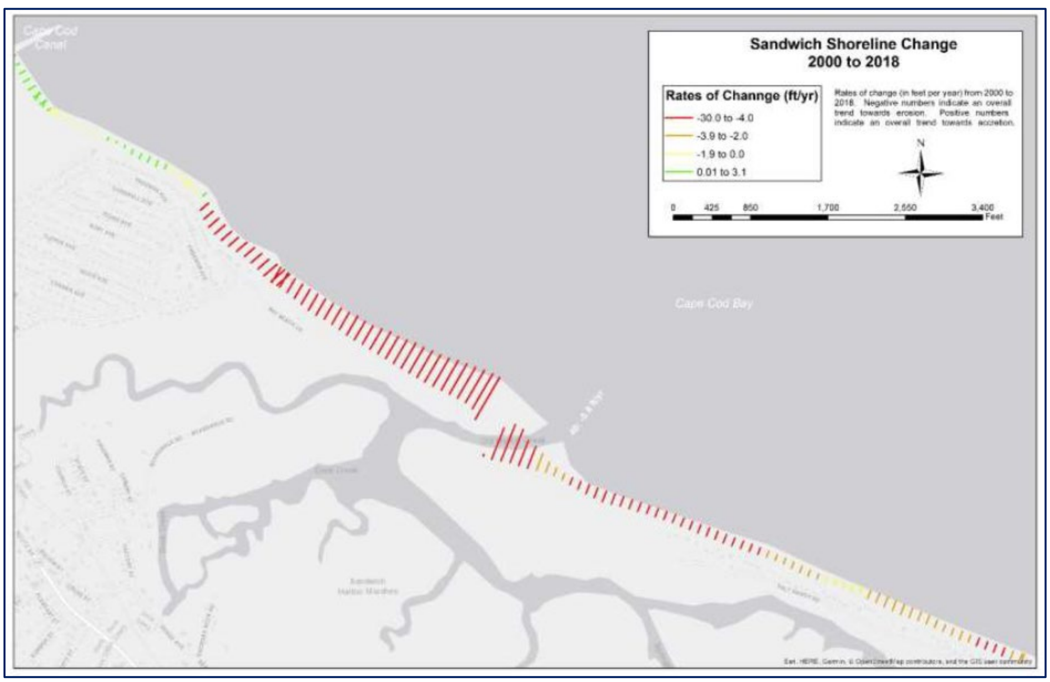

Figure 2-5: Short-term (2000-2018) shoreline change rates at Sandwich (WHG, 2020)

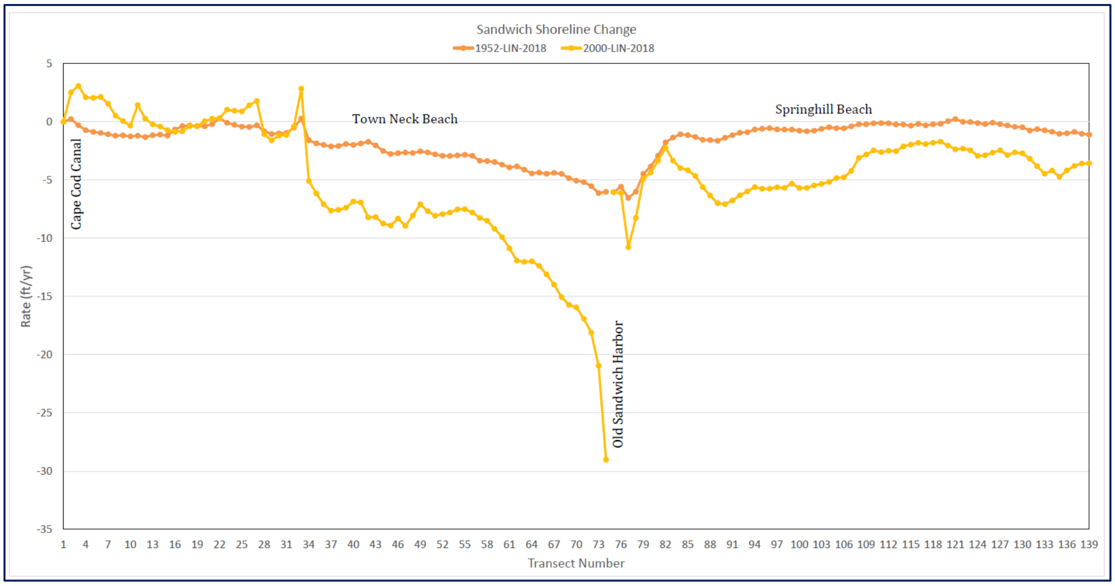

Figure 2-6: Long and short-term rates of shoreline change at Sandwich by transect (WHG, 2020)

The shoreline change analysis indicates that Town Neck Beach and Springhill Beach have experienced erosive conditions over both the short and long term, with increased rates of erosion observed in the short term. The highest rates of erosion occur on both sides of Old Harbor Inlet, and along Town Neck Beach. The Town Neck Beach shoreline from the Canal to the longer groin located near the intersection of Dillingham Avenue and Freeman Avenue (approximately Transect 31) has been relatively stable in both the short- and long-term, experiencing smaller erosion rates in the long-term and areas of accretion in the short-term. It is likely that this area, which lies in the shadow of the Canal jetties, experiences reduced wave energy afforded by the influence of the Canal jetties on local wave transformations. This is typical of an area immediately downdrift of a large coastal inlet with jetties, where the area immediately downdrift of the structures may experience reduced erosion rates and a reversal in sediment transport. This stretch of shoreline is sheltered by the Canal jetties from waves approaching from the north. The energy reduction, coupled with the stabilizing effects of the groins in the area and the slight reversal in sediment transport direction, has produced a more stable section of shoreline relative to areas further east.

Increasing rates of erosion are observed in both the short- and long-term moving east of the stabilizing groin in the vicinity of Transect 31 to Old Harbor Inlet at Transect 74. Although long-term erosion rates in this area range from -2 to -5 feet per year, much of this area has short-term erosion rates between -6 and -10 feet per year, with the 1,400 foot stretch of shoreline updrift of the inlet showing a dramatic increase in erosion up to -25 feet per year. The higher rates of erosion nearest the inlet are due to the inlet's migration outside its jetties, which is primarily the result of the lack of sediment supplied to the region which has reduced stability of the inlet system. During the October 1991 "No-Name" storm, the inlet breached out of its existing jetties. The inlet has continued to migrate east since then. Figure 2-7 shows Old Harbor Inlet prior to the October 1991 storm and its present condition. In addition to the inlet's migration and separation from its jetties, the loss of beach is evidenced by the groins at Town Neck Beach which are now detached from the shoreline and contain no sediment.

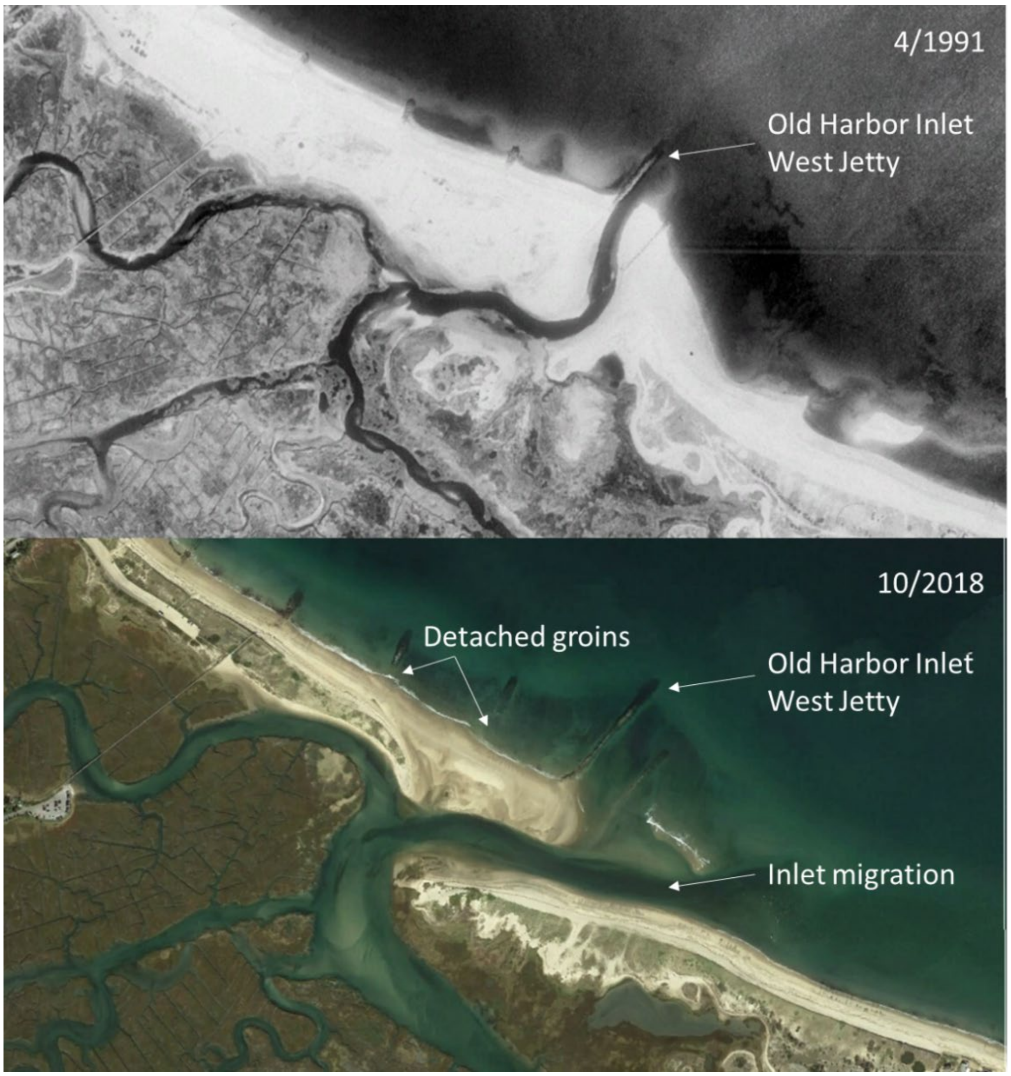

Figure 2-7: Aerial images showing shoreline changes in the vicinity of Old Harbor Inlet

Springhill Beach, east of Old Harbor Inlet, shows consistent but decreasing rates of erosion in both the short- and long-term. Long-term erosion rates at Springhill Beach are approximately -2 feet per year whereas short-term erosion rates are greater at approximately -5 feet per year. The erosional trend continues to approximately Transect 108, or 10,800 feet downdrift of the Canal, where erosion rates level off and the shoreline is increasingly stable. This distance of 10,800 feet was selected as a reasonable estimated extent of influence that the Canal has on downdrift erosion. In other words, the disruption to natural sediment transport attributable to the Canal and its structures was estimated to extend approximately 10,800 feet downdrift of the Canal.

2.4.2. Historical Change in Shoreline Position – Regional

In order to put shoreline change at Sandwich into context with the region and confirm erosion within the study area was not due to naturally occurring erosion alone, shoreline change rates within the study area were compared with those in the region. This shoreline change analysis was based on the shoreline data assembled as part of the Massachusetts Shoreline Change Project 2018 Update (Himmelstoss et al, 2019).The Massachusetts Office of Coastal Zone Management launched the Shoreline Change Project in 1989 to identify erosion-prone areas of the coast. The project, which illustrates how the shoreline of Massachusetts has shifted since the mid-1800s, has been updated several times since its initial publication as new shorelines have been incorporated. The most recent update (2018) includes shorelines through 2014. Figures 2-8 through 2-12 are snapshots from the Massachusetts CZM Shoreline Change mapping tool that depict the shoreline position at various intervals from pre- and post-construction of the Canal. They highlight the demonstrable change in shoreline within the study area compared to relative stability of the neighboring shoreline.

Using data from historical and modern sources, shorelines depicting the local high-water line have been generated with transects spaced at 50-meter (approximately 164-foot) intervals along the shoreline. At each transect, net distances of shoreline movement, shoreline change rates, and uncertainty values are provided. Long-term rates of shoreline change were determined by fitting a least squares regression line to all shoreline positions from the earliest (mid-1800s) to the most recent (2014), spanning an approximately 150-year record. Short-term rates of shoreline change were calculated using the most recent shoreline positions from 1978 and 2014, a 36-year record. Calculating long-term rates of shoreline change with many shoreline positions can increase confidence in the data by reducing potential errors associated with the data source and fluctuating short-term changes.

For this study, the Massachusetts Shoreline Change Project shoreline change rate data was used to determine regional and local shoreline change rates within the littoral cell in the extend study area from Stage Point in Plymouth to Sandy Neck in Barnstable (Figure 2-13). Ideally, shoreline and beach volume change should be evaluated for two distinct periods: one before project construction to determine the natural or background change, and the other after construction to quantify the response to the project. For the Canal, data available prior to its construction (1909-1914) had a high degree of error inherent with survey data from that time period. Therefore, regional shoreline change trends were determined and compared to the rate of shoreline change in the project area. This approach allowed comparison of shoreline change over contemporary time periods, during which coastal processes are similar. For this study, the regional change was calculated between Stage Point in Plymouth, the western boundary, and Sandy Neck in Barnstable, the eastern boundary, which includes about 23 miles of shoreline. It was found that for the period of 1860 to 2014, the regional shoreline change trend was recession at an average rate of 0.29 feet per year.

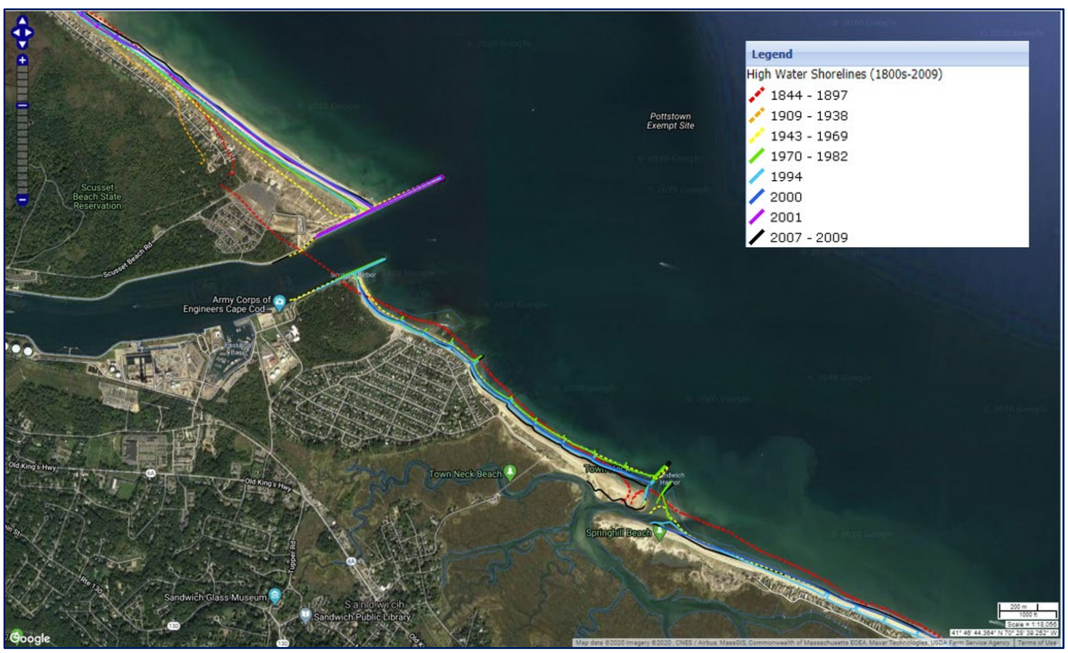

Figure 2-8: Massachusetts CZM Shoreline Change map for the entire study area

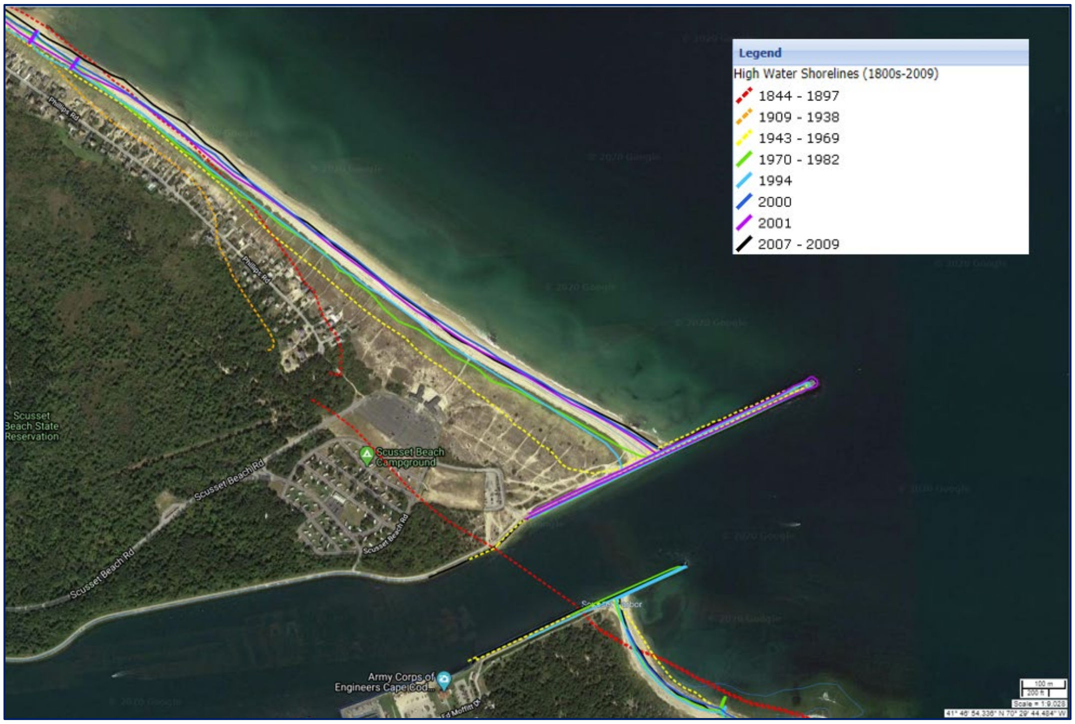

Figure 2-9: Massachusetts CZM Shoreline Change map updrift of the Canal

Figure 2-10: Massachusetts CZM Shoreline Change map immediately updrift of study area

Figure 2-11: Massachusetts CZM Shoreline Change map downdrift of the Canal

Figure 2-12: Massachusetts CZM Shoreline Change map immediately downdrift of study area

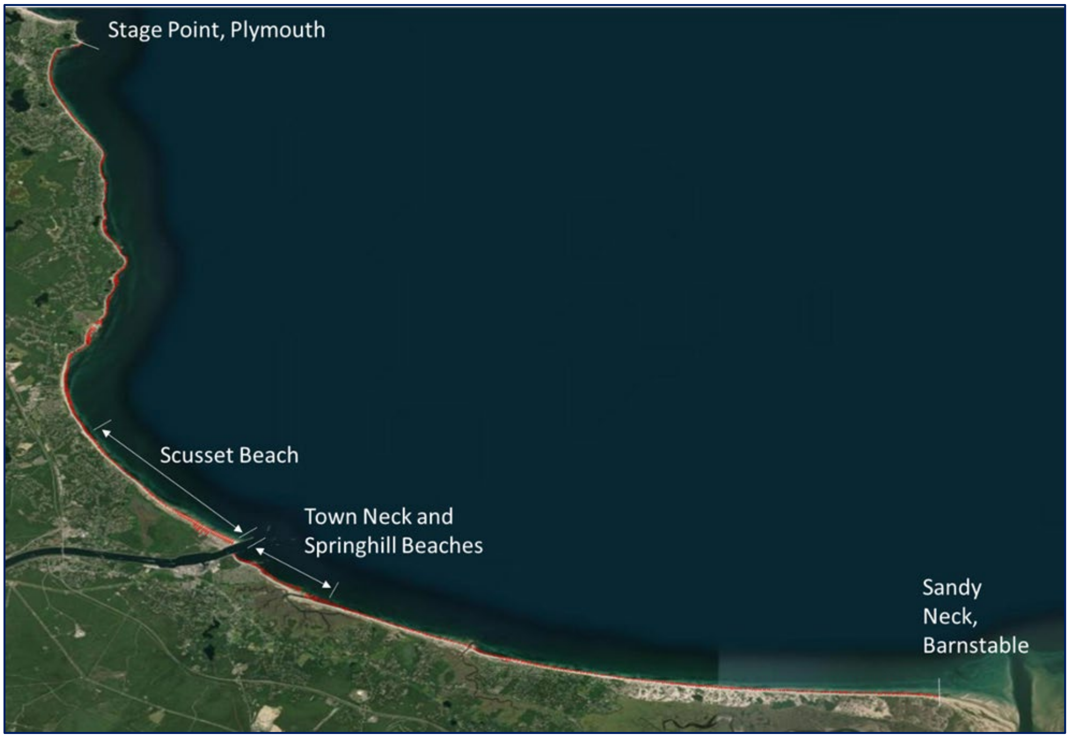

Figure 2-13: Regional shoreline change area from Stage Point, Plymouth to Sandy Neck, Barnstable

Within the region, rates of change along shorter segments of shoreline were evaluated to define more localized shoreline change rates. Similar to the regional trend of recession (-0.29 feet per year), long-term recession was observed both updrift and downdrift of the Canal. However, shoreline recession updrift of the Canal, from Stage Point to the Canal, was less than the regional average (-0.11 feet per year) while shoreline recession downdrift of the Canal, from the Canal to Sandy Neck, exceeded the regional average (-0.48 feet per year). The influence of the Canal and its structures is most pronounced along Scusset Beach, just updrift of the Canal, and downdrift of the Canal along Town Neck and Springhill Beaches. Along Scusset Beach, the long-term shoreline change trend is accretionary at 1.16 feet per year. On Town Neck Beach and Springhill Beach, the average shoreline change rate within 10,800 feet of the Canal is -1.33 feet per year. A summary of the short- and long-term shoreline change rates in the Canal region is provided in Table 2-1.

Table 2-1: Regional Shoreline Change Rates

Area	Short Term Rate (ft/year)	Long Term Rate (ft/year)
Region	0.07	-0.29
Stage Point to Canal	0.07	-0.11
Canal to Sandy Neck	0.06	-0.48
Town Neck and Springhill Beaches -- 10,800 ft of Shoreline East of Canal (WHG defined area of impact)	-2.58	-1.33
Scusset Beach	2.25	1.16

As noted previously, analysis of long-term shoreline change showed that shoreline recession attributable to the Canal extends for approximately 10,800 feet to the east of the inlet. Within this area, the long-term shoreline change averaged -1.33 feet per year. A residual shoreline change rate, or the change attributable to the FNP, was then determined by removing the average regional recession rate from the shoreline change rate for the 10,800 feet of shoreline adjacent to the project. This procedure gave a residual recession rate of 1.04 feet per year. Thus, the amount of shoreline change directly attributable to the FNP was determined to be 1.04 feet per year, or 78%.

2.4.3. Projected Future Shoreline Position

WHG estimated the future shoreline position considering the long-term shoreline change rates at Town Neck Beach and Springhill Beach and a sea level change projection of 4.29 feet by 2070. First, a projected 2068 shoreline (50 years from 2018) was generated using the long-term rates of change at each shoreline change transect. Next, the sea level rise projection was applied. The mean high water (MHW) shoreline in 2068 was estimated by adding the sea level rise of 4.29 feet to the present day MHW elevation to yield a projected MHW shoreline at elevation 8.4 feet NAVD88 (See appendix B for more detailed information pertaining to Sea Level Change).

The present and projected future shoreline positions along Town Neck Beach and Springhill Beach are shown from west to east in Figures 2-14 through 2-16. The present MHW shoreline is depicted in black while the 2068 shoreline is shown in red. Figure 2-16 shows areas projected to be inundated at MHW using the future MHW elevation of 8.4 feet NAVD88. The predicted MHW shoreline is again depicted in red. While shoreline loss is predicted throughout the project area, it is most severe along the east end of Town Neck Beach and in the vicinity of Old Harbor Inlet. In fact, almost a complete loss of the barrier beach at Town Neck Beach is predicted. In addition to the direct loss of beach areas, the future condition will result in significant ecological impacts to the expansive saltmarsh system inland of Old Harbor Inlet as well as lead to increased flooding of the Route 6A/Downtown area during storm events.

Figure 2-14: Existing (2018) and projected (2068) MHW shoreline positions, west end of Town Neck Beach (WHG, 2020)

Figure 2-15: Existing (2018) and projected (2068) MHW shoreline positions, east end of Town Neck Beach (WHG, 2020)

Figure 2-16: Existing (2018) and projected (2068) MHW shoreline positions, Springhill Beach (WHG, 2020)

Figure 2-16: Projected (2068) areas of MHW inundation (WHG, 2020)

2.4.4. Volumetric Shoreline Change

Sediment loss associated with shoreline change was estimated/projected volumetrically by WHG along Town Neck Beach and Springhill Beach for the previous 50 years (from approximately 1968 to 2018) and over the next 50 years (2018 to 2068). In order to determine volumetric losses, thirty shore-perpendicular transects spaced at 500-foot intervals were used to approximate the loss of sediment for different portions of the beach. Beach profiles were developed at each transect to characterize the slope and elevation of the beach. By comparing the present-day beach profiles to profiles representing the past and future shoreline conditions, described above, WHG estimated the volume of sediment lost to erosion in the past 50 years as well as the volume of sediment anticipated to be lost over the next 50 years. The locations of the thirty transects used in this analysis are shown in Figure 2-18.

Figure 2-18: Volume loss transect locations (WHG, 2020)

The 2068 beach profiles were generated by translating the 2018 profiles landward, using the previously calculated long-term shoreline change rates. A similar but seaward translation of the 2018 shoreline was used to represent the position of the 1968 shoreline. A projection of the volume of sand lost over the past 50 years and expected to be lost over the next 50 years was estimated by determining the change in area between the present and past as well as the present and future shorelines, while also accounting for the distance along the shoreline. An example of the beach profile translation for the estimated past and projected future conditions is shown in Figures 2-19 and 2-20.

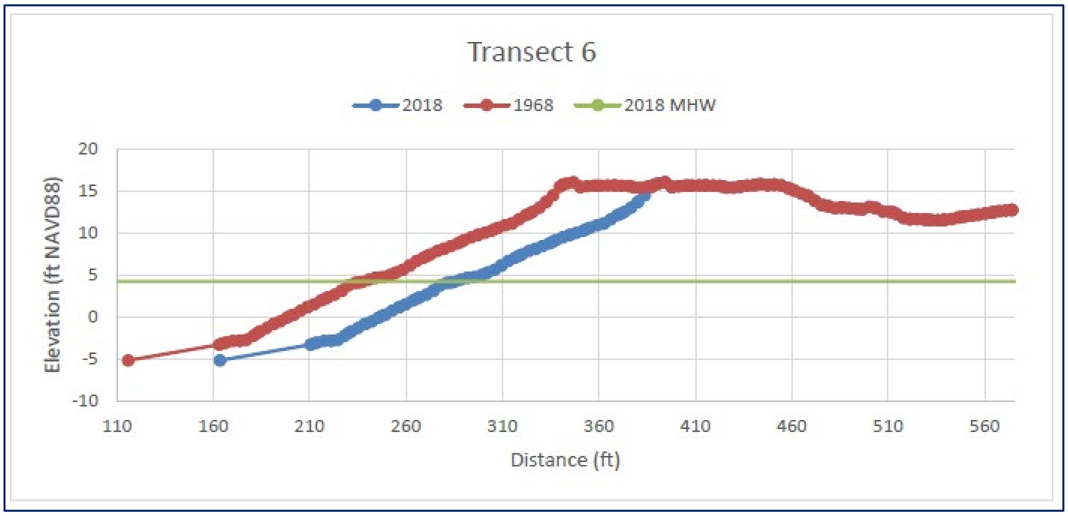

Figure 2-19: Example transect profile translation for estimated past conditions (WHG, 2020)

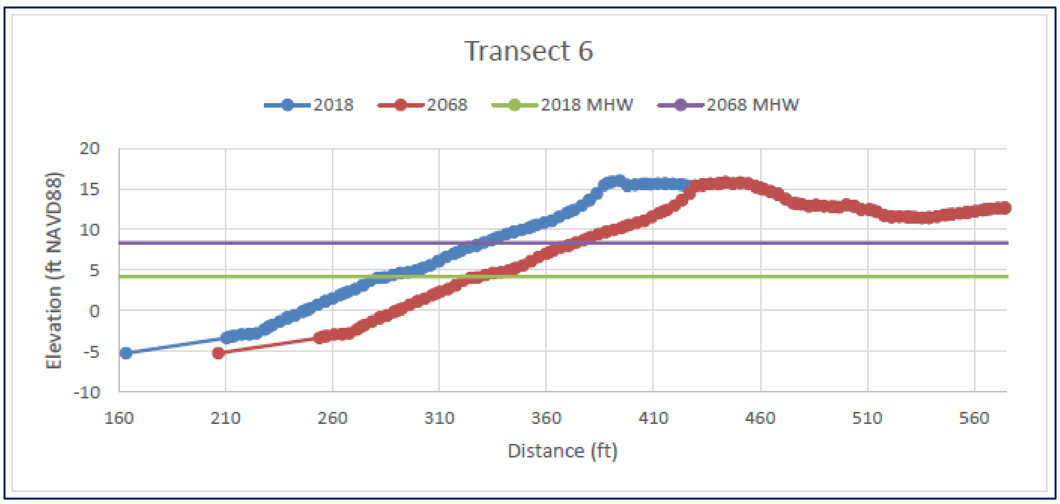

Figure 2-20: Example transect profile translation for projected future conditions (WHG, 2020)

This analysis determined the volumetric loss of shoreline over the past 50 years to be approximately 782,000 cubic yards or 1.45 cubic yards per foot of shoreline per year. Over the next 50 years, the estimated volume loss of beach was projected to be approximately 900,000 cubic yards or 1.66 cubic yard per foot of shoreline per year. It should be noted that because these profiles terminate offshore at -5 feet NAVD88 (0 feet MLW) and do not extend out to the depth of closure, these volumes may not fully capture the cross-shore volume loss. The Sediment Transport Analysis described in the next section of this report attempts to account for this information gap.

2.4.5. Summary of Shoreline Change Analysis

Local and regional analyses of historical shoreline change were performed for the Canal region, using a combination of data derived from the Massachusetts Shoreline Change Project, aerial photography, historical maps, and digital ortho-photographic quads. The shoreline change analysis resulted in the following key findings:

- The Town Neck Beach shoreline from the Canal to the longer groin located near the intersection of Dillingham Avenue and Freeman Avenue (approximately Transect 31) has been relatively stable in both the short- and long-term, experiencing smaller erosion rates in the long-term (-1 foot per year) and areas of accretion in the short-term.

- Increasing rates of erosion were observed in both the short- and long-term, from the stabilizing groin in the vicinity of Transect 31 towards Old Harbor Inlet at Transect 74. While long-term erosion rates in this area range from -2 to -5 feet per year, much of this area has short-term erosion rates between -6 and -10 feet/year, with the 1,400 feet stretch of shoreline updrift of the inlet showing dramatic increases in erosion up to -25 feet per year.

- Springhill Beach shows consistent but decreasing rates of erosion in both the short- and long-term. Long-term erosion rates are approximately -2 feet per year whereas short-term erosion rates are greater at approximately -5 feet per year. The erosional trend continues to approximately Transect 108, or 10,800 feet downdrift of the Canal, where the rates of erosion level off and the shoreline is increasingly stable. This distance of 10,800 feet was selected as a reasonable estimate of the extent of the influence of the Canal on downdrift erosion.

- The long-term regional shoreline change rate was -0.29 feet/year, while the long-term shoreline change for the 10,800 feet of shoreline immediately downdrift of the Canal was -1.33 feet per year. Based on the shoreline change analysis, approximately 0.29 feet per year (22%) of the erosion experienced downdrift of the Canal was considered to be naturally occurring, while the remaining 1.04 feet per year (78%) of that erosion was considered to be directly attributable to the Canal FNP.

- Approximately 782,000 cubic yards or 1.45 cubic yards per foot of material were estimated to have eroded from the downdrift shoreline over the past 50 years. Similarly, approximately 900,000 cubic yards or 1.66 cubic yard per foot of material were projected to erode from the downdrift shoreline over the next 50 years.

2.5 Sediment Transport Analysis

Where a shoreline change analysis was conducted in order to characterize direct changes to the profile of the Sandwich shoreline, a sediment transport analysis was conducted that characterized the capacity and direction that sediment moves through the littoral system in order to develop a more complete understanding of the influence that the Canal FNP has on shoreline change in the study area. A combination of sediment transport modeling and a sediment budget were used to accomplish this, and those efforts are described below.

2.5.1. Sediment Transport Modeling

Sediment movement in the coastal zone, as well as the effects of coastal structures on shoreline processes, can be estimated by using sediment transport models. A variety of different sediment transport models exist; all of which differ in their detail and complexity, and all of which assume a level of uncertainty associated with the predicting sediment transport in an inherently dynamic coastal environment. Although no single model of sediment transport may be fully representative of all conditions, these sediment transport models still provide a useful tool for analyzing the effects of structures on local coastal processes. For this study WHG developed a process-based model of the regional sediment transport trends in the presence of time-variable (in direction and height) waves. A more detailed explanation of this model can be found Section 4.3 of Appendix C, but this section provides a summary of their analysis.

The sediment transport model was primarily used to quantify sediment flux through the study area. Sediment flux represents the potential rate of sediment movement along the coast. This rate was used to quantify annual sediment transport rates across specific reaches within the study area, and flux divergence/convergence was subsequently calculated in order to identify areas of potential erosion and/or deposition. A flux divergence represents erosion and a flux convergence represents accretion. The sediment flux indicates that there is a strong net alongshore sediment transport region from northwest to southeast, consistent with the prevailing northeast wave approach direction. Along Scusset Beach, north of the Canal, the average annual longshore sediment transport is directed to the southeast at an average rate of approximately 95,000 to 115,000 cy/year, ending at the western Canal jetty. Southeast of the Canal and ending in the vicinity of Knott Avenue, there is a small zone of transport reversal, located in the shadow of the Canal jetties, which limits wave energy from the northeast yet allows energy from the less predominant eastern directions. Net transport at this reversal ranges from 10,000 to 20,000 cy/year toward the northwest. Southeast of the reversal, net longshore sediment transport patterns continue to be directed toward the southeast, where transport rates range from approximately 35,000 to 45,000 cy/year until reaching Old Harbor Inlet.

It should be noted that these calculations all assume a constant sediment supply is available for transport. If the shoreline is armored, doesn't have a sediment source readily available, or is interrupted by shore-normal structures such as groins or jetties, then the sediment transport rates would likely vary. Consequently, these calculated sediment transport rates are likely conservatively high, as they assume an infinite supply of sediment, and do not account for geomorphologic changes to the shoreline.

Figure 2-16 presents the average yearly sediment flux determined using the process-based sediment transport model for the Cape Cod Canal region. The arrows on the figure indicate direction of sediment transport while the colors of arrows indicate magnitude. In addition to presenting the net overall transport results, Figure 2-21 also overlays the model sediment flux results against the historic rates of shoreline change described in the previous section of this report. The transect lines represent the historic rates of shoreline change (in feet per year). Negative values of shoreline change indicate erosion, while positive values indicate accretion. Areas of erosion and accretion generally match the expected patterns of alongshore transport based on the modeled results.

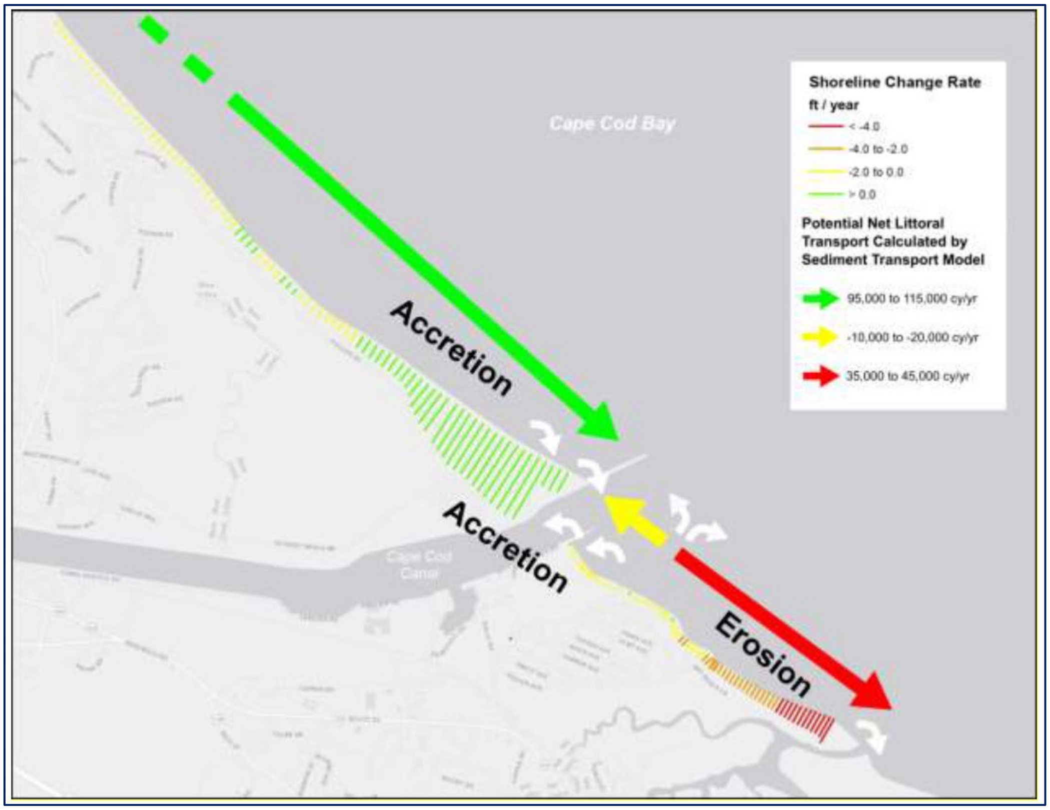

Figure 2-21: Annualized sediment flux and divergence for the Cape Cod Canal region (WHG, 2020)

2.5.2. Sediment Budget

A sediment budget at the east end of the Canal was also developed by WHG in order to further quantify sediment fluxes in the study area. As suggested previously, predicting sediment transport in a dynamic coastal environment is inherently difficult and the sediment transport modeling has its limitations. A sediment budget however, represents an accounting of all sources and sinks of sediment within a specified series of connected cells over a period of time, thus it was used to help paint a more complete picture of the sediment transport potential that exists within the study area. More specifically, the sediment budget sought to understand not just how much sediment can theoretically be moved through the system, but how much of that material goes where, based on site-specific conditions. By estimating the amount of material that gets trapped updrift of the Canal, shoals in the channel and is lost offshore, the significance of the interruption caused by the Canal jetties could then be quantified.

A sediment budget can conceptually be expressed by the following equation, where Q_{source} and Q_{sink} represent sources and sinks out of the budget cell, ΔV is the change of volume within the cell, and P and R represent the amounts of sediment placed or removed from the cell.

$$\boxed{\sum Q_{Source} - \sum Q_{Sink} - \Delta V + P - R = 0}$$

The cell budget is considered balanced when this equation is equal to zero. Figure 2-22 from USACE Coastal Engineering Technical Note (CETN IV-15) shows a conceptual box model version of the sediment budget equation with examples of the types of each parameter (Rosati and Kraus, 1999).

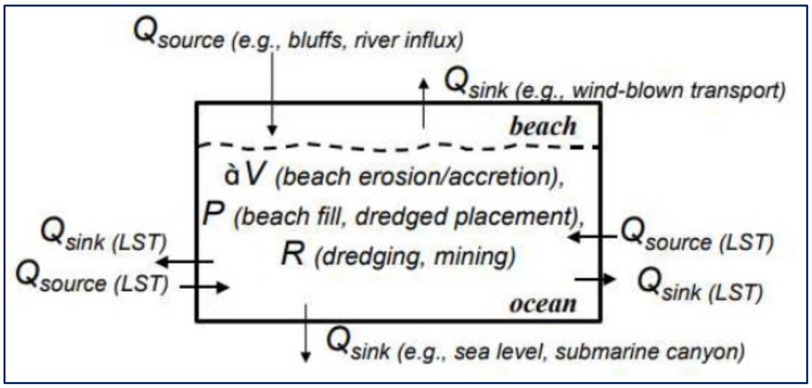

Figure 2-22: Conceptual box model of sediment budget

WHG developed individual sediment budget cells for the three specific areas (Scusset Beach Cell, Cape Cod Canal Cell, and Town Neck Beach Cell), which when combined resulted in a sediment budget for the entire study area as a whole. Figure 2-23 shows a graphical representation of the sediment budget results as determined for this study by WHG.

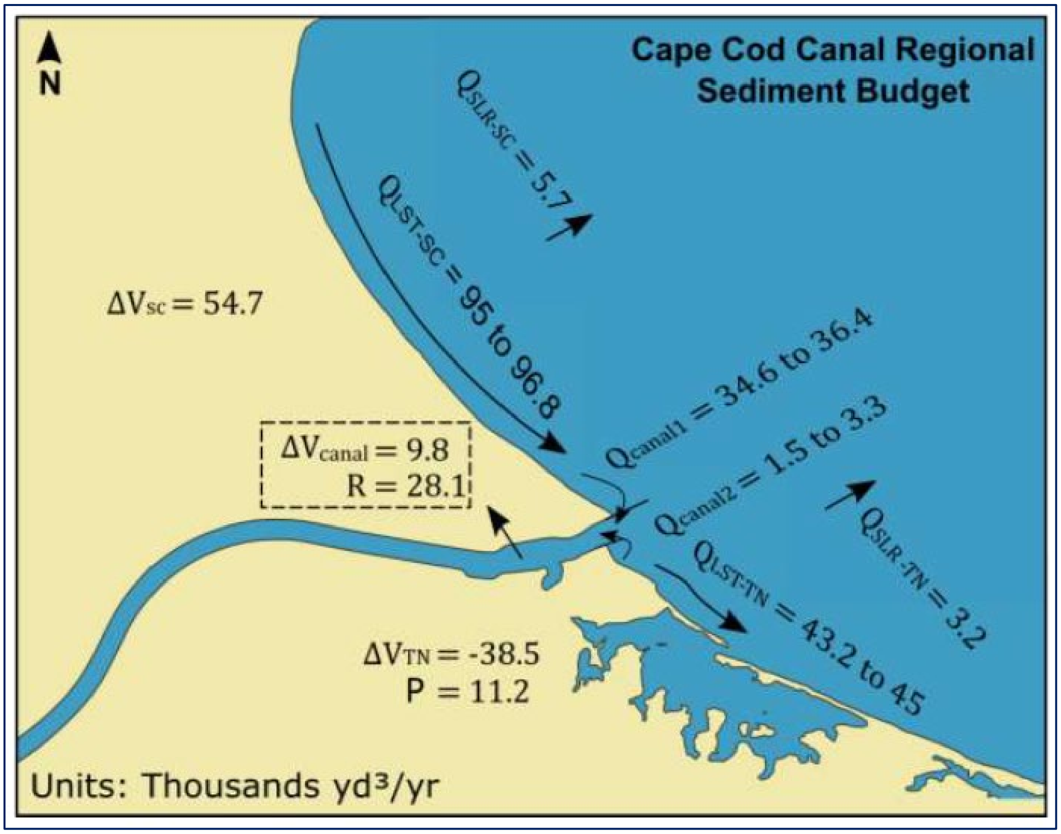

Figure 2-23: Sediment budget for the Canal region (WHG, 2020)

2.5.3. Summary of Sediment Transport Analysis:

The Sediment Transport Analysis resulted in the following key takeaways

- The average annual longshore sediment transport rate updrift of the Canal was estimated at 95,000 cy/year.
- Approximately 54,700 cubic yards of material are impounded updrift of the Canal by the jetties, annually.
- Approximately 28,100 cubic yards of material shoals within the Canal channel, annually.
- Approximately 9,800 cubic yards of material are lost offshore annually
- Based on three beneficial use projects over the last 30 years (Appendix B, Section 3.7) it was assumed 11,200 cubic yards of material from the Canal wind up on Town Neck Beach, annually.

- When considering all sediment inputs and losses, approximately 81,400 cubic yards of the approximately 95,000 cubic yards of material that could potentially migrate from the updrift to the downdrift shoreline, annually, do not actually reach the downdrift shoreline. In other words, the Canal jetties interrupt approximately 85% of sediment transport through the littoral system.

2.6 Cause-and-Effect Summary

Extensive modeling was conducted during this feasibility study to understand how the jetties at the east entrance of the Canal alter coastal processes in the study area and how those alterations influence erosion to the downdrift shoreline. A shoreline change analysis concluded that the jetties increase erosion along Town Neck Beach and Springhill Beach for approximately 10,800 linear feet. The shoreline change analysis also concluded that approximately 782,000 cubic yards of material have been lost along that reach, approximately 78% of which can be directly attributed to the Canal FNP. Further, it projected that approximately 900,000 cubic yards of material will erode from that shoreline over the next 50 years. The sediment transport analysis concluded that approximately 85% percent of the material that otherwise migrates naturally to the downdrift littoral system is either trapped updrift of the Canal, shoals in the channel itself or is lost offshore, resulting in only 15% of the material reaching the downdrift shoreline. In conclusion, these analyses demonstrated that the jetties at the east end of the Canal unquestionably and significantly increase erosion of the Sandwich shoreline along Town Neck Beach and Springhill Beach.

3. Existing Conditions Affected Environment

3.1 Topography and Geology

The project area is in the New England physiographic province of southeastern Massachusetts entirely within the Seaboard Lowland section (USGS, 2000). The Seaboard Lowland section rises uniformly from sea level to an elevation of about 300 to 400 feet with occasional hills rising above this elevation. Relief is generally low with rivers flowing southeasterly to the Atlantic Ocean (Flewelling and Lisante, 1982).

3.2 Shoreline Conditions

The geology of Cape Cod was created approximately 25,000 years ago by the advance and retreat of the Laurentide ice sheet and the subsequent rise in sea level. The location and shape of Cape Cod was formed by lobes of the Laurentide ice sheet occupying deep basins. As the ice sheet retreated, rock debris deposited by glaciers and meltwater overlaid the bedrock on Cape Cod creating the current sedimentology of the area. Modeling described in the previous section of this report indicates that sediment transport through the project area occurs in a northwest to southeast direction. This has produced significant accretion of material updrift of the Canal at Scusset Beach, while it has created erosive conditions downdrift of the Canal. With the exception of a small section of shoreline that has remained relatively stable due to sediment transport reversal, the majority of the downdrift shoreline has experienced erosive conditions since the Canal was construction, with erosion directly attributable to the Canal FNP extending approximately 10,800 feet eastward from the Canal jetties.

3.3 Sediments

The U.S. Department of Agriculture, Soil Conservation Service soil surveys (Flewelling, L.R. and Lisante, R.H., 1982) were used to determine and characterize the soils that are affected by the construction of the proposed project. These soils characterize the upland in and around Sandwich beaches and the community.

The project will affect approximately 41.2 acres of beach and dune area. According to the Web Soil Survey (2018), beaches in Barnstable County consist of reworked sandy and gravelly glaciofluvial deposits and/or reworked sandy and silty marine deposits. These sediments are in a coastal area that is partially or entirely covered by water during high tides or stormy periods. Since the primary sediment source to Town Neck Beach has been starved by the Canal jetties, a large portion of the beach is composed of coarse-grained sands, gravel, and cobble. Grain size analysis of samples taken within the project area by WHG show that 71.5% of the material is sand (coarse to very coarse), with the remainder made up of gravel and cobbles. No silt or clay was measured in any of the samples (WHG, 2014).

The Scusset nearshore area (potential source of beach nourishment material) is characteristic of a dynamic nearshore sedimentary environment that is dominated by wave energy. The interruption of sediment transport by the Canal jetties has resulted in a large accumulation of sand in this area. In 2016, WHG extensively surveyed the Scusset nearshore area using video imagery, side-scan sonar, and sediment sampling to characterize the site. The results of these surveys are contained in WHG's Notice of Project Change (2017). Sediment cores taken from the borrow site showed that the material present in the area is predominantly fine to medium sand. Side-scan sonar revealed that the nearshore area is characterized by a relatively uniform grain size composed of well-sorted sand. In general, the sediments found along Town Neck Beach are coarser than the material present in the nearshore area at Scusset Beach. Presumably continued erosion of the downdrift shoreline has influenced the composition of sediment grain size along the downdrift shoreline. Appendix A5 contains the grain size results from both of these areas.

Rocky intertidal shores and complex bottom habitat is in the intertidal and subtidal zone off the western end of the nourishment footprint. Additionally, a smaller patch (approximately 1.75 acres) of complex bottom habitat, and approximately 2.23 acres of rocky intertidal habitat is in the intertidal zone at the far eastern end of the nourishment site. Figure 3-1 shows the WHG's most recent (2018) mapping of complex bottom habitat within the study area as well as the most recent eelgrass survey results from 2019. The complex bottom habitat contains rocky substrate with attached macroalgae and marine invertebrates which serve as a food source for larger marine life and a variety of birds. Complex bottom habitat is also used as shelter and living area for crabs, lobsters, and fish species.

Figure 3-1. WHG 2018 complex bottom habitat and 2019 eelgrass survey results.

3.4 Water Resources

Cape Cod Bay is a semi-enclosed embayment located within the larger Massachusetts Bay. It encompasses 604 square miles of open water with a maximum depth of 206 feet. Its surface waters move in a generally counterclockwise pattern. Seasonal water column stratification and mixing occurs in the bay with different layers in spring, summer, and fall and relatively homogenous mixing in winter. Cape Cod Bay is connected to Buzzards Bay by via the Canal.

The Canal is a highly dynamic area with strong tidal currents and shifting shoals that form in various locations throughout the navigation channel. In order to reduce hazardous conditions caused by shoaling, the canal is dredged regularly by the USACE. The most recent maintenance dredging event took place in 2015-2016 when roughly 120,000 cubic yards of clean sand and gravel was removed from the channel and the east mooring basin.

3.4.1. Water Circulation and Waves

The region is influenced by both locally generated seas, produced within Cape Cod Bay, and swell waves generated in the Atlantic Ocean. This combination of wave sources produces a wide range of conditions at the Town Neck Beach shoreline that includes both high frequency and longer period waves. Locally generated sea waves during non-storm conditions are relatively small (1.7 to 2.4 feet) and short-crested (periods less than 3.5 seconds). Non-storm swell waves are slightly larger (2.2 to 3.6 feet) with longer periods up to 11 seconds. Offshore wave heights during storms, up to and including the 100-year event, can reach heights of 16.7 feet (WHG, 2014).

WHG modeled and evaluated the impacts of wave conditions in the study area, for both the preparation of the Town of Sandwich Dune and Beach Reconstruction Project Notice of Intent in 2014 and 2017. WHG modeled these conditions again in 2019, under contract with the USACE, for the purpose of this study. More detailed information regarding water circulation and waves can be found in Appendix B and C.

3.4.2. Marine Water Quality

The coastal waters offshore of Town Neck Beach and Scusset Beach (including the borrow site) are classified as SA waters by the Commonwealth of Massachusetts. Class SA waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation (314 CMR 4.00). Shellfish harvesting is indefinitely prohibited from within the Canal (Rausch, 2018).

3.5 Biological Resources

Biological resources in the project area, including populations of benthos, fish resources, essential fish habitats, marine and coastal birds, and upland/terrestrial wildlife, are typical of southern New England coastal and marine habitats. WHG scientists collected data on benthic resources and habitats from the placement and borrow sites in 2014 and 2015, respectively. Data collection methods included a series of strategically placed benthic grab samples to document the existing benthic infaunal community and underwater camera footage to document the presence of eelgrass (*Zostera marina*) within the project area. This information as well as information from other data sources was used to describe the natural resources in the project area in the following sections.

3.5.1. Submerged Aquatic Vegetation and Macroalgae

The intertidal and subtidal area of Town Neck Beach hosts a myriad of submerged aquatic vegetation (SAV) and macroalgae attached to rocks and growing in sandy substrate. Eelgrass (*Zostera marina*) makes up the majority of the plant community growing in the subtidal area off of Town Neck Beach. Many forms of macroalgae, including Irish moss (*Chondrus crispus*), bladder wrack (*Fucus vesiculosus*), and other species of rockweeds (*Ascophyllum nodosum* and *Fucus* spp.) grow on rocks and boulders in the intertidal and subtidal area of Town Neck Beach (WHG, 2018).

Rockweeds are seaweeds that attach to rocky substrates. They typically have branching fronds, and the larger species can grow up to 6 feet in length. Rockweed serves as both a food source and as shelter by marine organisms. Eelgrass is a saltwater angiosperm found in estuaries and shallow coastal areas. It produces organic material that becomes part of the marine food web, helps cycle nutrients, stabilizes marine sediments, and provides important habitat including breeding areas and protective nurseries for fish, shellfish, and crustaceans. Eelgrass is particularly susceptible to sedimentation and human activity.

Between the period of 1995-2012, eelgrass bed locations were mapped in the Cape Cod Bay area by the Massachusetts Department of Environmental Protection (MADEP) as part of the MADEP Eelgrass Mapping Project. Surveys were performed using aerial photography to delineate eelgrass extents. The data from MADEP indicate that eelgrass resources have been declining over the years in Cape Cod Bay. Surveys of the eelgrass bed's extent along the nourishment site on Town Neck Beach have been carried out by WHG annually from 2014-2019 for the Town of Sandwich. The most recent survey took place in 2019 and the results are shown in Figure 3-2 along with the results of the complex rocky habitat survey conducted in 2018. The most recent survey in 2019 was the third year of annual monitoring by WHG of the entire length of the project area, including inside and offshore the permitted nourishment footprint. The 2019 survey methodology consisted of two separate survey methods: a wading survey was conducted by WHG on 7 August 2019 and a boat-based survey was conducted by the Massachusetts Department of Marine Fisheries (MADMF) on 24 July 2019. Methodology is contained in the 2019 WHG Eelgrass Memo to MADEP (WHG, 2019).

Eelgrass was observed in the nearshore area of the nourishment site with 99.9% of the eelgrass observed outside of the nourishment footprint (Figure 3-2). The total area of eelgrass mapped by WHG in 2019 was 29.8 acres, representing a 7.5% increase from 2018. The increase was attributed to growth within an area at the western end of the surveyed area as well as growth along the seaward edges of the larger eelgrass meadow (WHG, 2019).

Figure 3-2. WHG 2019 eelgrass survey results

3.5.2. Upland Vegetation

Vegetation on the coastal dunes in the project area consists primarily of American beachgrass (*Ammophila breviligulata*) and spotted knapweed (*Centaurea stoebe*). Originally from Europe, *C. stoebe* is listed as an invasive plant in Massachusetts and in much of New England. Currently the majority of the dune seaward of the Wood Ave public parking lot in the eastern end of the project area is dominated by *C. stoebe*.

3.5.3. Wetlands

The salt marsh behind Town Neck Beach is extensive, covering approximately 600 acres of area and extending from the coast to downtown Sandwich. Coastal marshes and estuaries are highly productive ecosystems with high habitat value offering breeding, sheltering, foraging, and nursery habitat for fish, birds, and invertebrates. Mill Creek, flowing from Shawme Lake, and Old Harbor Creek are two of the biggest tributaries running through the salt marsh and eventually into Cape Cod Bay through the Old Harbor Inlet. The inlet is located between Springhill Beach and Town Neck Beach. The marsh is heavily ditched with many small creeks and streams running throughout. Vegetation in the marsh is predominantly smooth cordgrass (*Spartina alterniflora*) and salt hay grass (*Spartina patens*).

3.5.4. Benthos

The placement site on Town Neck Beach contains sandy subtidal and intertidal benthic habitat as well as rocky intertidal and subtidal benthic habitat. The majority of benthic habitat in the placement area is made up of sandy, intertidal substrate. This exposed intertidal area is often disturbed, scoured and covered by sand transported during daily tides and coastal storms, thus, limited benthic resources are anticipated to be present in the placement site. No benthic survey of the placement site was conducted.

Rocky intertidal shore habitat is also present within and adjacent to the nourishment footprint (Figure 3-1). In 2018, WHG reported that the westernmost portion of rocky intertidal habitat that will be impacted by nourishment was relatively devoid of biota with low density barnacles making up the biological community. At the eastern end of the nourishment area, approximately 2.23 acres of rocky intertidal area will be impacted by nourishment. WHG (2018) characterized this area as high energy with large volumes of shifting sand. The 10 inch-diameter cobbles in this area were subject to movement by waves with low amounts of biota viewed on the substrate.

No benthic survey was conducted of the Scusset Beach borrow site, but a shellfish survey showed that no significant shellfish populations occur within the site. No bedrock exposures are within the borrow site footprint (WHG, 2017).

3.5.5. Shellfish

Shellfish suitability areas, as delineated by the MADMF, for blue mussels (*Mytilus edulis*) and Atlantic surf clams (*Spisula solidissima*) are mapped along Town Neck Beach. Suitable habitat for blue mussels, soft-shelled clams (*Mya arenaria*), and quahog (*Mercenaria mercenaria*) is present in the marsh and throughout the Old Harbor Inlet. Blue mussel habitat is mapped in the Scusset borrow area as well (Figure 3-3).

Atlantic surf clams inhabit sandy continental shelf habitats from the southern Gulf of St. Lawrence to Cape Hatteras, North Carolina. They are typically found to a depth of three feet below the water/sediment interface, and generally occur from the beach zone to a depth of about 200 feet. However, beyond about 125 feet abundance is low. Surf clams spawn in the summer and early fall; growth is most rapid during those months as well. The majority of the Atlantic surf clam fishery is concentrated in northern New Jersey, the Delmarva Peninsula, and Georges Bank. Surf clams are planktivorous siphon feeders (NMFS, 1999). Quahogs are managed under the same fishery management plan by the National Marine Fisheries (NMFS) as surf clams. Quahogs spawn once a year, in the summer or fall and are slow growing, reaching a commercially harvestable size at about age 20 (NMFS, 2015).

Soft-shelled clams burrow deeply into soft sediments and unless disturbed, they will spend their adult lives in one place. Soft shell clams spawn from late spring to fall; once the eggs develop into free-swimming larvae, they eventually settle onto a hard substrate (URI EDC, 1998a). Blue mussels range from Labrador to Cape Hatteras, NC and are most common in the littoral to sublittoral zones of ocean and estuarine environments. They live in dense colonies of mussel beds and are regularly harvested for human consumption. Blue mussels spawn from April to September (Newell, 1989).

WHG performed shellfish surveys of both the placement and borrow sites in 2014 and 2016, respectively. No shellfish were found in or near the Town Neck Beach placement site (WHG, 2014). Within the borrow site, surf clams were found in densities ranging from 0.1 to 0.01 per square foot and no blue mussels were observed (WHG, 2017). The MADMF provided an assessment to the WHG that the borrow area is not a productive shellfish habitat and that recovery of the surf clam community will likely occur within one year following sand extraction.

Lobsters (*Homarus americanus*) are widely distributed over the continental shelf of the western North Atlantic Ocean and are most abundant from Maine to New Jersey in inshore waters out to a depth of 40 m. Post-larval lobsters have been observed settling into rock or gravel often covered with algae, salt-marsh peat, eelgrass, seaweed substrates, and firm mud. The preferred habitat for settlement of post-larval lobster appears to be any area with three-dimensional structure where they can build and maintain burrows for shelter from predators. Adult lobsters have been found in waters from the intertidal zone to as deep as 700 meters. Coastal populations concentrate in areas where shelter is readily available. When inactive, lobsters find shelter in burrows under rocks or in mud tunnels. In winter, especially when the water temperature is below 5°C, lobsters have been found close to the mouth of their burrow with sediment and debris and remain in their burrow for weeks (Palma et al., 1998).

Although a lobster survey was not conducted for this study, adult lobsters are not expected to be in the project areas given the shallow depths. Juvenile lobsters may be found in the subtidal rock-cobble areas and in beds of eelgrass along Town Neck Beach. Early life stage juvenile lobsters may also be found in the salt marsh utilizing peat reefs created by large blocks of *Spartina alterniflora* peat that have separated from the marsh surface and fallen into the adjacent subtidal marsh channels (Able et al., 1988). Green crabs (*Carcinua maenus*) and cunners (*Tautogolabrus adspersus*) are the most abundant potential predators in this habitat (Barshaw et al., 1994).

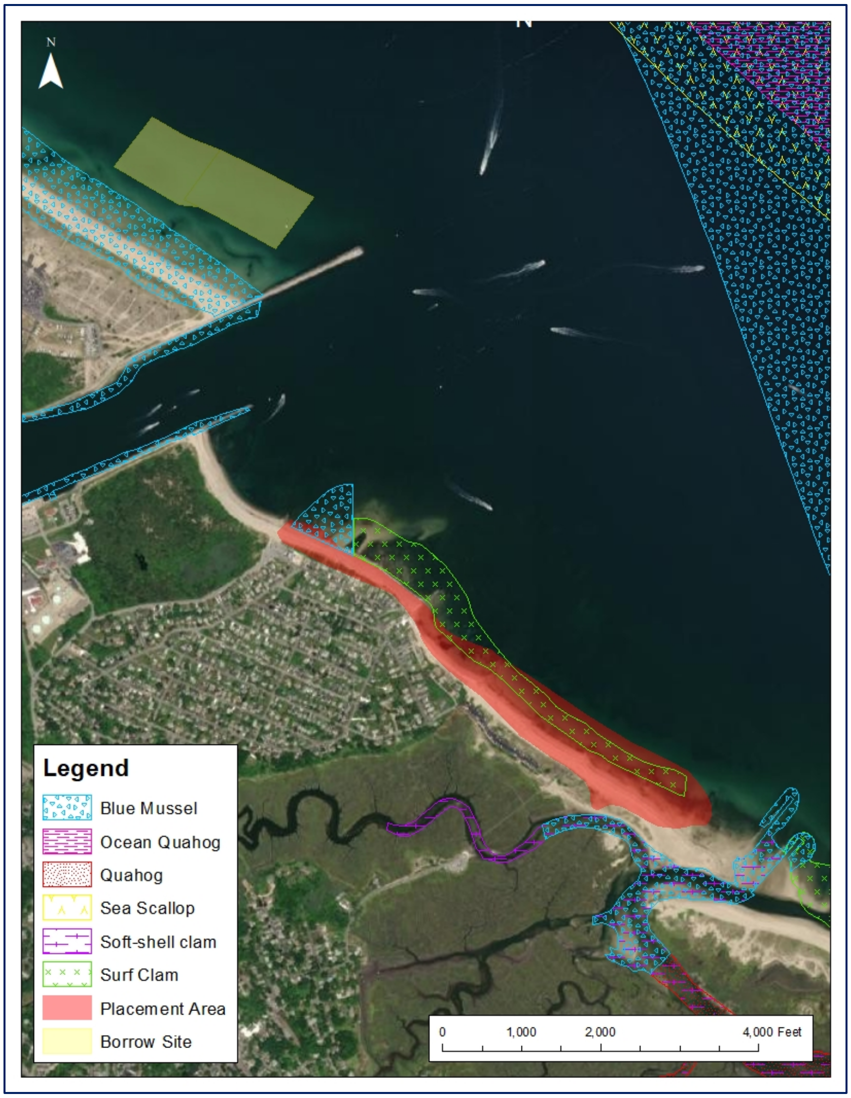

Figure 3-3: Shellfish Suitability Areas, Sandwich

3.5.6. Fisheries

Fish species which may be found within Cape Cod Bay include: striped bass (*Morone saxatilis*), black sea bass (*Centropristis striata*), bluefish (*Pomatomus altatrix*), mackerel (*Scomber scrombrus*), bonito (*Sarda sarda*), tautog (*Tautoga onitis*), scup (*Stenotomus chrysops*), cod (*Gadus morhua*), summer flounder (Paralichthys dentatus), weakfish (*Cynoscion regalis*), pollock (*Pollachius pollachius*), halibut (*Hippoglossus hippoglossus*), yellowfin (*Thunnus albacares*) and bluefin tuna (*Thunnus thynnus*), haddock (*Melanogrammus aeglefinus*), wolffish (*Anarhichas lupus*), winter flounder (*Pseduopleuronectes americanus*), rainbow smelt (*Osmerus mordax*), and shortfin mako (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*).

Two times a year, the MADMF conducts trawl surveys in state coastal waters to determine fish stock conditions which aid in fishery management and protection. The surveys collect information on the distribution, relative abundance, and size and composition of fish and select invertebrate species. The closest sampling stations to the Sandwich and Sagamore shorelines were trawled in 2016. Tables 3-2 and 3-3 list the species found at the stations located closest to the project areas by expanded catch number and weight. The MADMF Spring 2016 survey at station 9 (closest to project site) was taken at a depth of 55 feet; 23 species were caught in that station. Winter flounder presented the highest relative abundance by catch number and weight. Station 1 of the 2016 Fall MADMF survey (nearest the project areas) was taken at a depth of 52 feet. At this station 14 total species were caught, and longfin squid (*Doryteuthis pealeii*) had the highest abundance by weight and catch.

Juvenile Atlantic cod (*Gadus morhua*) may utilize the eelgrass beds in the nearshore zone adjacent to the nourishment area and the rocky intertidal habitat within the project area. In 2002, the MADMF published the results of years of survey data showing that a cod nursery is located off the eastern Massachusetts coastline and within state waters (Howe et al., 2002). The MADMF Technical Report TR-12 (Howe et al., 2002), concluded that accounts in Bigelow and Schroeder (1953) were consistent with contemporary research findings. These accounts were that young cod are more plentiful on rough inshore bottoms where they have shelter from predators. Several other studies confirmed that for age 0 Atlantic cod, shallow water depths (<16 feet) and protective bottom habitat (complex, eelgrass, etc.) provide newly settled juveniles nursery habitat (Tupper and Boutilier, 1995; Grant and Brown, 1998). Young-of-the-year appear to lose site fidelity and disperse into deeper water during the December-January period (Tupper and Boutilier, 1995; Gregory and Anderson, 1997) adopting winter behavior of reduced activity and food consumption (Brown et al., 1989).

Tables 3-2 and 3-3. Results of the Spring and Fall 2016 MA DMF Inshore Trawl Survey at stations located closest to the project areas.

Spring 2016 MA DMF Survey		
Expanded Catch Number	Expanded Catch Weight (kg)	Species Name
228	52.770	Winter Flounder
88	6.560	Whiting
85	13.192	Rock Crab Atlantic
29	19.310	Little Skate
20	3.463	Red Hake
18	3.680	Windowpane Flounder
13	4.140	Longhorn Sculpin
10	1.920	Northern Searobin
9	0.154	Spotted Hake
7	2.310	Lobster
3	0.252	Longfin Squid
2	0.728	Winter Skate
2	0.488	Cunner
2	0.018	Rock Gunnel
1	3.400	Spiny Dogfish
1	0.115	Alewife
1	0.001	Cod
1	0.225	Yellowtail Flounder
1	0.024	Black Sea Bass
1	1.150	Sea Raven
1	1.422	Tautog
1	0.169	Wrymouth
1	0.384	Jonah Crab

Fall 2016 MA DMF Survey		
Expanded Catch Number	Expanded Catch Weight (kg)	Species Name
7934	18.470	Longfin Squid
69	16.920	Winter Flounder
20	13.430	Little Skate
19	0.798	Scup
22	3.570	Rock Crab Atlantic
9	0.046	Butterfish
14	3.420	Lobster
3	1.150	Winter Skate
3	2.298	Fluke
2	0.280	Windowpane Flounder
1	0.046	Fourspot Flounder
1	0.014	Sea Raven
1	0.030	Cunner
0	2.018	Loligo Egg Mops

The New England Fishery Management Council's Essential Fish Habitat (EFH) Technical Team found that juvenile age 1 cod are also typically found in shallow inshore waters, associated with rocky substrate and macroalgae. Older juveniles are generally found farther away at deeper depths (>82 ft) (NMFS, 1999). According to the EFH Technical Team's report, juvenile cod (age 1+) generally feed in deeper waters but may utilize the intertidal zone for feeding purposes despite no recent studies confirming that possibility (NMFS, 1999).

3.5.7. Upland Wildlife

The onshore habitat of Sandwich supports a variety of mammalian wildlife species typical in southern Massachusetts. Gray squirrels, raccoons, red fox, skunks, and small mammals (mice, chipmunks, voles, etc.) are likely present within the project area.

3.5.8. Birds

The sandy shores and salt marsh estuary in the project area offer habitat for a number of bird species. According to the Cornell Lab of Ornithology eBird data, the Town Neck and Scusset Beach areas support high counts of shore and sea birds such as common eiders (*Somateria mollissima*), black scoters (*Melanitta Americana*), herring gulls (*Larus argentatus*), laughing gulls (*Leucophaeus atricilla*), common terns (*Sterna hirundo*), least terns (*Sternula antillarum*), and piping plovers (*Charadrius melodus*) (Cornell, 2020). For more information on the latter two species, please see Section 3.5.2 below.

3.6 Threatened and Endangered Species

3.6.1. Flowering Plants

American chaffseed (*Schwalbea americana*) was identified by the USFWS's Information for Planning and Consultation (IPaC) system as possibly occurring within the project area (USFWS, 2020). American chaffseed is an herbaceous perennial plant that grows to a height of 12-18 inches. It blooms in early July and fruits from August to November. American chaffseed is generally found in early successional habitats described as open flatwoods or grasslands which are not present in the project area.

3.6.2. Birds and Bats

Several species of Federally and State-listed threatened or endangered birds may use Town Neck and Scusset Beach, their intertidal and subtidal areas, and the marsh located behind Town Neck Beach for forage and feeding. The Federally-listed Endangered roseate tern (*Sterna dougallii dougallii*), the Threatened piping plover (*Charadrius melodus*), the Threatened red knot (*Calidris canutus rufa*), and the Threatened northern long-eared bat (*Myotis septentrionalis*) are listed in the project area by the USFWS's IPaC system (USFWS, 2020). Common terns (*Sterna hirundo*) and least terns (*Sternula antillarum*) are State-listed Species of Special Concern in Sandwich, MA that could also utilize the project area. The Massachusetts Natural Heritage and Endangered Species Program (MANHESP) lists the entire project area as "Priority Habitat" for common terns, least terns, and piping plovers (MANHESP, 2020). The Town of Sandwich's Beach Management Agreement outlines the Town's endangered species management activities which includes daily monitoring during the April-August timeframe, setting up symbolic fencing around any discovered nesting sites, implementing crowd control measures, and enforcing dog prohibitions (WHG, 2013).

In North America, roseate terns breed in two separate populations, one from Nova Scotia to New York, and the second in the Caribbean. The northern population arrives in Massachusetts from late-April to mid-May to nest at coastal locations. Roseate terns depart from their breeding colonies in late-July and August and concentrate in staging areas around Cape Cod and the Islands before departing in September for wintering grounds. Roseates generally nest on sandy, gravelly, or rocky islands and less commonly at the ends of long barrier beaches. Roseate terns are often associated with common terns due to the fact that they choose similar nesting sites with denser vegetation and/or large boulders (MADFW, 2015a). Roseate terns have been sighted on Town Neck and Scusset Beaches in 2019 and 2018 (Cornell, 2020), but have not nested on any of Sandwich's beaches in recent years (MADFW, 2015a).

Piping plovers are known to nest on Scusset Beach and at the eastern end of Town Neck Beach near the Old Harbor Inlet. Figure 3-4 shows the latest (July 2020) locations of piping plover broods on Town Neck Beach. Nesting has occurred in this location consistently for at least the last 10 years with 1-3 pairs each year on average (A. Hoenig, personal communication, 28 August 2020). Table 3-4 shows the year, number of nesting pairs, and chicks fledged from 2017-2020 on Town Neck Beach (MANHESP, 2019a).

Figure 3-4: Piping plover nesting locations on Town Neck Beach, Sandwich, MA in 2020. Nests STN-01b and STN-02a were active as of 2 July 2020, nest STN-01a was abandoned earlier in the season

Table 3-4: Piping plover nesting activity on Town Neck Beach, Sandwich, MA

Year	Number of Pairs	Chicks Fledged
2020	2	6
2019	2	5
2018	1	4
2017	3	4

On Scusset Beach, piping plovers have nested or attempted to nest intermittently since 2006 (A. Hoenig, personal communication, 28 August 2020). No plovers nested on Scusset Beach in 2020 or 2019, one pair attempted nesting in 2018, but no eggs were found, and one pair was sighted in 2017, but no nest was found. (MANHESP, 2019a).

Piping plovers nest in open, sandy beaches close to dunes. Piping plovers return to their breeding grounds in late March and early April and the nesting season may extend into late August, although individual pairs may fledge their young as early as July. Nesting habitat consists of sandy beaches, sand flats at the ends of barrier islands, gently sloping foredunes, sandy patches created by blowouts in frontal dunes, and wash over areas in frontal dunes. Nests are situated above the high tide line and consist of a shallow scraped depression in the sand (or in shell and pebble cobble). The nest site usually has sparse vegetation, or none, and occasionally is understands of American beachgrass.

There are no nesting records of red knots in Massachusetts; however, this species uses coastal areas in Massachusetts as a migratory stopover for foraging in the spring and fall. Few red knots are observed in Massachusetts during their spring migration (May-June), but high numbers of birds stopover in the state in their fall migration (July-September). According to the Cornell Lab of Ornithology's eBird website, no red knots have been observed on Town Neck or Scusset Beach within the area of the project (Cornell, 2020).

The northern long-eared bat (NLEB) is found across much of the eastern and north central United States and all Canadian provinces from the Atlantic coast west to the southern Northwest Territories and eastern British Columbia. The species' range includes 37 states. White-nose syndrome, a fungal disease known to affect bats, is currently the predominant threat to this bat, especially throughout the Northeast where the species has declined by up to 99 percent from pre-white-nose syndrome levels at many hibernation sites.

During summer, NLEBs roost singly or in colonies underneath bark, in cavities, or in crevices of both live and dead trees. Males and non-reproductive females may also roost in cooler places, like caves and mines. Northern long-eared bats emerge at dusk to fly through the understory of forested hillsides and ridges feeding on moths, flies, leafhoppers, caddisflies, and beetles, which they catch while in flight using echolocation. Breeding begins in late summer or early fall when males begin swarming near hibernacula. Most females within a maternity colony give birth around the same time, which may occur from late May or early June to late July, depending where the colony is located within the species' range. Young bats start flying by 18 to 21 days after birth (USFWS, 2015b). No known maternity roost trees or hibernacula are located within or adjacent to the project area. The closest maternity roost trees are over two miles south of the project area (MA NHESP, 2019b).

Least terns also often nest on the eastern end of Town Neck Beach. The Town of Sandwich Natural Resources Department reported that two least tern colonies nested on Sandwich beaches in 2020, at the western end of Spring Hill Beach, and the eastern end of Town Neck Beach (D. DeConto, personal communication, 20 August 2020). A family of least terns were also reported to nest on the eastern end of Town Neck Beach in 2019. There are no records of nesting common terns on beaches in Sandwich in 2020 or in recent years past (D. DeConto, personal communication, 20 August 2020). Least terns used to abundantly nest in Massachusetts, but their numbers declined by the end of the 19th century and the species required legal protection to prevent extinction. In spring, least terns typically arrive by the end of April/early May, but nesting does not occur until later in May and sometimes into mid-June, dependent on weather. Their preferred nesting habitat is expansive sandy or pebbly beaches just above high tide which can be unstable and subject to washout by coastal storms (MassAudubon, 2020). Departure typically occurs before September 1, but they may be observed at sites later into September (A. Hoenig, personal communication, 28 August 2020).

3.6.3. Whales

Two species of Federally endangered whales are known to use Cape Cod Bay which is within and borders the project area. The whales are the fin whale (*Balaenoptera physalus*) and the North Atlantic right whale (*Eubalaena glacialis*). The project areas seaward of MHW falls within the limits of the "Right Whale Critical Habitat Area" (NOAA, 2017a). Critical habitat is defined by Section 3 of the ESA as "(1) the specific areas within the geographical area occupied by the species, at the time it is listed, on which are found those physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species (NOAA, 2016)."

The final rule (81 FR 4837) identifies the following four physical and biological features of foraging habitat that are essential to the conservation of the right whale: (1) The physical oceanographic conditions and structures of the Gulf of Maine and Georges Bank region that combine to distribute and aggregate *Calanus finmarchicus* for right whale foraging, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes; (2) Low flow velocities in the Jordan, Wilkinson, and Georges Basins that allow diapausing *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained in the basins; (3) Late stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank region; and (4) Diapausing *C. finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region.

Overwintering and foraging fin whales are listed within the project location. Fin whales are ordinarily found in deep, offshore waters. During the summer, fin whales feed on krill, small schooling fish, and squid, and are often observed in social groups that include humpback whales, sei whales, and Atlantic white-sided dolphins (NOAA, 2015). The greatest densities of foraging fin whales are observed from March to August with lower densities from September to November (NOAA, 2019).

The North Atlantic right whale is one of the world's most endangered large whales. Over-exploitation by commercial whalers in the 19th and early 20th centuries reduced the population to a fraction of its original size. Although killing right whales has been prohibited since the 1930's, the population has not increased to any appreciable degree. Threats to the low population of roughly 300-400 individuals include ship strikes and entanglement in fishing nets. In 2017, the species experienced an unusual mortality event when seventeen right whales were found dead off the coasts of New England and Canada. Most sightings of North Atlantic right whales in Massachusetts waters are during the spring and summer when they migrate north to feeding grounds. North Atlantic right whales feed primarily on copepods and krill larvae. Females move south in autumn to temperate waters to give birth. NMFS has noted increasing evidence of overwintering right whales (approximately November – January) in Cape Cod Bay, Jeffreys and Cashes Ledge, Jordan Basin, and Massachusetts Bay (e.g., Stellwagen Bank) (NOAA, 2019).

Multiple sighting of North Atlantic right whales have been recorded in the waters of the project area. The majority of sightings generally occur in April and May, but some observations have occurred as late as November and February of some years. Several sightings of right whales have also occurred in the Canal, with the most recent observation made in May 2019 (NOAA, 2020a).

3.6.4. Fish

Adult shortnose sturgeon (*Acipenser brevirostrum*), and subadult and adult Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) may also utilize the nearshore waters of Scusset and Town Neck Beaches. Shortnose sturgeon are designated as endangered and Atlantic sturgeon are threatened under Section 7 of the Endangered Species Act.

Shortnose sturgeons have a range that extends from St. John River in New Brunswick, Canada to St. Johns River in Florida. Shortnose sturgeons are anadromous, spending a portion of their lives in salt water, but returning to freshwater to spawn. However, in some northern populations (e.g., in the Kennebec River), a portion of the population forages in the saline estuary while others forage in fresh water. The shortnose sturgeon exhibits delayed sexual maturity, high reproductive capacity, and long-life expectancy (NOAA, 2014). Adult shortnose sturgeon primarily eat mollusks and large crustaceans. Feeding and overwintering activities may occur in both fresh and saline habitats; overwintering occurs in freshwater from late fall to early spring (NOAA, 2014). The Merrimack River, which empties into Ipswich Bay, is the closest known spawning, rearing, foraging, and overwintering habitat for this species. The Merrimack River is located approximately 65 miles north of the project area. The time of year for coastal migrations, when shortnose sturgeon may be in the project area, is roughly from April 1 to November 30 of any year (NOAA, 2014).

Atlantic sturgeon subadults and adults live in coastal waters and estuaries when not spawning, generally in shallow (32-164 foot depth) nearshore areas dominated by gravel and sand substrates. The project area is within this species' range as defined by NOAA (2019). Atlantic sturgeon migrate into freshwater rivers in May and June to spawn. Females migrate back to the ocean soon after spawning, but males may remain in the rivers until colder weather arrives in the fall. The closest rivers to the project area noted for foraging use by Atlantic sturgeon are the North River and the Merrimack River, which is also known spawning habitat for the species (MADFW, 2015b). Subadult and adult Atlantic sturgeon opportunistically forage year-round and therefore have the potential to be within the project area at any time of year (NOAA, 2019).

3.6.5. Sea Turtles

Four species of ESA-listed sea turtles have been observed using Cape Cod Bay as seasonal habitat. Sea turtles are generally found in Massachusetts waters from June through November, but each species' distribution varies depending on the time of year and the availability of prey (Evans et al., 2011). The endangered Kemp's Ridley turtle (*Lepidochelys kempii*) is regularly found stranded on bayside beaches of Cape Cod in winter; live sightings are otherwise rare. The only known existing nesting area is in Mexico. These turtles are often found in the Cape Cod area in late autumn, and data suggests this is more related to cold-stunning than fishing activity (Prescott, 1982; Meylan, 1986; Battelle, 1990).

Most sea turtle sightings within the Cape Cod Bay waters involve the endangered leatherback sea turtle (*Dermochelys coriacea*). This species is the most cold hardy of all the sea turtles and found world-wide. Leatherbacks feed exclusively on jellyfish and in the spring, they move to the northeast U.S. continental shelf to forage. Although leatherback sea turtles are primarily an open ocean species, they also come into shallow coastal waters during the summer months to feed on concentrations of jellyfish. Twenty or more are reported annually along the Massachusetts coast, mostly in southern Cape Cod Bay near the Cape Cod Canal, and in waters south of the cape (MADFW, 2015c). Aerial surveys if the mid and north Atlantic noted the presence of leatherback turtles from April to November in the Gulf of Maine (NMFS, 1992). Sporadic sightings of endangered juvenile loggerhead turtles (*Caretta caretta*) occur in coastal New England waters when water temperatures reach 68-73° F. Nesting areas for this species are in the southern United States and more southerly regions (MADFW, 2015d).

Threatened green sea turtles (*Chelonia mydas*) have been reported in Cape Cod Bay, however sightings are extremely rare. Green sea turtles generally inhabit shallow waters where they have access to seagrass beds. Most nesting occurs in Florida. In Massachusetts, juvenile green sea turtles are found on the southern and eastern beaches of Cape Cod Bay in December and January as the water temperatures drop (MADFW, 2015e).

Like other reptiles, most sea turtles are poikilothermous. As these turtles migrate south beginning in October, some do not leave the northern latitudes before the water temperatures drop below 60° F and they have a hypothermic reaction, which causes lethargy, shock, pneumonia, and often death. Many of these “cold-stunned” turtles wash ashore on Cape Cod beaches. Cold-stunned juvenile Kemp’s ridley, loggerhead, and green sea turtles have been found on Town Neck Beach from late October through December. Stranded sea turtles found in November or December are rarely found alive or responsive to rehabilitation efforts (Mark Fahey, Massachusetts Audubon). In last weeks of November 2018, 227 sea turtles were found on Cape Cod beaches. Of these, 76% (173) died and 24% (54) survived (Katz, 2018). Of turtles that stranded earlier in the 2018 season, 20% died and 80% survived (Nett, 2018).

3.7 Essential Fish Habitat

The NMFS has designated specific areas as EFH in accordance with the Magnuson-Stevens Fishery Conservation Act, as amended by the Sustainable Fisheries Act of 1996. The Sustainable Fisheries Act includes requirements for evaluating fish habitat loss and protection of fisheries identified as essential fisheries. EFH are those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (50 CFR Part 600).

The proposed project occurs in designated EFH habitat areas. Species with designated EFH within the project area are listed in Table 4-4. Appendix A3 contains the EFH Assessment.

Table 3-5: EFH species designations for the Town Neck Beach placement area (designated by "A") and the Scusset Borrow Site (designated by "B")

Species	Eggs	Larvae	Juveniles	Adults
American plaice (*Hippoglossoides platessoides*)	A B	A B	A B	A B
Atlantic cod (*Gadus morhua*)	A B	A B	A B	A B
Atlantic wolffish (*Anarhichas lupus*)	A B	A B	A B	A B
Ocean pout (*Macrozoarces americanus*)	A B	A B	A B	A B
Pollock (*Pollachius virens*)		A B	A B	A B
White hake (*Urophycis tenuis*)	A B	A B	A B	A B
Windowpane flounder (*Scophthalmus aquosus*)	A B	A B	A B	A B
Winter flounder (*Pseudopleuronectes americanus*)	A B	A B	A B	A B
Yellowtail flounder (*Limanda ferruginea*)	A B	A B	A B	A B
Silver hake (*Merluccius bilinearis*)	A B	A B		A B
Red hake (*Urophycis chuss*)	A B	A B	A B	A B
Monkfish (*Lophius americanus*)	A B	A B		
Thorny skate (*Amblyraja radiata*)			A B	
Little skate (*Leucoraja erinacea*)			A B	A B
Winter skate (*Leucoraja ocellata*)			A B	A B
Atlantic sea scallops (*Placopecten magellanicus*)	A B	A B	A B	A B
Atlantic herring (*Clupea harengus*)		A B	A B	A B
Albacore tuna (*Thunnus alalunga*)			A B	A B
Bluefin tuna (*Thunnus thynnus*)				A B
Basking shark (*Cetorhinus maximus*)			B	B
White shark (*Carcharodon carcharias*)			A B	A B
Smoothhound shark (*Mustelus mustelus*)			B	B
Sand tiger shark (*Carcharias taurus*)			B	

3.8 Socioeconomics

According to the 2012-2016 American Community Survey, the population of Sandwich is 20,508 and the median household income is $89,461. The average annual labor force is 11,459, of which 10,674 are employed, 700 are unemployed, and 5,230 are not in the labor force for the population 16 years and over. The unemployment rate is 6.2 percent. Average annual employment by occupation is shown in Table 3-6 (U.S. Census Bureau, 2012-2016 American Community Survey).

The race distribution in Sandwich is depicted in Figure 3-5 (U.S. Census Bureau, 2012-2016 American Community Survey). The rate for individuals living below the poverty level in the town of Sandwich in 2016 was 5.2% which is lower than the national average (12.7%) for that year (U.S. Census Bureau, 2012-2016 American Community Survey).

TABLE 3-6. Average Annual Employment for Sandwich by Occupation (U.S. Census Bureau, 2012-2016)	
Occupation	**Estimate**
Management, professional and related occupations	4,385
Service occupations	1,983
Sales and office occupations	2,516
Natural resources, construction, and maintenance occupations	899
Production, transportation, and material moving occupations	918
Total	**10,674**

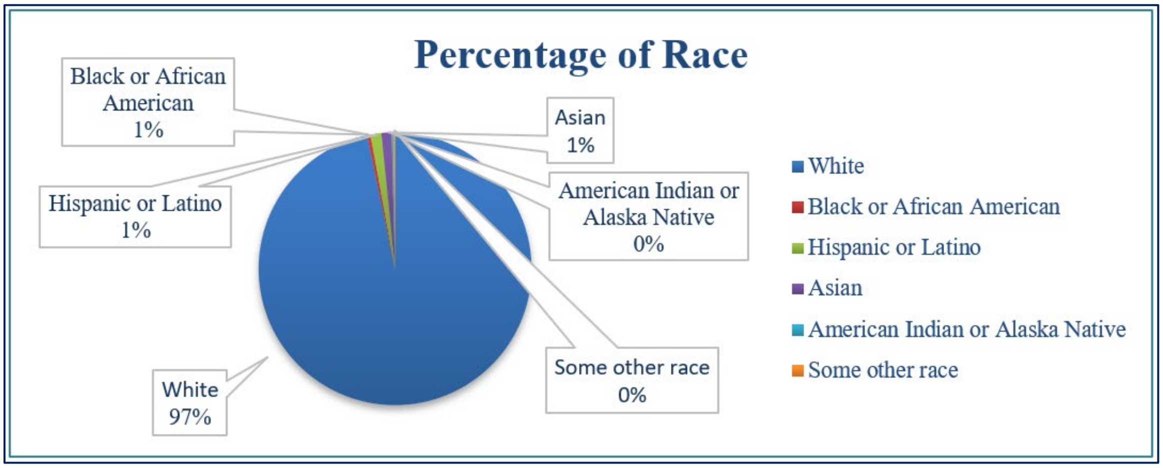

Figure 3-5: Percentage of race in Sandwich, Massachusetts (U.S. Census Bureau, 2012-2016 American Community Survey)

3.9 Cultural Resources

The study area is located within the Town Neck Area of Sandwich which encompasses the neck of land between the Shawme Marsh and the Cape Cod Canal. The area was originally a cow pasture from the 17th century until as late as the early 20th Century. Today, Town Neck bears little resemblance to its historic appearance or utilization. A map from 1825 depicts the area as marsh. With the opening of the Cape Cod Canal in 1914, the rural agricultural landscape of town Neck was changed. Town Neck is composed of a wide range of resources including a fish freezer, Coast Guard Station, boat basin, wharves, breakwaters, modern commercial properties, a residential subdivision, and an abandoned dairy farm. None of these properties are located within the project area of potential effect.

A review of the historic and archaeological site files from the Massachusetts Cultural Resources Information System (MACRIS) online database identified several historic properties within the project's area of potential effect (APE). One site, 19-BN-547 Town Neck Road, is listed as a pre-

Contact archaeological site along the shoreline and extending inland, just south of the Canal. This site is described as within the dune and open grassy meadow west of the parking lot for the Drunken Seal restaurant extending to the mouth of the Canal. No further information is available, but it is indicated that portions of the site may have been disturbed by Canal and residential construction and collecting activities.

Several National Register historic districts are located in the town of Sandwich including the Jarvesville, Town Hall Square and Spring Hill Historic Districts as well as local districts including Town Neck and the Old King's Highway Regional Historic District.

A brick kiln or brickyard site is depicted on the 1857 Walling map at Town Neck and available on the Town of Sandwich Historical Commission's website (https://sandwichhistory.org/a-brickyard-at-town-neck/). According to the Town, "a lens of fine clay suitable for brick making was discovered, perhaps as early 1790 when construction of houses and mills picked up in earnest." Bricks and ash from the brick kiln have been exposed along the shore by erosion and were reported in 2015. The placement of sand along Town Neck Beach as beach nourishment should help protect any existing remnants from the brickyard while addressing the erosion of the shoreline.

A review of shipwreck databases identified several submerged historic properties well off the coast of Sandwich. One unknown wreck is depicted off Scusset Beach in the vicinity of the proposed borrow area. Gray and Pape conducted a remote sensing archaeological survey in 2016 as part of the permitting process for the current borrow area. No submerged historic properties were identified. No visible remains of the unknown wreck above were noted in the field. No further investigations were recommended.

3.10 Coastal Barrier Resources Act Units

The USFWS oversees the Coastal Barrier Resources Act (CBRA), a law that was passed in 1982 to provide protection to undeveloped coastal barriers along the Atlantic and Gulf coasts. Areas designated under the 1982 CBRA became part of the John H. Chafee Coastal Barrier Resources System (CBRS), thus becoming ineligible for most new Federal expenditures and financial assistance. The law encourages the conservation of hurricane prone, biologically rich coastal barriers by restricting Federal expenditures that encourage development, such as Federal flood insurance. Areas within the CBRS can be developed provided that private developers or other non-Federal parties bear the full cost.

CBRS Unit MA-14P is located within the project area and is designated as an Otherwise Protected Area (OPA). See Figure 3-6. OPAs are predominantly comprised of conservation and/or recreation areas such as national wildlife refuges, state and national parks, etc. though they may contain private areas that are not held for conservation and/or recreation. The only Federal spending prohibition within OPAs is the prohibition on Federal flood insurance.

Figure 3-6: Coastal Barrier Resource Act Unit Map, MA-14P

3.11 Recreation and Scenic Resources

The project areas offer recreational opportunities such as swimming, sunbathing, walking, and fishing. The scenery of the area is that of a coastal, beach landscape. Town Neck Beach is closed to recreational vehicles, but is popular with the public and pedestrians who can access the beach via the parking lot next to The Drunken Seal restaurant at the western end of the beach as well the Town Neck Beach Parking Lot on Wood Avenue near the eastern end of the beach. The latter of these two parking areas offers access to the Sandwich boardwalk which goes through the marsh connecting to another parking area at the end of Boardwalk Road. Recreational opportunities in the marsh include kayaking, boating, and stand-up paddle boarding. On the Scusset Beach side of the Canal, the borrow site is located off of the Scusset Beach State Reservation. The public reservation is on land owned by the USACE but operated by the Commonwealth of Massachusetts. The beach offers a wheelchair-accessible boardwalk, restrooms, and snack bar. Camping is also available in the reservation (MADCR, n.d.).

3.12 Air Quality

The Clean Air Act (CAA) establishes the framework for modern air pollution control, and delegates primary responsibility for regulating air quality to the States, with oversight by the U.S. Environmental Protection Agency (EPA). The EPA develops rules and regulations to preserve and improve air quality as minimum requirements of the CAA, and delegates specific responsibilities to State and local agencies. The EPA has identified seven specific pollutants (called criteria pollutants) that are of concern with respect to the health and welfare of the general public. The criteria pollutants are carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3), particulate matter 10 micrometers or less in aerodynamic diameter (PM10), particulate matter 2.5 micrometers or less in aerodynamic diameter (PM2.5), and lead (Pb). These pollutants have established National Ambient Air Quality Standards (NAAQS).

Areas that do not meet the NAAQS are called non-attainment areas. For nonattainment areas, the CAA requires States to develop and adopt State Implementation Plans (SIPs). The SIP sets the basic strategies for implementation, maintenance, and enforcement of the NAAQS. The Commonwealth of Massachusetts is authorized by the EPA to administer its own air emissions permit program, which is shaped by its SIP. In Massachusetts, Federal actions must conform to the Massachusetts Ambient Air Quality Standards which are consistent with the National Standards. The USACE must evaluate and determine if the proposed action (construction and operation) will generate air pollution emissions that aggravate a non-attainment problem or jeopardize the maintenance status of the area for ozone. When the total direct and indirect emissions caused by the operation of the Federal action/facility are less than threshold levels established in the rule (40 C.F.R. § 93.153), a Record of Non-applicability (RONA) is prepared and signed by the facility environmental coordinator.

The entire Commonwealth of Massachusetts is designated as an attainment zone for sulfur dioxide, lead, carbon monoxide, nitrogen dioxide, particulate matter-10, and particulate matter-2.5. The project location in Barnstable County, Massachusetts is also in attainment for ozone (O_3). Attainment zones are areas where the NAAQS have been met. The entire project area is located within a designated attainment zone according to the NAAQS set forth by the EPA (EPA, 2018).

3.13 Greenhouse Gases

Greenhouse gases (GHGs) trap heat within the earth's atmosphere which increase temperatures. The largest source of greenhouse gas emissions from human activities in the United States is from burning fossil fuels for electricity, heat, and transportation (EPA, 2016). Each Federal Agency project's NEPA assessments needs to consider and evaluate GHGs consistent with CEQ draft guidance released on the consideration of GHGs emissions and the effects of climate change (CEQ, 2019). For purposes of this guidance, CEQ defines GHGs as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Also, for purposes of this guidance, "emissions" includes release of stored GHGs as a result of destruction of natural GHG sinks such as forests and coastal wetlands, as well as future sequestration capability. The common unit of measurement for GHGs is metric tons of carbon dioxide (CO_2) equivalent [mt CO_2-e]). The Massachusetts Global Warming Solutions Act, passed in 2008, required the MADEP to put into effect mandatory GHG reporting regulations. The MADEP issued 310 CMR 7.71, outlining the facilities required to report and establishing the methods for calculating and verifying emissions. Reportable emissions are for CO_2, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorcarbons (MADEP, n.d.). The latest data available from the MADEP GHG Reporting Program is from 2015. In that year, 296 facilities in the state reported 18,959,938 mt CO_2-e. This number represents only approximately one quarter of the total GHG emissions inventory since only large stationary facilities are required to report. About 80% of the total CO_2-e came from fossil fuel combustion (MADEP, 2015).

3.14 Hazardous, Toxic and Radioactive Waste

The EPA's National Priorities List (NPL) is the list of sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories. These substances are also known as hazardous, toxic and radioactive waste (HTRW). Sandwich and its neighboring towns do not have any sites listed on the existing or proposed NPL (EPA, 2021). No underground storage tanks (USTs) are within any of the project areas either (MADEP, 2020).

The EPA's Toxic Release Inventory (TRI) tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. Certain industrial facilities in the U.S. must report annually how much of each chemical is recycled, combusted for energy recovery, treated for destruction, and disposed of or otherwise released on- and off-site. One site in Sandwich is required to report to the TRI. Canal Generating LLC, located approximately 0.75 miles south of the project site on Town Neck Beach, released approximately 17 pounds of polycyclic aromatic compounds on-site in 2019 (EPA, 2019).

3.15 Noise

Noise is defined as unwanted sound. The day-night noise level (L_{dn}) is widely used to describe noise levels in any given community (EPA, 1978). The unit of measurement for L_{dn} is the "A"-weighted decibel (dBA), which closely approximates the frequency responses of human hearing. The primary source of noise in the study area is ocean waves breaking on the beaches, boat traffic utilizing the Canal, and any local construction projects that may be underway. Although noise level measurements have not been obtained in the study area, they can be approximated based on existing land uses. Land use around the project area consists of residential homes and recreational use of the beach. Noise levels for residential beachfront areas with the primary source of sound coming from ocean waves and wind were in the 54-64 dBA range (AECOM, 2017).

3.16 Environmental Justice

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" require Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of its program, policies, and activities on minority and low-income populations in the U.S., including Native Americans. Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA, 2020).

The EPA compiles environmental justice indices to compare populations vulnerable to environmental factors across the United States in their EJSCREEN tool. The EJSCREEN was used to draw a one-mile buffer from the center of the Town of Sandwich to include the project area. Within the buffer, the EJSCREEN reported that approximately 9% of the population was classified as people of color, 19% as low income, and 64% as over the age of 64. The

EJSCREEN also reported that the Town of Sandwich buffer ranged from the 40th to the 58th percentile, meaning that vulnerable populations in the area have a low exposure to environmental hazards relative to the rest of Massachusetts (EPA, 2020).

4. Without Project Conditions

4.1 Introduction

The without-project conditions are a projection of those conditions that can reasonably be expected to exist in the future, assuming the USACE does not implement a project. The without-project conditions were developed to better understand the impact of the problem if left unmitigated. It is important to note that the Section 111 authority is unique from other Civil Works study authorities with respect to the without-project conditions and establishing Federal Interest. Most other study authorities require the without-project conditions to include a quantification of monetary and/or environmental damages that can be used as a baseline for developing, evaluating, and comparing alternatives. Section 111 of the CAP program, however, implicitly assumes that Federal Interest exists based on the cause-and-effect relationship between an FNP and the attributable damages. A formal economic analysis was therefore not required for this study and future without-project conditions were characterized qualitatively.

4.2 Projected Conditions

Based on the coastal modeling described in Section 2 of this document, erosion of the Sandwich shoreline downdrift of the Canal is expected to continue if the problem is left unaddressed. Volumetrically, it was estimated that approximately 900,000 cubic yards of material can reasonably be expected to erode from the downdrift shoreline over the next 50 years. Geospatially, the long-term shoreline change rates were applied to current shoreline topography, producing an approximation of where the shoreline would be in the year 2068. Those projections show that a significant portion of the barrier dune along Town Neck Beach will erode, including the complete loss of approximately 1,000 linear feet of the dune. Graphic representations of the future shoreline conditions are shown again in Figures 4-1 through 4-4.

4.3 Projected Impacts

Erosion is projected to continue downdrift of the Canal for the foreseeable future in a without-project scenario. Assuming the erosion continues at similar rates as it has in the past, some reaches will be impacted more severely than others; most notably, the area between the prominent groin at Transect 31 and Old Harbor Inlet. Because this study did not include a formal comparison of costs and benefits, the projected impacts were considered qualitatively. Potential impacts to Town Neck Beach, Great Marsh and the Route 6A/Downtown Sandwich areas resulting from continued erosion of the downdrift shoreline are outlined below

Figure 4-1: Existing (2018) and projected (2068) MHW shoreline positions, west end of Town Neck Beach (WHG, 2020)

Figure 4-2: Existing (2018) and projected (2068) MHW shoreline positions, east end of Town Neck Beach (WHG, 2020)

Figure 4-3: Existing (2018) and projected (2068) MHW shoreline positions, Springhill Beach (WHG, 2020)

Figure 4-4: Projected (2068) areas of MHW inundation (WHG, 2020)

4.3.1. Town Neck Beach

The ‘upper’ section of Town Neck Beach, the first ½ mile from the Canal to the groin at Transect 31, has proven to be relatively stable over the last 50 years. Although some erosion may continue in absence of a project, the risk of significant shoreline loss along this reach and subsequent damage to property and infrastructure is relatively low. The ‘lower’ section of Town Neck Beach however, the ¾ mile reach from the groin at Transect 31 to Old Harbor Inlet, has experienced significant erosion directly attributable to Canal FNP. If the problem is left unaddressed then the majority of the beach profile along this reach, including much of the remaining dune itself, would erode by the year 2068. Direct impacts, in addition to the loss of recreational use of the beach, would include the loss of at least 10 shorefront residential structures (based on where the projected shoreline intersects with structures) as well as significant damage to the town beach parking lot and other associated riparian access features (boardwalks, signage, fencing, etc.). It should also be noted that the property owners of those shorefront structures have recently placed sacrificial sand between their respective structures and the eroding shoreline in order to prevent their homes from being undermined. This is an extremely costly undertaking for an individual property owner, so it is plausible that those property owners would be unable to continue taking such measures in future years.

It is subsequently plausible that actual shoreline retreat along this stretch of shoreline could exceed what was projected through the shoreline change analysis, and that structures immediately behind them could also be impacted in a without project scenario. Figure 4-5 highlights the structures that would be impacted by continued erosion based on projected shoreline retreat rates.

Figure 4-5: Structures projected to be directly impacted by continued erosion

4.3.2. Great Marsh

Great Marsh is a 600+ acre healthy, contiguous salt marsh ecosystem situated immediately behind the barrier dunes of Town Neck Beach and Springhill Beach. A sizeable breach of the dune occurred during Winter Storm Juno in 2015 that filled in the main channel and exposed the marsh to direct wave attack. Emergency action to excavate the channel and restore the dune was required in order to prevent the breach from having a more lasting and damaging impact on the system. The threat of dune failure and subsequent damage to Great Marsh is already imminent, but if ongoing erosion along the Town Neck Beach and Springhill Beach areas is left unaddressed, the majority of the dune will erode and offer little to no protection at all. The consequences of the shoreline retreat projected in the shoreline change analysis would likely result in catastrophic damages to a large portion of Great Marsh.

4.3.3. Route 6A/Downtown Sandwich

Route 6A is located immediately landward of Great Marsh and is a primary access route to and from Cape Cod that also serves as a primary evacuation route for the entire Cape Cod region. This roadway currently floods during extreme storm events and some stretches have been closed accordingly. Although flooding does occur naturally due to the low-lying nature of the road relative to baseline water surface elevations, frequency and intensity of the flooding is dictated by water surface elevation. In a without project scenario where the barrier dune fails, the flooding impacts would be significantly worsened, for several reasons. The barrier dune plays two key roles with respect to flooding. First, with a barrier dune in place, there is a temporal component to the tidal rise and fall of water surface elevations within Great Marsh because Old Harbor Inlet is the only source of tidal flow for the entire 600 acres marsh system, which limits the rate at which the marsh floods. Therefore, and to a lesser extent Old Harbor Inlet limits the maximum water surface elevations within the marsh and thereby reduces the frequency and severity of coastal flooding of Route 6A. If portions of the dune no longer exist due to continued erosion, as the current projections suggest will happen, then water surface elevations within the marsh would be far less restricted, thereby increasing the frequency and severity of flooding along Route 6A. Secondly, and more importantly, the barrier dune currently absorbs the wave energy produced by the open ocean. If large portions of the dune no longer exist due to continued erosion, then Route 6A would be subject to wave runup in addition to tidal increases in water surface elevation, which would significantly increase flooding of the roadway. Further, the increased exposure to wave energy would also leave Route 6A vulnerable to wave attack and erosion that it currently does not experience. Cumulatively these two increases in coastal storm risk would translate to increased closures of a primary evacuation route, reduced emergency response capabilities throughout the town and increased road repair costs borne by the town.

Loss of the dunes would similarly increase coastal storm risk for the Downtown area, If the dune were to fail, then the Historic Downtown, which is a commercial hub for the town, would be increasingly exposed to storm surge, wave runup and wave attack. That would increase the frequency and severity of coastal flooding which would ultimately translate to increased flood damages to residential properties, registered historic buildings, more frequent closures of local businesses and an overall reduction in locally generated revenue.

It should be noted that quantitatively analyzing the economic impacts resulting from loss of the dune is possible, but extensive and time-consuming modeling would be required in order to do so and it would be difficult to determine the extent to which those impacts can be specifically attributed to the Canal FNP. Due to the time sensitive nature of the problem and given that such an evaluation is not specifically required under the Section 111 authority, such an analysis was not conducted during this study and the damages were considered implicitly as justification for USACE participation in a mitigation project.

4.3.4. Springhill Beach

Lastly, although the Canal FNP influences erosion along Springhill Beach, the projected shoreline retreat line does not intersect with any structures along that reach. Long term erosion rates along Springhill Beach were also found to be more consistent with naturally occurring erosion in the region. That is not to suggest that the Canal FNP has no impact on erosion along Springhill Beach so much as it suggests that damages to property and infrastructure along that reach are far less attributable to the Canal FNP. As a result, the alternatives analysis did not focus on mitigating damages specifically to Springhill Beach. Most of the alternatives focused on addressing the more directly impacted area of Town Neck Beach. If a beach nourishment project is ultimately recommended and implemented then the entire littoral system would benefit from an increase in sediment supply, which would then indirectly help to stabilize conditions along Springhill Beach too.

5. Alternatives Analysis

5.1 Introduction

The goal of the alternatives analysis under the Section 111 authority is to develop and identify the most cost-effective method of mitigating shoreline damages attributable to the Canal FNP. The analysis was iterative in nature and included several refinements to both the list of alternatives and their respective costs. As mentioned previously, the alternatives analysis for a feasibility study conducted under Section 111 authority is unique in that it does not require a traditional economic analysis focused on identifying a National Economic Development plan or National Environmental Restoration plan. The alternatives analysis instead focuses on identifying the least costly, environmentally acceptable alternative for adequately mitigating damages. Consequently, this study considered the costs of each alternative, and their relative effectiveness, but benefits were not specifically monetized or otherwise quantified in economic/environmental terms. This section describes the nature of each iteration of the analysis, descriptions of the specific measures/alternatives considered, and an evaluation/comparison of those alternatives.

5.2 Initial Screening

5.2.1. Methodology

During the first iteration of the alternatives analysis a suite of coastal storm risk management measures were considered in a general sense in order to narrow the scope of the study and focus the effort on just those measures with a high likelihood of being developed into an implementable plan. Each measure was screened for its ability to mitigate damages, its constructability/cost-effectiveness, and its overall impact on the environment/existing usage of the area. This process allowed for measures to be eliminated from consideration quickly and decisively while ensuring that all reasonable measures were considered objectively and not ruled out prematurely.

5.2.2. Initial Measures Considered

The initial screening of measures considered coastal storm risk management strategies ranging from conservative measures such as beach nourishment and rock revetments to more aggressive measures such as major modifications to the jetties and even filling in the Canal entirely. Table 5-1 depicts the matrix that was used to screen those measures as well as a brief explanation for why they were carried forward or eliminated from consideration. A full-sized view of this matrix can be found in Appendix E. The initial screening process resulted in five primary measures being considered in greater detail: Beach nourishment; modification of the existing groin field located along Town Neck Beach; dune core stabilization (sand envelopes); modification of the Canal jetties; and a permanent sand bypass system.

Table 5-1: Initial Screening Matrix

Cape Cod Canal 111 Initial Measures Screening											
Measures		Objectives		Feasibility		Impacts			Retained for Further Evaluation?	Notes
		Reduce coastal storm hazards & damages?	Provide protection for health/safety?	Constructible?	Economically Justifiable?	Restrict or significantly alter current coastal access & use?	Potentially significant impacts to the environment?	Adversley impact existing storm protection measures?		
Structural	Seawall	No	No	No	No	No	Yes	Yes	NO	A seawall would likely worsen impacts and may not be constructible when considering the need for high ground tie-ins
	Revetment	No	No	Yes	No	Yes	Yes	Yes	NO	A revetment would likely worsen impacts and it would significantly reduce recreational usage of the shoreline
	Breakwater	Yes	Yes	Yes	No	No	Yes	No	NO	A breakwater would likely reduce erosive wave energy but this measure would not add sediment to the system, would be cost-prohibitive and it would have significant environmental impacts
	Alternative Technology	Possibly	Possibly	Yes	Not likely	No	Yes	No	NO	Experimental concepts considered were cost prohibitive and inherently untested/unreliable
	Beach Nourishment	Yes	Yes	Yes	Yes	No	Yes	No	YES	High likelihood of being recommended plan
	Dune Core Stabilization	Possibly	Possibly	Yes	Possibly	No	No	No	YES	Could not be constructed as a standalone project but could be incorporated into and improve a beach nourishment measures
	Jetty Modifications	Possibly	Possibly	Yes	Not likely	Not Likely	No	Not Likely	YES	Altering the jetties is expected to be cost prohibitive and marginally effective, but should be considered for completeness and better understanding of the problem
	Groin Modifications	Possibly	Possibly	Yes	Possibly	No	No	No	YES	Would not provide standalone value but has the potential to improve sediment retention in conjunction with a beach nourishment measure
	Sand Bypass System	Yes	Yes	Probably	Not likely	No	Yes	No	YES	A sand bypass system could be effective but has significant implementation risks/drawbacks
	Abandon the Canal	Potentially	Potentially	Yes	No	Yes	Yes	Not Likely	NO	Theoretically, closing the Canal and removing the jetties would allow for more natural sediment migration to the downdrift shoreline, but the economic impacts of doing so would far outweigh the mitigation it would afford and it could actually worsen conditions temporarily
	Reefs	Not Likely	Not Likely	Not Likely	No	No	Possibly	No	NO	An artificial reef would not likely be constructible or effective in this environment
Non-Structural	Acquisition/Relocation	Yes	Yes	Yes	Not likely	Yes	No	No	NO	Acquisition/relocation of some properties would remove them from the hazard but it would not address the primary coastal hazard or its further reaching impacts to the community. It would also not likely be cost justified or locally acceptable
	Floodproofing	No	No	Yes	No	No	No	No	NO	Floodproofing would not address the coastal storm risk presented by continued erosion nor was it expected to be cost justified
	Structure Raising	No	No	Yes	No	No	No	No	NO	Structure raising is an effective strategy for mitigating against flood risk, but the primary concern at this site is wave attack and erosion which structure raising would not address

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5.3 Initial Array of Alternatives

5.3.1. Methodology

An initial array of alternatives was developed based on the measures carried forward from the initial screening process. The alternatives were modeled for their physical performance and effectiveness in addressing the problem and then a rough order of magnitude cost estimate was developed for each. This iteration allowed the study team to quantitatively evaluate and determine which alternatives had a high likelihood of resulting in an implementable project and which did not. The analysis resulted in a short list of alternatives that could be carried forward for a more detailed analysis. In essence, evaluating the initial array of alternatives was a means of taking individuals and turning them into conceptual projects. The initial array of alternatives included six primary alternatives, with several sub-alternatives specific to material source (sediment source significantly influenced total project costs). The list included three (3) beach nourishment alternatives, two (2) jetty modification alternatives and one (1) permanent sediment bypass alternative.

5.3.2. Alternative 1: Beach Nourishment-Only

Alternative 1 included the construction of a 388,000 cubic yard engineered dune and berm beach along approximately 5,000 feet of Town Neck Beach. Figure 5-1 depicts the footprint and features associated with Alternative 1. Although approximately 782,000 cubic yards of material were estimated to have been lost from the beach over the past 50 years, placing that volume of material was not expected to be feasible from a cost standpoint and it was expected to result in significant environmental impacts. The Town of Sandwich however, had recently obtained permits for construction of a 388,000 cubic yard dune and berm beach along Town Neck Beach aimed at addressing the same erosion problem. Their design maximized the amount of material that could be placed on the beach without causing significant negative environmental impacts. It was seemingly constructible and cost-effective; thus the town's recently permitted beach design was used as the foundation for of Alternative 1 and the other two beach-nourishment alternatives considered in this study. Several permutations of this design were considered as sub-alternatives that attempted to account for the variability in potential sand sources and their respective influences as project cost drivers. Potential sources of material included mining surplus sand from the nearshore area at Scusset Beach, using material that shoals in the navigational channel and is dredged on a recurring basis, and lastly, trucking in material from an upland source.

Figure 5-1: Alternative 1 overview

Alternative 1 had estimated initial construction costs ranging from $14.3 million to $40.1 million (depending on sediment sources). Beach nourishment is sacrificial, however. It widens the buffer between the ocean and dry land, but it does not stop erosion as a coastal process. Any engineered beach built for the purpose of erosion control will exist and function as intended for a limited period of time before needing to be renourished, thus the long-term renourishment costs needed to be considered in addition to initial construction costs. For all three beach nourishment alternatives, renourishment costs for were estimated based on the assumption that when 70% of the beach fill material erodes then the beach profile would be rebuilt to its original design. Alternative 1 was projected to reach that threshold after nine years, resulting in approximately six renourishment cycles. Alternative 1 therefore had a total project cost ranging from $196 million to $508 million (depending on sediment source) over a 50-year period of performance. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

5.3.3. Alternative 2: Beach Nourishment with Dune Core Stabilization

Alternative 2 included an engineered dune and berm beach like Alternative 1 (including sub-alternatives for sand source), but Alternative 2 also included the use of stabilization features built into the core of the dune itself. Figure 5-2 depicts the footprint and features associated with Alternative 2. Geotextile matting would be used to fold and stack some of the beach fill material to create envelopes of material built within the dune. These semi-solid features would be more tolerant of wave energy than would unconsolidated sand, which would thereby create a more resilient dune system. Examples of this type of feature have been built elsewhere in New England, and even along this specific shoreline (as installed by individual property owners). Figure 5-3 is an image of these features currently in place and partially exposed along Town Neck Beach. Because these dune stabilization features would be built into the core of the dune, they wouldn't begin to perform until the beach has already eroded significantly, thus they would only minimally improve the lifespan of the engineered beach relative to long term erosion. Instead, during moderate to severe coastal storm events, the sand envelopes would serve as a last line of defense. They would absorb and deflect wave energy during these events, thereby limiting total sand loss behind them and reducing the likelihood of a catastrophic failure of the dune. This effect was clearly and unfortunately demonstrated in March of 2018 when the property at 103 Wood Ave was undermined during Winter Storm Riley, but the neighboring property was far less significantly impacted (Figure 5-4). Therefore, the primary benefit of the core stabilization measures would be the added level of protection against acute, coastal storm related erosion.

Figure 5-2: Alternative 2 overview

Figure 5-3: Sand envelopes currently installed along Town Neck Beach

Figure 5-4: Sand envelopes (shown in Figure 5-3) following Winter Storm Riley in 2018

Alternative 2 had estimated initial construction costs ranging from $23.3 million to $49.0 million (depending on sediment source). Similar to Alternative 1, long term renourishment of the beach would need to be considered in the cost analysis for this alternative. Additionally, because the fiber matting is biodegradable, the sand envelopes themselves would have a limited shelf life and would need to be replaced approximately every 5-7 years to maintain effectiveness. Assuming the beach would need to be nourished when 70% of the original material is lost, the beach was projected to need renourishment every 11 years, which would result in five renourishments over a 50-year period. Additionally, replacing the stabilization measures themselves every 5-7 years would result in eight (8) replacements over that same 50-year period. Based on these assumptions, Alternative 2 had a total project cost ranging from $562 million to $828 million (depending on sediment source) over a 50-year period of performance. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

5.3.4. Alternative 3: Beach Nourishment with Groin Modifications

Alternative 3 included the construction of an engineered beach like Alternative 1 (including sub-alternatives for sand sources), but Alternative 3 also included the reconstruction/improvement of an existing groin field located along Town Neck Beach. Figure 5-5 depicts the footprint and features associated with Alternative 3. Four (4) dilapidated shore-perpendicular stone groins exist along Town Neck Beach that are currently underperforming due to their state of disrepair. Under Alternative 3, those dilapidated groins would be reconstructed and enhanced in order to create four (4) 250 linear foot, notched groins in their place. The rebuilt groins would help retain the newly placed beach material as would typically be the case with shore-perpendicular structures, and each groin would also be designed to include a 50 linear foot notch that would allow for some material to pass through them and continue migrating eastward towards Springhill Beach. Such a design feature would prevent a complete interruption of the longshore sediment transport through the littoral system (similar to that currently associated with the Canal jetties).

Figure 5-5: Alternative 3 overview

Alternative 3 had estimated initial construction costs ranging from $18.8 million and $44.5 million (depending on sediment source). Like Alternatives 1 and 2, long term renourishment of the beach would also be needed in order for the project to continue performing over a 50-year period. Modeling demonstrated that reconstructing/enhancing the existing groin field along Town Neck Beach would significantly increase the life expectancy of the engineered beach profile relative to Alternative 1. If the beach would need to be renourished after 70% of the original material is lost, Alternative 3 would require renourishment every 13.5 years as opposed to every 9 years, resulting in a 50% increase in performance life. This would result in four (4) renourishments over a 50-year period. Based on these assumptions, Alternative 3 had a total project cost ranging from $148 million to $378 million (depending on sediment source) over a 50-year period of performance. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

5.3.5. Alternative 4: Shorten the North Jetty

Alternative 4 considered shortening of the northern jetty at the east entrance of the Canal by 550 linear feet. In addition to the jetties generally interrupting natural alongshore sediment transport inherent to their shore-perpendicular nature, with a length of approximately 2,500 feet, the northern of the two jetties is also demonstrably longer than its southern counterpart, which is only about 700 feet long. Shortening the northern jetty would conceptually increase the potential for material to migrate around the Canal and reach the downdrift shoreline, thereby feeding the littoral system and stabilizing the beach. Alternative 4 did not include a beach nourishment component. Figure 5-6 depicts the features and concept of Alternative 4. The red arrow depicts how sediment currently accretes immediately updrift of the northern jetty while the green arrow depicts how that material would conceptually migrate if 550 linear feet of the jetty were removed.

Figure 5-6: Alternative 4 overview

Modeling did not however support the potential efficacy of this concept. When considering sediment availability and site-specific coastal processes, it was estimated that shortening the northern jetty by 550 linear feet would only result in a maximum potential increase of 160 cubic yards of material bypassing the northern jetty per year. This is highly inconsequently relative to the rate of sediment loss downdrift of the Canal. Further, modeling suggested that the limited volume of material that would bypass the jetty would more likely shoal in the channel or be lost beyond the littoral zone than it would be to actually reach the downdrift shoreline. With an estimated total project cost of $16.4 million, Alternative 4 was considered both ineffective and in exceedance of the federal expenditure limit of the study authority. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

5.3.6. Alternative 5: Lengthen the South Jetty

Alternative 5 was developed with a similar concept in mind as Alternative 4. The southern jetty is much shorter than its northern counterpart, which allows a local sediment transport reversal to pull material from the downdrift shoreline back into the Canal where it shoals. Alternative 5 considered increasing the overall length of the southern jetty by 900 feet in order to prevent material from migrating back into the Canal, thereby inreasing sediment retention along the downdrift shoreline. Alternative 5 did not consider any beach nourishment. Figure 5-7 depicts the features and concept of Alternative 5. The red arrow depicts how sediment currently migrates back into the Canal while the green arrow depicts how that material would conceptually settle and accrete along Town Neck Beach if the jetty were extended by 900 linear feet.

Figure 5-7: Alternative 5 overview

Modeling did not support the conceptual efficacy of this alternative, however. Based on the the sediment transport analysis, extending the southern jetty was only projected to increase net sediment retention along the downdrift shoreline by 80 total cubic yards per year. With an initial construction cost of $43.1 million, Alternative 5 was considered both ineffective and in exceedence of the federal expenditure limit of the study authority. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

5.3.7. Alternative 6: Permanent Sand Bypass System

The material accumulating updrift of the Canal makes for an ideal source of material, as it is material that would otherwise migrate naturally to the downdrift shoreline but for the interruption created by the jetties. A permanent sand bypass system would use a pump station located in the nearshore subtidal area at Scusset Beach to pump sediment through a pipeline under the Canal and onto the shoreline at Town Neck Beach. It would not include the grading of an engineered beach profile as Alternatives 1, 2 and 3 would. Rather, it would supply a smaller volume of material to the downdrift shoreline on a continual basis. This would effectively mimic natural sediment transport processes thereby helping to maintain a more robust littoral system and a more stable beach profile along the downdrift shoreline over time. Figure 5-8 depicts the features and concept of Alternative 6.

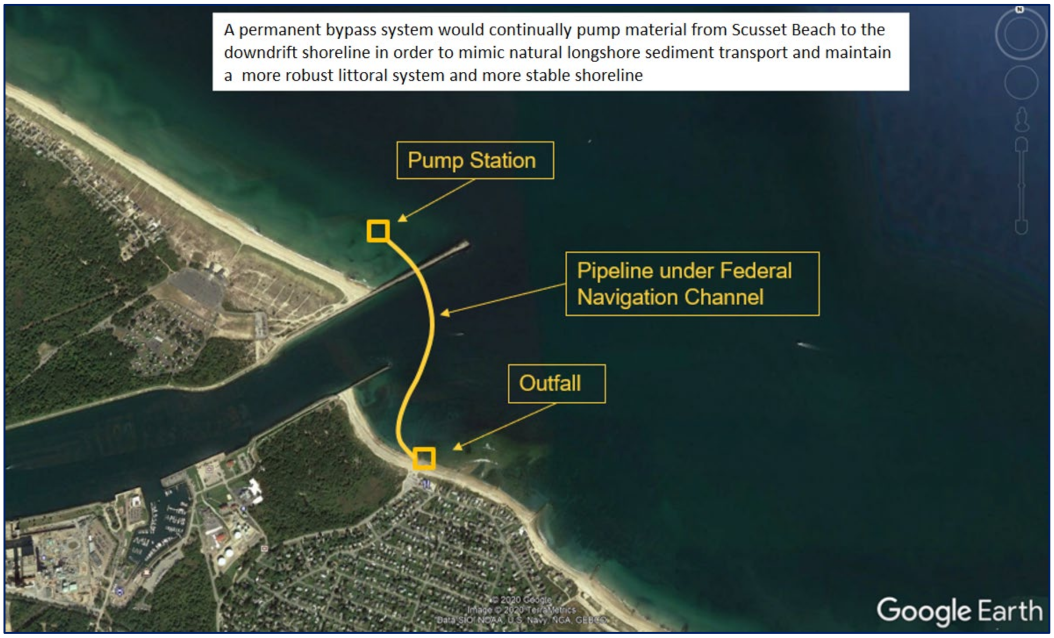

Figure 5-8: Alternative 6 overview

Permanent bypass systems have been shown to work at other locations, such as at the Indian River Inlet in Bethany Beach, Delaware (Figure 5-9), but they are not often implemented due to constructability and maintenance challenges, long term costs and environmental impacts. At Scusset/Town Neck Beach, all three of these concerns are present and reduce the likelihood that a permanent bypass system would be a viable alternative at this location. Construction of a permanent bypass system at the east end of the Canal would be particularly challenging due to the lack of a nearby overpass and a deep, heavily trafficked navigational channel. If there was a nearby overpass, then ideally a pipeline would be affixed to it allow material to be pumped over the channel, but that is not the case at Scusset Beach/Town Neck Beach. The abovementioned project at Indian River takes advantage of a bridge located 500 feet away from the beach, thereby requiring a total of 1,500 feet of pipeline. By comparison, the nearest overpass to Scusset Beach/Town Neck Beach is approximately 2.5 miles away, requiring a total of approximately 5.5 miles of pipeline. Since that is not a viable means of constructing a permanent bypass, the pipeline would instead need to be directionally drilled under the channel itself. That is inherently risky from a constructability and initial cost standpoint. From a long-term cost standpoint, a permanent bypass system would require significant operation and maintenance costs over the life of the project. Based on details recently developed by the USACE's Philadelphia District for a comparable project at Cape May in New Jersey, the pumps would need to be replaced approximately once every 12 years and the entire system would need to be replaced after 25 years in order for the project to continue functioning as intended. Those costs don't even include the annual operations costs that were estimated to be $600,000 per year for Cape May. Lastly, with respect to environmental impacts, if a permanent bypass were installed along Town Neck Beach, it would be designed to distribute material to the downdrift littoral system in an unconsolidated fashion. The material would be pumped onto the beach and into the intertidal zone, relying on natural processes to then redistribute the material along the shoreline over time. This would likely have significant negative environmental impacts on the intertidal zone as compared to an engineered beach nourishment project.

The efficacy of a sediment bypass project was also a concern in addition to the implementation challenges. Sand bypass plants replicate natural sediment migration through the littoral system but they rely on natural coastal processes slowly building up the beach profile over time. In the case of Town Neck Beach, the threat of erosion and loss of additional properties is quite imminent. Unfortunately, the latency associated with a sand bypass system reducing that threat makes such a project less viable as a standalone project. Therefore, in order for a sand bypass plant to legitimately mitigate the damages to the downdrift shoreline, it would likely need to be installed in conjunction with construction of an engineered beach.

Figure 5-9: Permanent Sediment Bypass System at Indian River in Bethany Beach, Delaware

Although there were significant concerns associated with the viability of a sediment bypass plan, a cost estimate was developed to vet the alternative more thoroughly; especially considering that such a project would intuitively address the problem. A cost estimate was prepared for a sand bypass system both as a standalone project and in conjunction with a 224,000 cubic yard engineered beach. The standalone alternative had an estimated initial construction cost of $9.9 million, with a total project cost of $137.4 million. The sand bypass with engineered beach alternative had an estimated initial construction cost of $17.8 million, with a total project cost of $145.3 million. Table 5-2 outlines the modeled performance and estimated costs associated with Alternatives 1 through 6.

Table 5-2: Cost Comparison of Initial Array of Alternatives

Cape Cod Canal 111 Alternatives Analysis (Initial Array of Alternatives)										
Alternative		Sand Volume	Initial Construction Cost	Renourishment Rate	Renourishment Cycles	Renourishment Costs	Repair Frequency	Repair Cycles	Repair/O&M Costs	Total Project Cost
1A	Beach Nourishment (Scusset)	388,000	$ 14,337,000	9 years	6	$ 182,614,000	N/A	N/A	N/A	$ 196,951,000
1B	Beach Nourishment (Scusset, Upland)	388,000	$ 26,701,000	9 years	6	$ 240,618,000	N/A	N/A	N/A	$ 267,319,000
1C	Beach Nourishment (Scusset, O&M, Upland)	388,000	$ 18,977,000	9 years	6	$ 176,429,000	N/A	N/A	N/A	$ 195,406,000
1D	Beach Nourishment (Upland)	388,000	$ 40,064,000	9 years	6	$ 468,857,000	N/A	N/A	N/A	$ 508,921,000
2A	Beach Nourishment w/ Core Envelopes (Scusset)	388,000	$ 23,304,000	11 years	5	$ 231,466,000	5.5 years	8	$ 306,891,000	$ 561,661,000
2B	Beach Nourishment w/ Core Envelopes (Scusset, Upland)	388,000	$ 35,668,000	11 years	5	$ 278,364,000	5.5 years	8	$ 306,891,000	$ 620,923,000
2C	Beach Nourishment w/ Core Envelopes (Scusset, O&M, Upland)	388,000	$ 27,944,000	11 years	5	$ 226,071,000	5.5 years	8	$ 306,891,000	$ 560,906,000
2D	Beach Nourishment w/ Core Envelopes (Upland)	388,000	$ 49,032,000	11 years	5	$ 472,079,000	5.5 Years	8	$ 306,891,000	$ 828,002,000
3A	Beach Nourishment w/ Groin Modifications (Scusset)	388,000	$ 18,803,000	13.5 years	4	$ 128,988,000	N/A	N/A	N/A	$ 147,791,000
3B	Beach Nourishment w/ Groin Modifications (Scusset, Upland)	388,000	$ 31,166,000	13.5 years	4	$ 163,035,000	N/A	N/A	N/A	$ 194,201,000
3C	Beach Nourishment w/ Groin Modifications (Scusset, O&M, Upland)	388,000	$ 23,443,000	13.5 years	4	$ 125,939,000	N/A	N/A	N/A	$ 149,382,000
3D	Beach Nourishment w/ Groin Modifications (Upland)	388,000	$ 44,529,000	13.5 years	4	$ 333,824,000	N/A	N/A	N/A	$ 378,353,000
4	Reduce Length of North Jetty	0	$ 16,388,000	N/A	N/A	N/A	N/A	N/A	N/A	$ 16,388,000
5	Increase Length of South Jetty	0	$ 43,182,000	N/A	N/A	N/A	N/A	N/A	N/A	$ 43,182,000
6A	Permanent Bypass System	0	$ 9,870,000	continual	N/A	N/A	varies	varies	$ 127,515,000	$ 137,385,000
6B	Permanent Bypass System (with beach nourishement)	388,000	$ 24,207,000	continual	N/A	N/A	varies	varies	$ 127,515,000	$ 151,722,000

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5.3.8. Key Findings from Initial Array of Alternatives

Evaluation of the initial array of alternatives considered the performance and rough order of magnitude costs of six distinct alternatives. Table 5-8 presents the complete list of alternatives evaluated during this iteration, with the alternative highlighted in green representing that which was carried forward to the Focused Array of Alternatives, and those highlighted in red representing those which were not carried forward. A full-sized view of all of the tables presented in this section can be found in Appendix E. Below are the key findings from this iteration of the alternatives analysis.

- All three beach nourishment alternatives (Alternatives 1, 2 and 3) were projected to directly and significantly improve upon the future without-project conditions but all three had initial construction costs and total project costs that exceeded the $12.5 million federal expenditure limit of the Section 111 authority.

- Cost estimates prepared for the Initial Array of Alternatives are cursory in nature. Although the initial construction costs of the three beach nourishment alternatives exceeded the federal expenditure limit of the study authority, the initial construction cost of Alternative 1A was very close to $12.5 million. Consequently, it was presumed that a more refined cost estimate might identify a permutation of the original concept that could at least be constructed under Section 111 authority, even if it could not be renourished.

- Neither of the two jetty modification alternatives demonstrated an ability to significantly improve upon the future without-project conditions. Shortening the northern jetty and lengthening the southern jetty were projected to increase sediment transport/retention by 160 cubic yards and 80 yards respectively. This was insignificant relative to a projected loss of 900,000 cubic yards of material along the downdrift shoreline over the next 50 years and both of these alternatives were considered to be ineffective in addressing the problem. Additionally, the total project costs for both alternatives exceeded the $12.5 million federal expenditure limit of the study authority.

- A permanent bypass system has a high likelihood of improving conditions along the downdrift shoreline by feeding the sediment starved littoral system. Total project costs exceeded the $12.5 million federal expenditure limit of the study authority though. Constructability challenges, environmental impacts and short-term efficacy further reduce the viability of this alternative in addition to the total project costs. For these reasons, a permanent bypass plant was not considered to be a feasible alternative.

- Although a permanent bypass plant was not considered feasible under this study, conceptually, it would be the most effective means of recreating natural coastal processes and conditions to the downdrift shoreline. Therefore, this study does not explicitly suggest that such a project could not be considered in the future as a supplemental means of feeding the sediment starved littoral system downdrift of the Canal.

Analysis of the Initial Array of Alternatives did not identify any alternatives that could address the erosion problem and be constructed within the fiscal constraints of the study authority. Beach nourishment, as described in Alternative 1A did however demonstrate the potential to be constructed for under $12.5 million dollars and would provide substantial mitigation of the negative impacts attributed to the Canal FNP, independent of any long-term renourishment needs. Although the goal of this study was to identify a readily implementable project that would provide a long-term solution to erosion along the Sandwich shoreline, both the USACE and the town of Sandwich agreed that implementing a project with a shorter life-span would be better than implementing no project at all. The team therefore decided at this juncture to focus on maximizing the initial construction effort by identifying a beach nourishment alternative that would include one-time placement of material along Town Neck Beach but that would not include long-term renourishment. Consequently, Alternative 1A was carried forward for additional development and consideration in the Focused Array of Alternatives.

5.4 Focused Array of Alternatives

5.4.1. Methodology

During the third iteration if the alternatives analysis, Alternative 1A was developed into a more detailed Focused Array of Alternatives and evaluated accordingly. Several additional permutations of these alternatives were developed that considered specific dredge types, sediment sources and sediment quantities. Those refinements are described below, and a complete list of the Focused Array of Alternatives can be found in Table 5-3. Refined cost estimates were then prepared for each of the additional alternatives and compared against each other both for project lifespan and total project cost.

5.4.2. Dredging Method

Different dredging methods were evaluated to determine the most feasible means of supplying in-water source sand for the project. The Focused Array of Alternatives was developed to include multiple different dredging methods. Those methods included hydraulic dredging, hopper dredging and mechanical dredging. It should be noted that while all three dredging methods can be used to remove the material offshore of Scusset Beach, historically only hopper dredges have been used for maintenance dredging of the Canal. Hopper dredges have a far less impact on navigability of the Canal during dredging operations. Thus, this analysis assumed that all dredging done in the Canal would be conducted via hopper dredge.

5.4.3. Sediment Sources

Sources of material included the nearshore area at Scusset Beach and the Canal itself. Because sediment accretes immediately updrift of the Canal by virtue of the northern jetty, there is a surplus of beach compatible sediment in the nearshore area that could readily be dredged and placed on Town Neck Beach. Similarly, because a significant volume of material migrating from the updrift shoreline shoals in the navigational channel, that material is routinely dredged for operation and maintenance of the Cape Cod Canal FNP and could also be placed on Town Neck Beach. That material could either be beneficially reused as part of the disposal plan for the routine maintenance dredging, or it could be dredged specifically for the purpose of being placed on Town Neck Beach as a standalone effort. It is important to note that there is a significant difference in the cost of using material from the Canal if it is beneficially reused as part of the disposal plan for maintenance dredging versus if it if a separate dredging project was initiated for the sole purpose of being placed on Town Neck Beach. If the material were incorporated into a maintenance dredging project that would be separately funded, then the cost of using the material on Town Neck Beach would be limited to only the additional cost of using it on the beach instead of disposing of it offshore. By contrast, if the material were dredged specifically for the purpose of being used at Town Neck Beach, then all mobilization, dredging and disposal costs would be included in the project costs. Development of the Focused Array of Alternatives considered both approaches as separate sources.

5.4.4. Sediment Quantities

Alternative 1A assumed a full beach nourishment template of 388,000 cubic yards of material. This assumption carried two primary risks: project costs and sediment availability. The initial cost estimate was developed at a rough order of magnitude and simply refining the cost estimate could result in the original concept being feasible. Beyond simple refinements to the cost estimate, the Focused Array of Alternatives considered that using less material, provided it still mitigated erosion of the downdrift shoreline, could also result in significant reductions to the project costs. With respect to the sediment availability, two additional concerns were taken into consideration during this iteration. First, it was assumed that 388,000 cubic yards of material are not currently available for dredging purposes from the Canal, nor would they likely become available in the future. On average, approximately 90,000 cubic yards of material are removed from the east end of the Canal every seven years for maintenance purposes. In 2016, approximately 120,000 cubic yards were removed from the Canal and placed on Town Neck Beach. Consequently, this iteration assumed that 100,000 cubic yards could reasonably be expected to be available from the Canal if needed. Secondly, the Town of Sandwich recently obtained permits to dredge approximately 224,000 cubic yards of material from the nearshore area at Scusset Beach. Obtaining those permits drew a lot of concern from environmental resource agencies with respect to environmental impacts, thus this analysis assumed the possibility that dredging 388,000 cubic yards from Scusset Beach is not permittable.

Table 5-3: Focused Array of Alternatives descriptions

Cape Cod Canal 111 Alternatives Analysis (Focused Array of Alternatives)		
Alternative		Alternative Description
1A	Beach Nourishment (Scusset)	Placement of approximately **388,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the Scusset Beach nearshore via **hydraulic** dredge
1E	Beach Nourishment (Scusset)	Placement of approximately **388,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the Scusset Beach nearshore via **mechanical** dredge
1F	Beach Nourishment (Scusset)	Placement of approximately **388,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the Scusset Beach nearshore via **hopper** dredge
1G	Beach Nourishment (Scusset)	Placement of approximately **224,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the previously permitted Scusset Beach borrow area via **hydraulic** dredge
1H	Beach Nourishment (Scusset)	Placement of approximately **224,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the previously permitted Scusset Beach borrow area via **mechanical** dredge
1I	Beach Nourishment (Scusset)	Placement of approximately **224,000** cubic yards of material on Town Neck Beach. Material would be obtained entirely from the previously permitted Scusset Beach borrow area via **hopper** dredge
1J	Beach Nourishment (Scusset/Canal)	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,000** cubic yards would be obtained from the permitted borrow area at Scusset Beach via **hydraulic** dredge and approximately **100,000** cubic yards would be obtained from the Cape Cod Canal via **hopper** dredge
1K	Beach Nourishment (Scusset/Canal)	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,00**0 cubic yards would be obtained from the permitted borrow area at Scusset Beach via **mechanical** dredge and approximately **100,000** cubic yards would be obtained from the Cape Cod Canal via **hopper** dredge
1L	Beach Nourishment (Scusset/Canal)	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,000** cubic yards would be obtained from the permitted borrow area at Scusset Beach via **hopper** dredge and approximately **100,000** cubic yards would be obtained from the Cape Cod Canal via **hopper** dredge
1M	Beach Nourishment (Scusset/Canal (O&M delta))	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,000** cubic yards would be obtained from the permitted borrow area at Scusset Beach via **hopper** dredge and approximately **100,000** cubic yards would be obtained from the next O&M dredging of the Cape Cod Canal via **hopper** dredge
1N	Beach Nourishment (Scusset/Canal (O&M delta))	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,000** cubic yards would be obtained from the permitted borrow area at Scusset Beach via **hopper** dredge and approximately **100,000** cubic yards would be obtained from the next O&M dredging of the Cape Cod Canal via **hopper** dredge
1O	Beach Nourishment (Scusset/Canal (O&M delta))	Placement of approximately **324,000** cubic yards of material on Town Neck Beach. Approximately **224,000** cubic yards would be obtained from the permitted borrow area at Scusset Beach via **hopper** dredge and approximately **100,000** cubic yards would be obtained from the next O&M dredging of the Cape Cod Canal via **hopper** dredge

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5.4.5. Performance/Cost Comparison

Cost estimates were prepared for each alternative and are outlined in Table 5-4. Alternatives highlighted in green were considered feasible while alternatives in red were considered not feasible. Alternatives 1G, 1H and 1I were the least cost alternatives, but these alternatives had a projected lifespan of 1 year before requiring renourishment. Therefore, they were determined not to be effective in addressing the problem and were not considered feasible alternatives. Alternatives 1J, 1K and 1L had projected lifespans of 6 years before requiring renourishment, which was considered to be effective, but their construction costs exceeded $12.5 million. Therefore, they too were considered not feasible. Alternatives 1M, 1N and 1O would also last 6 years before requiring additional renourishment, which was considered to be effective, and their construction cost were under $12.5 million. Therefore, for the purpose of this exercise they could be considered feasible. These three alternatives, however, require that the next Canal maintenance dredging effort occurs at the same time as the implementation of a mitigation project resulting from this study. Although the timing of the two projects could ultimately align properly, there is a considerably high likelihood that they would not. Therefore, these three alternatives were considered technically feasible, but they were not recommended for implementation due to the high level of risk and uncertainty associated with linking the project to future maintenance dredging of the Canal. Lastly, Alternatives 1A, 1E and 1F all had a projected lifespan of 9 years before requiring renourishment, thus they were all determined to be effective in mitigating the problem. Alternative 1F, had construction costs that exceeded $12.5 million, and it was considered not feasible. Alternatives 1A and 1E on the other hand, both had estimated costs $11.6 million. Consequently, they were both considered feasible.

Table 5-4: Performance/cost matrix for the Focused Array of Alternatives

Focused Array of Alternatives (performance/cost comparison)					
Alternative		Sand Volume	Dredge Type	Performance Period	Total Project Cost
1A	Beach Nourishment (Scusset)	388,000	Hydraulic	9 years	$ 11,656,000
1E	Beach Nourishment (Scusset)	388,000	Mechanical	9 years	$ 11,669,000
1F	Beach Nourishment (Scusset)	388,000	Hopper	9 years	$ 16,737,000
1G	Beach Nourishment (Scusset)	224,000	Hydraulic	1 year	$ 7,925,000
1H	Beach Nourishment (Scusset)	224,000	Mechanical	1 year	$ 8,136,000
1I	Beach Nourishment (Scusset)	224,000	Hopper	1 year	$ 11,201,000
1J	Beach Nourishment (Scusset/Canal)	324,000	Hydraulic/Hopper	6 years	$ 13,427,000
1K	Beach Nourishment (Scusset/Canal)	324,000	Mechanical/Hopper	6 years	$ 14,029,000
1L	Beach Nourishment (Scusset/Canal)	324,000	Hopper/Hopper	6 years	$ 14,577,000
1M	Beach Nourishment (Scusset/Canal (O&M delta))	324,000	Hydraulic/Hopper	6 years	$ 10,094,000
1N	Beach Nourishment (Scusset/Canal (O&M delta))	324,000	Mechanical/Hopper	6 years	$ 10,435,000
1O	Beach Nourishment (Scusset/Canal (O&M delta))	324,000	Hopper/Hopper	6 years	$ 10,625,000

5.5 Recommended Alternative

The Recommended Alternative was the alternative tentatively recommended for implementation, specifically because of this Alternatives Analysis. The recommended alternative was then carried forward for an in-depth assessment of its environmental impacts as well as for a detailed cost estimate, before being identified as the final Recommended Plan.

Alternatives 1A and 1E were both determined to be effective in addressing the erosion problem downdrift of the Canal for a projected period of nine years before needing substantial renourishment. Neither alternative would address the problem on a perpetual timeframe, but both alternatives had a construction cost of approximately $11.6 million dollars which rendered them implementable through Section 111 of the CAP program. Although the estimated costs for both alternatives was effectively the same, there was a nominal difference in cost that was used to identify a single alternative that could be carried forward and recommended for implementation. Alternative 1A had an estimated cost of $11,656,000, while Alternative 1E had an estimated cost of $11,669,000, making Alternative 1A $13,000 less costly. Consequently, Alternative 1A, one-time construction of a 388,000 cubic yard engineered dune and berm beach along Town Neck Beach, using material dredged from the nearshore area at Scusset Beach via hydraulic dredge, was identified as the Recommended Alternative, which is depicted in Figure 5-10

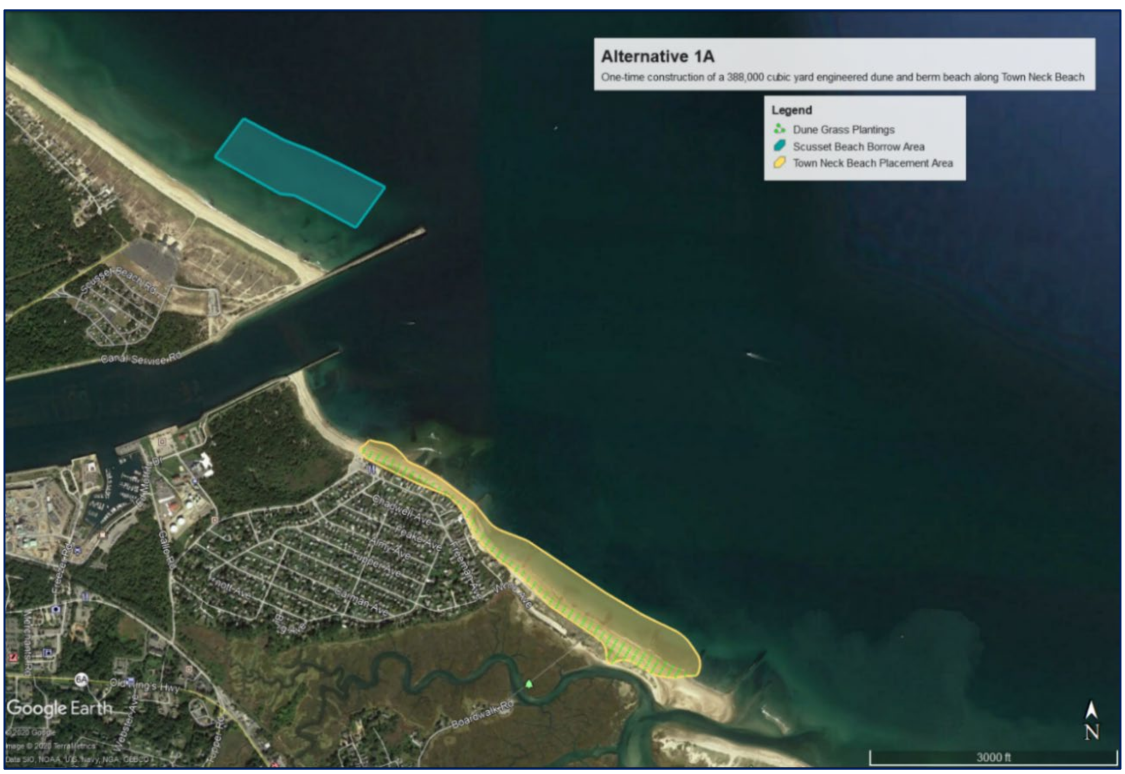

Figure 5-10: Overview of the Recommended Alternative; Alternative 1A

5.6 Alternatives Analysis Summary

Erosion problems attributable to the Canal FNP are well understood and the solutions for addressing them are fairly intuitive in concept. Those potential solutions are very expensive however, particularly with respect to the fiscal constraints of the Section 111 authority. Consequently, the study team considered a fairly exhaustive list of potential solutions in order to identify a single and complete project that could be implemented through this authority. The alternatives analysis ultimately identified the one-time construction of a 388,000 cubic yard engineered dune and berm beach along Town Neck Beach, using material dredged from the nearshore area at Scusset Beach via hydraulic dredge as the recommended alternative. The Alternatives Analysis section of this report details the process by which such an alternative was identified and it also attempted to thoroughly and transparently explain the rationale behind recommending a project that would address the problem in the short-term but would not provide the true long-term solution that the Town and local community was hoping would result from this study.

6. Environmental Impacts

This section evaluates the environmental effects of the proposed project and the no action alternative only. The other alternatives were not evaluated for their environmental impacts because they did not present solutions that were cost effective, with many exceeding the spending limitation of the Section 111 authority, or environmentally practicable. The proposed action was determined to be the most cost effective, least environmentally damaging option to address the erosion caused by the Cape Cod Canal FNP jetties. The environmental impacts of future nourishment of Town Neck Beach within the project footprint would be the same as those outlined below. The periodic placement of sand on the beach would have no more adverse effects than that of each individual placement.

6.1 Topography and Geology

No Action Alternative

Under the no action alternative, topography will change due to soil erosion as well as through climate change-driven sea level rise and coastal storms. In 2020, the town of Sandwich Natural Resources Department published an interactive web viewer that shows the expected inundation level in Sandwich for the years 2030 and 2070 if no action is taken to mitigate those pressures. The WHG-developed web viewer shows how far the ocean could encroach into historic Sandwich Village. By 2030, currently dry portions of Route 6A and some areas within the downtown Sandwich area will be underwater during the 1% annual chance flood event according to the web viewer (Town of Sandwich, 2020). The effects of coastal storms and sea level rise may be mitigated to some extent by actions taken by the town of Sandwich to nourish and stabilize Town Neck Beach. The underlying geology of the project area is not expected to change within the lifespan of the project under the no action alternative.

Proposed Action

With the proposed action, sand and dune nourishment will increase the width and height of Town Neck Beach. The material will be placed along approximately 5,000 linear feet of shoreline, beginning 1,000 feet southeast of the Cape Cod Canal in the west, and extending to within 600 feet of the Old Harbor Inlet in the east. The placement site on Town Neck Beach is approximately 41.1 acres consisting of private and public parcels. Within the placement site, approximately 15.5 acres of supratidal (above MHW) land, approximately 12.7 acres of intertidal (between MHW and MLW) land, and approximately 12.9 acres of subtidal (below MLW) land will be impacted by the sand nourishment.

The crest of the newly created dune will be at an elevation of approximately 15 to 21 feet NAVD88, with a width ranging from 50 to 150 feet (depending upon location). For the eastern barrier beach portion of the project, the beach berm will be increased in width by at least 100 feet at an elevation of 6 feet (NAVD88), and then extend seaward at a slope of 1V:20H to approximately –4 feet to –10 feet NAVD (depending upon existing grade). Dunes will have a slope of 1V:10H to 1V:15H and will be graded to match existing slopes. At the western end of the project area, the design is constrained by the presence of rocky intertidal habitat and complex hard bottom resources. Dunes at this end of the project will have a slope of 1V:5H, and the beach will slope seaward from the toe of dune at a slope of 1V:10H. This action serves to decrease the chance of storm damages to properties along and behind Town Neck Beach for the duration of the project's design life. To maintain the level of protection provided by the project, sand would need to be replaced to restore the design profile every nine years. Between nourishment cycles, the sand will erode causing the elevation of the dunes and beach berm of Town Neck Beach to decrease. As it erodes, the placed sand will be transported to the east replicating the natural sand transport process in the area. This will likely cause the elevation of beaches downdrift such as Springhill Beach to increase.

At the proposed borrow site, the approximately 39-acre subtidal area will get deeper. The average excavation depth across the site is approximately 5.7 feet with side slopes grading up to a 1V:3H slope to meet the surrounding grade. The majority of the site will be dredged to an excavation depth of approximately -26 feet NAVD88. According to WHG studies of sediment transport, the infilling rate for the Scusset borrow area will be about 105 cy/day (WHG, 2017). Therefore, the borrow area is expected to fill in over a period of approximately 10 years. No adverse effects to the topography of upland or adjacent nearshore areas are anticipated because of the extraction. This is because the source of sediments, the glacial cliffs in Plymouth (Fitzgerald, 1993), will remain unchanged. Furthermore, a shoreline change analysis of Scusset Beach adjacent to the borrow site indicated long-term accretion rates between 3 feet per year and 9 feet per year which will not change with the extraction of sand (WHG, 2017). The underlying geology of the project areas will not change with the implementation of the Recommended Plan.

6.2 Sediments

No Action Alternative

Erosion of Town Neck Beach and updrift accretion on Scusset Beach will continue to occur under the no action alternative allowing a continuation of shoreline loss and threatening homes along Town Neck Beach, Springhill Beach, Great Marsh and Route 6A/Downtown areas. The erosion attributed to the Canal FNP jetties has resulted in property damages which will continue if no action is taken. As erosion continues, the beach will eventually convert to rocky substrate from its existing condition as a sandy beach. This is evidenced by the uncovering of rocky habitat in the intertidal zone of Town Neck Beach which has occurred since the jetties' construction.

Proposed Action

The purpose of the Recommended Plan is to reduce the erosion caused by construction of the Canal FNP jetties. This will be accomplished by nourishing Town Neck Beach with sandy sediments that have accreted updrift of the northern jetty. These sediments would have naturally transported onto Town Neck Beach if the jetties were not present. Beach nourishment on Town Neck Beach will be accomplished by placing approximately 388,000 cy of sand dredged from the Scusset Beach borrow site. This will move both the high and low tide lines on Town Neck Beach seaward, providing a wider berm and dune system.

As a result of erosion, the sediments on Town Neck Beach are coarser grained than the sand in the borrow site. Appendix A5 details the results from grain size samples taken from the proposed borrow site and placement area. Complex and rocky bottom habitat is in the intertidal and subtidal zone off the western end of the nourishment footprint on Town Neck Beach. Additionally, a smaller patch of complex rocky bottom habitat is in the intertidal zone at the far eastern end of the nourishment site. The project will avoid covering ecologically significant essential fish habitat at the western end of the site created by rocky intertidal and complex bottom habitat, and eelgrass resources. At the eastern end of the site, approximately 2.23 acres of rocky intertidal habitat and approximately 1.75 acres of complex bottom habitat will be covered by the sand placement. According to WHG surveys from 2018, the ecological value of resources in this area is low, and the beach width has narrowed to the extent that the nourishment footprint cannot be adjusted without negatively affecting project performance. Prior to construction, the most recent surveys of complex rocky habitat will be used in the design of the final nourishment template. These surveys will be used to avoid as much complex bottom habitat as possible will still accomplishing the project purpose.

Placed sediment will eventually erode off Town Neck Beach without additional sand input. It is anticipated that the placement of 388,000 cy of sand will take approximately nine years to reach a point at which the beach fill is reduced to 70% of the original design. At this point, an additional 279,000 cubic yards of material will need to be placed on the beach for the project to continue performing as intended. Sand for future nourishment work may be dredged from the Scusset borrow site, the Canal FNP, brought in by truck from upland sources, or come from a currently unidentified source. Necessary permit applications and environmental coordination will occur at the time of nourishment proposal(s) in the coming years. It is anticipated that placements will use sediments like that described in this section, therefore, the effects of future placements are expected to be the same.

Sediments in the borrow area are anticipated to infill within about 10 years following dredging. Sediment transport potential will not significantly change at the Scusset Beach borrow site with the extraction. The majority of the sediment being carried through nearshore sediment transport processes is sand, thus, it is unlikely that the dredged borrow area will accumulate different material (i.e. fines) than it currently contains (WHG, 2017). The beach and dunes at Scusset Beach State Park should be unaffected by the extraction of sand from the nearshore site. The borrow site is expected to fill with material from the littoral zone that is transported southeast in accordance with the natural movement of sediment in the area. Therefore, the proposed action is not anticipated to cause significant adverse effects to sediments within the project area including upland areas.

6.3 Water Resources

No Action Alternative

The project area's water resources will remain the same under the no action alternative.

Proposed Action

No long-term impacts will occur to water resources because of the proposed action. The following two sections describe anticipated effects to water circulation and water quality.

6.3.1. Water Circulation and Waves

No Action Alternative

Town Neck Beach will continue to erode, and Scusset Beach will continue accreting under the no action alternative. This means that the MHW line will extend out to sea at Scusset Beach and retreat further inland on Town Neck Beach over time. On Town Neck Beach, this will cause storm surge to reach further inland and allow waves to more closely approach properties during storms. The reverse is true on Scusset Beach.

Proposed Action

The MHW line will move seaward with the placement of sand on Town Neck Beach. Regional water circulation and wave climatology will remain the same. On Scusset Beach, sand extraction will impact wave transformation with a relatively small increase in wave heights (<0.05 meters) during the majority of storm simulations (WHG, 2017). During the 50-year storm, maximum wave heights of 0.6 and 0.7 meters at various locations on the Scusset shoreline were recorded during model runs by WHG. Due to the borrow site's location off Scusset Beach, these increases in wave heights are not expected to impact neighboring properties to the west of the (WHG, 2017). The increased wave energy is also not anticipated to adversely affect the beach given the extensive dune system that fronts Scusset Beach. The impact to wave heights will dissipate over time as the borrow site naturally fills with sand.

6.3.2. Marine Water Quality

No Action Alternative

Marine water quality is not anticipated to change with no action.

Proposed Action

The proposed action will not cause long-term impacts to water quality. During the dredging and placement process, water column turbidity will increase within and adjacent to the borrow site and nourishment area. However, these increases are expected to be localized and short-term given that the material is sand which will settle out of the water column rapidly. Burlas et al. (2001), found that the turbidity plume and elevated total suspended solids (TSS) levels were expected to be limited to a narrow area of the swash zone up to 1,640 feet down current from the discharge pipe. Five years later, Wilber et al. (2006) reported that elevated TSS concentrations associated with an active beach nourishment site were limited to within 1,312 feet of the discharge pipe in the swash zone which is defined as the area of the nearshore that is intermittently covered and uncovered by waves. Based on this and the fact that the material to be dredged and placed is sand which should settle rapidly, TSS concentrations created by beach nourishment operations are expected to be between 34.0-64.0 mg/L; limited to an area approximately 1,640 feet down-current from the discharge pipe; and, settle within several hours after discharge cessation. The TSS levels expected for beach nourishment (up to 64.0 mg/L) are below those shown to have adverse effect on fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton, 1993; Wilber and Clarke, 2001) and benthic communities (390.0 mg/L (EPA, 1986)). Furthermore, dredged sand that is pumped onto Town Neck Beach will be dewatered prior to grading on the beach. This will allow suspended sediments to settle out above the MHW line limiting increased levels of water column turbidity in the nearshore waters of Town Neck Beach.

Based on the cost estimates prepared for this study, the recommended plan includes the use of a hydraulic dredge to excavate material from the Scusset Beach borrow site. However, as is described in Section 5 of this document, the specifications pertaining to dredge type are expected to be refined during the design and implementation phase of this project. Consequently, the work could ultimately include use of a mechanical dredge if that proves to be a more cost-effective option. TSS concentrations associated with mechanical clamshell bucket dredging operations have been shown to range from 105 mg/L in the middle of the water column to 445 mg/L near the bottom (210 mg/L, depth-averaged) (USACE, 2001). The TSS levels expected for both mechanical (up to 445.0 mg/L) and cutterhead dredging (up to 550.0 mg/L) are below those shown to have adverse effect on fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton, 1993; Wilber and Clarke, 2001). Assuming that a hydraulic dredge is used, then a cutterhead pipeline dredge would be used. TSS concentrations above background levels are expected to be present throughout the bottom six feet of the water column for approximately 1,000 feet from the cutterhead (USACE, 1983). TSS concentrations associated with cutterhead dredge sediment plumes typically range from 11.5 to 282.0 mg/L with the highest levels (550.0 mg/L) detected adjacent to the cutterhead dredge and concentrations decreasing with greater distance from the dredge (Nightingale and Simenstad, 2001; USACE, 2005; 2010; 2015).

Once placed, the sand will erode off Town Neck Beach at a rate consistent with the long-term rate which was measured at -1.1 feet per year in the project area (WHG, 2014). The borrow site is expected to infill at a rate of 102 cy/day which is not anticipated to cause adverse impacts to the water quality of the area. Therefore, no significant impacts to marine water quality are anticipated as a result of the proposed action.

6.4 Biological Resources

The direct and indirect effects of the no action and proposed action alternatives on biological resources are described in the following subsections. In general, ecological impacts from the proposed action will be positive, with the majority of negative impacts occurring during the short timeframe of construction.

6.4.1. Submerged Aquatic Vegetation and Macroalgae

No Action Alternative

Under the no action alternative, no impacts to existing communities of SAV or macroalgae will occur. In the future, as the sand on Town Neck Beach erodes and more rocks are revealed in the intertidal zone, macroalgae may have more rocky area to establish; however, the project area is subject to shifting sediments and vegetation establishment could be ephemeral. Additionally, as erosion reveals rocky habitat and removes sand from the system, eelgrass habitat may decline.

Proposed Action

A relatively small amount of macroalgae will be impacted by the sand placement. Any macroalgae that is covered by sand will be smothered. According to the 2019 eelgrass survey performed by WHG, 99.9% of the eelgrass mapped is outside of the nourishment footprint. Additional eelgrass surveys will continue to be performed in accordance with the special condition in the Town of Sandwich's MEPA certificate. The WHG (or another entity) will continue conducting eelgrass surveys in accordance with a special condition in the Town of Sandwich’s MEPA certificate. Prior to final project design, the USACE will conduct an additional SAV survey of the beach nourishment area, if deemed necessary. The nourishment footprint has been and will continue to be designed to avoid direct impacts to eelgrass resources. The placement of material outside of a 100-foot buffer around eelgrass beds will also attempt to be achieved, however, in some areas this buffer may not be possible. Due to the narrow width of the existing beach which has been subject to extensive erosion, and the numerous residential properties that are highly vulnerable to storm damage, the nourishment template may require a buffer width closer than 100 feet to eelgrass resources in certain areas.

The material to be dredged and placed on Town Neck Beach is 96% sand. Given that the material will be dewatered above the MHW line before being reworked, sedimentation and light attenuation impacts to eelgrass caused by the placement are expected to be minimal. Eelgrass is subject to shifting sands and wave action causing localized water column turbidity. Thus, the eelgrass growing along Town Neck Beach can withstand these temporary increases in turbidity and is not expected to be adversely impacted by the project. The contractor will not be permitted to place equipment, run pipelines, or anchor within areas of eelgrass. Furthermore, the nourishment template will be adjusted if eelgrass beds are discovered in the project footprint prior to construction. Therefore, no direct and only minimal indirect impacts to eelgrass beds are anticipated because of the project. Although some loss of macroalgae will occur with sand placement, areas containing established rocky intertidal shore habitat with attached macroalgae will primarily be avoided thereby maintaining the majority of macroalgae in the project area.

6.4.2. Upland Vegetation

No Action Alternative

Upland vegetation will not be affected by the no action alternative in the short-term. As the beach continues to erode over time, upland vegetation growing on the dunes will die-back and be lost as the MHW water line moves further shoreward.

Proposed Action

Existing upland vegetation on the dunes along the nourishment footprint on Town Neck Beach will be impacted by the proposed action. Sand placement for dune construction will smother some areas of existing vegetation. At the western end of the project area, construction vehicles will access the beach from the parking lot adjacent to The Drunken Seal restaurant but will use the unvegetated area on the western side of the parking lot. At the eastern end of the nourishment area, existing paths and unvegetated areas will be used as much as possible for access to the beach. However, some vegetation may be removed to expand the access route for heavy equipment.

The majority of plants growing on the dunes is American beachgrass and spotted knapweed, which is listed as an invasive plant in Massachusetts. Following construction, the created dunes will be planted with American beachgrass and any areas that were disturbed for construction access will also be replanted with beachgrass. Therefore, the project should have no long-term, negative impacts to vegetation.

6.4.3. Wetlands

No Action Alternative

Under the no action alternative, no short-term impacts to wetlands are expected. Without action, erosion of Town Neck Beach will eventually lead to a fully reduced beach berm which could cause the inlet at Old Harbor to shift and/or for more inlets into the marsh to open. This will potentially drown portions of the marsh and cause a migration of the lower and upper marsh zones into upland areas.

Proposed Action

The proposed action will have no adverse short or long-term impacts to wetlands behind the project area. The goal of the proposed action is to address erosion of Town Neck Beach which threatens the long-term viability of the marsh system located behind it. The addition of sand on the beach will stabilize the shoreline and provide an enhanced buffer for coastal storms, thereby reducing impacts to the marsh. Without future additional nourishment, the marsh will be under threat of the same impacts detailed in the No Action Alternative.

6.4.4. Benthos

No Action Alternative

Benthic communities will be unaffected over the short term with no action. As Town Neck Beach continues to erode over time, different assemblages of benthic biota will begin to colonize the area as it transforms from sandy bottom substrate to rocky substrate.

Proposed Action

Under the proposed action, benthic resources that inhabit the Scusset borrow site and the placement area will suffer mortality because of the dredging and placement process. Settling of suspended sediments may indirectly impact any benthic organisms in adjacent areas as well. These organisms are not expected to be significantly affected though because benthic organisms inhabiting intertidal and surf zone areas are well adapted to and tolerant of considerable changes in their environment (Naqvi and Pullen, 1982).

Recovery of the benthos in intertidal or nearshore environments may occur in as little as two to seven months (Nelson, 1993; USACE, 2001) depending on the season of disturbance (Reilly and Bellis, 1983; Versar, 2004). Slower recovery is expected from organisms that spend their entire life history (brood eggs and young) on the beach such as with some *Haustorius* species of amphipods (Reilly and Bellis, 1983). Wilbur and Clarke (2007) demonstrated that benthic communities in temperate regions occupying shallow waters with substrate of sand, silt, or clay show recovery times between one and eleven months after dredging. Overall, the benthic communities in the borrow site and placement area are anticipated to recover over time and no long-term adverse effects are expected.

6.4.5. Shellfish

No Action Alternative

Shellfish in the project area are not expected to be impacted in the short term under the no action alternative. Conversely, erosion of the beach and subsequent impacts to the marsh system may have deleterious effects to shellfish such as lobsters that use the peat reefs within the salt marsh.

Proposed Action

According to a survey conducted by WHG in 2014, no shellfish were found within the nourishment site, thus the proposed action should have no direct effects to shellfish resources on Town Neck Beach. Lobsters and other shellfish may use the eelgrass beds and rocky habitat outside of the nourishment footprint which will be subject to the movement of sediment as the placed sand erodes off the beach over time. These areas are adapted to the natural fluctuations of sand transport and are not expected to experience any significant adverse effects. WHG and the MADMF surveyed the Scusset borrow site for shellfish in 2016 and found no substantial communities (WHG, 2017). The MADMF determined that the borrow site will likely recover within one year following project activities. Therefore, no significant adverse impacts to shellfish resources are anticipated because of the proposed action.

6.4.6. Fisheries

No Action Alternative

The no action alternative is not expected to have any short-term impacts to fisheries in the project area. Over the long-term, climate change driven sea level rise and continued erosion of Town Neck Beach may inundate the marsh which provides nursery and foraging habitat for fish. Erosion and inundation will convert portions of the beach and salt marsh areas to open water habitat decreasing the current value that the marsh provides to fisheries.

Proposed Action

With the proposed action, temporarily increased water column turbidity because of dredging and placement operations may cause fish species to avoid the project area. Benthic food resources within the borrow site and placement area that suffer mortality as a result of construction will temporarily be unavailable as prey items for fish. Benthos will colonize the newly placed sand and recruitment from adjacent areas will ensure that the borrow site is recolonized over time leading to a short-term impact. Studies on the effects of turbid waters on fish suggest that concentrations of total suspended solids will reach thousands of milligrams per liter before an acute toxic reaction is expected. The TSS levels expected as a result of the proposed action are below those shown to have an adverse effect on fish, which generally range from 580 mg/L for sensitive fish to 1,000 mg/L for non-sensitive fish (Burton, 1993). As the highest levels of TSS from this project will not reach these levels, significant adverse effects to fish species will not occur.

No deleterious impacts to intertidal or nearshore fish assemblages were identified in beach renourishment monitoring studies in New Jersey (USACE, 2001) or North Carolina (Versar, 2004) for sandy areas. Overall beach renourishment resulted in short-term declines in abundance, biomass and taxa richness. The response of surf zone fish has been localized attraction (northern Kingfish) or avoidance (bluefish) when pumping sand onto a beach due to the increase in suspended sediments (USACE, 2001). The highly mobile nature of the fish community constrained the ability of researchers to detect impacts and recovery, but the study indicated the fish could move in and out of the areas impacted by renourishment activities (Versar, 2004). As this project will replace some rocky habitat with sandy habitat, there will be a shift of biota in these areas.

Fish such as juvenile Atlantic cod that use rocky substrate with vegetation could be negatively impacted by modifications to these habitats, if they use the project area. Within the project areas there is no eelgrass habitat that provides any cover for juvenile cod. Eelgrass in the nearshore environment of the beach will not be directly impacted by the project, but sand may move through the area as the beach equilibrates. However, declines in eelgrass are not anticipated because it is adapted to natural sand transport and movement within the littoral zone. The proposed action will temporarily decrease the amount of intertidal rock in the area and therefore, it will decrease potentially available sheltering habitat for juvenile cod. The nourishment footprint has been designed to avoid most areas of complex and intertidal rocky habitat that juvenile Atlantic cod are known to use; therefore, the impact will be minimized to the extent practicable. Further, the time of year for construction (October to December) avoids the spawning season for the majority of fish, including winter flounder, as well as the time of year that young-of-year cod are likely inshore. Therefore, the proposed action is not expected to cause significant short or long-term impacts to fish resources.

6.4.7. Upland Wildlife

No Action Alternative

The project area will continue to experience erosion which may affect upland wildlife species habitat and food resources over the long term, especially within the marsh system behind Town Neck Beach. No short-term impacts to upland wildlife are anticipated with no action.

Proposed Action
During construction, upland wildlife will likely avoid the project area. This is not expected to be a significant impact since abundant food resources and living habitat are not present within the project site. Beach nourishment will ultimately provide more land for upland species and protect the marsh which provides habitat and food resources for these organisms leading to a positive impact.

6.4.8. Birds

No Action Alternative
Under the no action alternative, bird species that utilize Town Neck Beach for nesting, foraging, and resting will experience more limited habitat as erosion continues. This may lead to territorial disturbances and birds seeking out other areas for habitat. In the short-term, no impacts to bird species are expected with no action.

Proposed Action
Construction activities will likely cause any birds utilizing the project area to avoid it. However, construction will take place from October to December which is outside of the time year that the majority of bird species are typically present. Further, nourishment will create a larger dune and berm system which will provide more habitat for bird species while also protecting the marsh behind Town Neck Beach which also hosts bird habitat.

6.5 Threatened and Endangered Species

6.5.1. Flowering Plants

No Action Alternative
No direct or indirect impacts to American chaffseed are anticipated under the no action alternative.

Proposed Action
American chaffseed has not been documented within or adjacent to the project area and will therefore be unaffected by the proposed action.

6.5.2. Birds and Bats

No Action Alternative

Under the no action alternative, listed bird species that nest, forage, and rest on Town Neck Beach, particularly piping plovers and least terns, will experience more limited habitat as erosion continues. This may lead to territorial disturbances as the available beach shrinks and/or the relocation of birds to other areas. No immediate impacts to plovers or terns are expected with no action in the short term. Northern long-eared bats are not anticipated to be affected over the short or long-term, directly, or indirectly as a result of no action.

Proposed Action

The proposed action will nourish Town Neck Beach thereby adding habitat for piping plovers and least terns which currently nest at the eastern end of the beach. Direct impacts to listed species will be avoided by constructing the project between October 1 and December 31 which is outside of the time of year that species are typically present in the area. No work associated with the project (except for dune planting), equipment, or construction materials will take place or be present on the beach between April 1 and August 31 to avoid direct impacts.

American beachgrass will be planted on the dunes primarily in the western portion of the project area. No planting will take place on dunes east of the boardwalk where the majority of plover and tern nesting occurs so as not to present hiding places for predators. Dune plantings of American beachgrass may occur after December 31, but this work is not expected to cause adverse impacts since terns and plovers typically nest east of the boardwalk.

Additionally, the material proposed to be dredged from the Scusset borrow site is similar in grain size to what is currently on the beach which will maintain similar habitat for bird species. Although the placed sand may initially be a darker color than what is presently on Town Neck Beach, the dredged sand is expected to naturally bleach with exposure to the sun and blend with the existing sand over time. All material will be placed on a grade suitable for nesting habitat with slopes of 1V:10H for the beach berm. The dunes at the eastern end of the project area will be graded to match existing slopes with grades of 1V:10H to 1V:15H. Rocky intertidal shore constrains the area at the western end of the nourishment site so at this location, dunes will be graded to 1V:5H, but the beach will slope seaward from the toe of the dune at 1V:10H.

The town of Sandwich has committed to further conditions as a part of their 2014 permit approvals and coordination with the MANHESP. These conditions include beach profile surveys, beach grass monitoring, and continued implementation of the Town's Beach Management Agreement. These efforts by the Town and those presented above are expected to avoid and minimize any adverse impacts to listed bird species in the project area.

No impacts to NLEB's will occur as a result of the proposed action. No known maternity roost trees or hibernacula are within the project area, and the closest maternity roost trees are more than two miles away from the project site (MA NHESP, 2019b).

6.5.3. Whales

No Action Alternative
No direct or indirect, temporary, or long-term impacts to whales are expected with the no action alternative.

Proposed Action
The proposed action is not likely to adversely affect fin whales or North Atlantic right whales because of conditions that have been adopted and that will be incorporated into the project's contract. These conditions are primarily related to reducing the chance of vessel strike to whales that may be in the project area at the time of construction. The conditions for endangered species are outlined in Town of Sandwich's permit from the USACE Regulatory office (Department of Army permit no. NAE-2016-00624) and were coordinated with the NMFS Protected Resources Division (PRD). They include that:

1. No dredging or disposal activities, which includes vessel transits between the dredge site and placement area, shall occur from January 1 to June 30 of any year.

2. A NMFS-approved endangered species observer (ESO) shall be onboard all disposal vessels transiting between the Scusset borrow site and the placement area throughout the entirety of the project.

3. The ESO shall follow all tracking and reporting requirements as required in the Department of Army permit (NAE-2016-00624).

4. All disposal vessels transiting between the borrow site and the placement area shall operate at speeds not to exceed 10 knots. If the speed requirement cannot be met due to weather or sea conditions, then placement shall not occur. If any

deviations to the speed restriction are required for reasons of safety or otherwise, then a justification shall be recorded in the vessel's logbook.

5. Transiting and disposals shall be avoided when visibility is lessened to an extent that the ESO cannot observe a whale within 1,500 feet.

6. A searchlight shall be used in low visibility situations while transiting for the benefit of the ESO.

7. No vessels shall approach a whale within 1,500 feet.

No adverse effects to listed whale species are anticipated because of increased water column turbidity. No information is available on the effects of TSS on whales. While the increase in suspended sediments may cause whales to alter their normal movements, these minor movements will be too small to be meaningfully measured or detected. Whales breathe air and are able to swim away from the turbidity plume and not be adversely affected by passing through the temporary increase in TSS (NOAA, 2020b).

Finally, no impacts to critical habitat for North Atlantic right whale are expected as a result of the proposed action. While the action area overlaps with designated critical habitat, only one of the four physical and biological features essential to right whale foraging, as described in Section 3.5.3 may occur (Feature 1, the physical oceanographic conditions and structures of the Gulf of Maine and Georges Bank region that combine to distribute and aggregate *Calanus finmarchicus*). The proposed excavation of sandy material is anticipated to have a temporary effect as a result of slightly and temporarily increased turbidity and disturbance to benthic communities, but this effect is anticipated to last no more than a maximum of a few hours post-dredging and disposal, and thus will not affect whale foraging areas. Based on the best available information, the proposed action will not affect physical and biological feature #1, or any of the other physical and biological features for right whale critical habitat.

6.5.4. Fish

No Action Alternative

No direct or indirect, temporary or long-term impacts to listed fish species are expected as a result of taking no action.

Proposed Action

No direct impacts to Atlantic or shortnose sturgeon as a result of dredging and placement are expected to occur. Regardless of the dredge methodology, it is highly unlikely that the dredge will entrain a sturgeon even if they were located on the bottom. These fish are highly mobile and able to swim away from the area of disturbance. Based on past interactions between dredges and sturgeon, the greatest risk of capture is likely when dredging occurs in areas where sturgeon are densely aggregated with sedentary behavior in overwintering areas. Sturgeon are not expected to overwinter in the action area, as shortnose generally overwinter in the freshwater portions of rivers and Atlantic sturgeon usually overwinter in offshore areas deeper than the borrow site.

Indirect impacts to sturgeon as a result of the project are related to temporarily increased water column turbidity and the removal of benthic prey items. The life stages of sturgeon most vulnerable to increased TSS are eggs and non-mobile larvae, which are subject to burial and suffocation. The project area is composed of entirely saline waters that are not suitable for any sturgeon life stages other than subadults and adults. Therefore, neither sturgeon eggs nor non-mobile larvae will be present. Elevated total TSS levels could affect adult sturgeon if a plume causes a barrier to normal behaviors, but effects to sturgeon from exposure to the sediment plume are expected to be limited to behavioral responses. Sturgeon are highly mobile, and they can avoid a sediment plume with minor movements to alter course out of the sediment plume with no adverse effects (NOAA, 2020b). The proposed project will dredge predominantly sand which will not elevate TSS to levels or the length of time that will cause a plume detectable beyond the dredge area.

Studies done by Wilbur and Clarke (2007) demonstrated that benthic communities in temperate regions occupying shallow waters with substrate of sand, silt, or clay show recovery times between one and eleven months after dredging. Therefore, it is expected that benthic communities within the project area will recover within a year of dredging and the proposed project will not result in the permanent removal of foraging resources in the Scusset borrow area. At the placement site, the TSS levels expected for beach nourishment (up to 64.0 mg/L) are below those shown to have adverse effect on fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton 1993; Wilber and Clarke 2001) and benthic communities (390.0 mg/L (EPA 1986)). Thus, the proposed action is not anticipated to cause any significant, negative impacts to sturgeon species.

6.5.5. Sea Turtles

No Action Alternative

Under the no action alternative, no long-term or short-term, direct, or indirect effects to sea turtles are anticipated.

Proposed Action

Sea turtles are known to be vulnerable to capture in hydraulic hopper dredges, in particular the loggerhead, green, and Kemp's Ridley turtles, are more vulnerable based on their life histories and behavioral patterns. Nonetheless, fewer than five sea turtle entrainment incidents have been documented from this type of dredging equipment in over 35 years of monitoring dredging impacts on sea turtles. The slow-moving dredging head for a cutterhead dredge must be buried into the sediment to allow the dredging to happen. Therefore, pelagic turtles or even turtles swimming near the ocean floor are less vulnerable to entrainment by a cutterhead dredge (D. Dickerson, personal communication, 17 April 2019).

Although sea turtles (leatherback, loggerhead, green, and Kemp's Ridley) can be found in New England waters, they usually migrate south in the fall as waters cool. Between one and five sea turtles, during a five-year period (2013-2017), have been found cold-stunned on the beach adjacent to the proposed borrow pit from late October to December. Thus, a sea turtle could be present at the borrow site during dredging operations in the late fall or winter. Floating cold-stunned turtles will be less vulnerable to entrainment by a cutterhead (D. Dickerson, personal communication, 17 April 2019) or mechanical bucket dredge (Henwood, 1990; NMFS, 2013), but cold-stunned sea turtles at or near the bottom of the water column could be impacted. However, the chances that a cold-stunned or alert sea turtle will be entrained by any type of dredge is low given that the turtle(s) would have to be in the direct path of the cutterhead or bucket, be on the substrate (not floating in the water column), and not show a startle response to avoid the dredge. Regardless, an ESO will be present on all disposal vessels to monitor for alert and cold-stunned sea turtles. The ESO will ensure that vessels do not approach within 600 feet of a sea turtle and shall report any interactions to the NMFS.

At the placement site, between one and 21 turtles were found cold-stunned on or near Town Neck Beach between 2013 and 2017. Cold-stunned turtles found on beaches are under the authority of the U.S. Fish and Wildlife Service. Because the project is proposed to occur between October and December, cold-stunned turtles that washed ashore are at risk of being buried by the placed sand. In order to ensure that the project reduces the risk of impacts to cold-stunned turtles, a beach monitor shall inspect the placement area prior to nourishment activities each day that work occurs. If a cold-stunned turtle is found, then the Wellfleet Bay Wildlife Sanctuary shall be contacted immediately, and the NMFS will be alerted within 12 hours of the discovery. These measures, which were previously coordinated with the NMFS PRD by the USACE Regulatory Division, minimize the likelihood that the proposed action will cause direct adverse effects to sea turtles.

Temporarily elevated TSS levels as a result of dredging (up to 445 mg/L) could be above those shown to have adverse effect on benthic communities that could be used as forage for sea turtles (390.0 mg/L, (EPA, 1986)). However, recovery of the benthic communities in the project area are anticipated within one year following construction (Wilbur and Clarke, 2007). The proposed project has been designed to avoid impacts to eelgrass beds which could be used by sea turtles for foraging. Furthermore, there are a variety of foraging resources in the area immediately outside of the dredge footprint in Cape Cod Bay which sea turtles will have access to while the benthic communities recover within the dredge and placement area. Temporarily increased TSS is not anticipated to cause barriers to movement of other adverse effects to sea turtles. Therefore, the proposed action is not expected to cause significant, adverse effects to any listed sea turtles.

6.6 Essential Fish Habitat

No Action Alternative

EFH is not anticipated to be affected in the short-term with no action. Over time, more areas of rocky habitat on Town Neck Beach are likely to be exposed if no action is taken. This will lead to an alteration in the EFH of the project area, increasing habitat for certain species while decreasing habitat for species that currently utilize the area. As erosion continues, the profile of Town Neck Beach will change with the MHW line moving further inshore. This action threatens the stability of the beach and the protection it affords the salt marsh located behind it which also provides EFH. Therefore, EFH will be negatively impacted over the long-term under the no action alternative.

Proposed Action

Under the proposed action, the Scusset borrow area will be dredged and Town Neck Beach will be nourished leading to temporary, negative impacts to EFH. Benthic prey species located within the borrow area and nourishment footprint will suffer mortality because of dredging and placement operations. However, once construction is complete, the areas will be recolonized over time by recruitment of opportunistic species and by organisms living in adjacent areas. Temporarily increased water column turbidity as a result of construction may also affect EFH;

however, the material to be dredged and placed is sand which will settle out of the water column rapidly.

The project has been designed to avoid placement of material on eelgrass beds and to avoid rocky intertidal habitat areas with large populations of attached macroalgae. Although a portion of rocky intertidal habitat (approximately 2.23 acres) and approximately 1.75 acres of complex bottom habitat will be covered with sand, there are many adjacent areas presenting similar or better habitat which will be unaffected and continue to provide EFH. For further information on expected impacts to EFH as a result of the project, please refer to Appendix A3. Coordination with the NMFS is on-going to ensure the proposed action avoids and minimizes impacts to EFH and EFH-managed species.

6.7 Socioeconomics

No Action Alternative

Over the long term, the no action alternative may have a negative effect on socioeconomics. Erosion of Town Neck Beach will eventually lead to increased levels of storm surge in the marsh that may then inundate downtown Sandwich which includes businesses. More extensive flooding will negatively affect the local economy of Sandwich and threaten businesses and homes in the area.

Proposed Action

Nourishment of Town Neck Beach will not only provide protection of the homes along the nourished area, but also provide indirect protection of downtown Sandwich, positively affecting the socioeconomics of the Town. This protection is estimated to last for the duration of the project's design life which is approximately 9-12 years. Nourishment of the beach will also help to preserve the area as an attractive coastal destination which should have positive socioeconomic impacts over the period of analysis. In the construction phase of the project, the introduction of construction workers into the community may result in their purchasing of supplies and food, contributing to a minor temporary economic benefit to the local economy.

6.8 Cultural Resources

No Action Alternative

The no action alternative has the potential to contribute to long-lasting and continuing impacts to the existing shoreline of Town Neck Beach and loss of the current bank, including any historic properties and artifacts from the brickyard/kiln deposits already uncovered due to erosion. Additionally, continued erosion has the potential to impact the backshore area of Sandwich behind Town Neck Beach including the inlet, marshland, and historic properties associated with Town Neck, Downtown Sandwich, and the Jarvesville Historic District.

Proposed Action

Implementation of the recommended plan for beach nourishment along Town Neck Beach, with material from the Scusset Beach nearshore site, will have "no adverse effect" upon historic properties in accordance with Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended and implementing regulations 36 CFR 800. The Massachusetts State Historic Preservation Officer (SHPO) has concurred with this determination. Additionally, the Massachusetts Board of Underwater Archeological Resources (BUAR), the Mashpee Wampanoag Tribe, the Wampanoag Tribe of Gay Head (Aquinnah), and the Sandwich Historical Commission were contacted and notified of the proposed action and no comment or objection was received within 30-day review period; therefore, we are assuming concurrence with our determination for purposes of NHPA compliance.

6.9 Coastal Barrier Resources Act Units

No Action Alternative

The no action alternative will have a negative, long-term effect to CBRS Unit MA-14P (Figure 3-4, Section 3.9). This is because erosion of Town Neck Beach will continue eventually encroaching into the marsh system that is primarily covered by the CBRS unit. CBRS Unit MA-14P is an OPA, which are predominantly comprised of conservation and/or recreation areas such as national wildlife refuges, state and national parks, and lands used for recreation and conservation.

Proposed Action

CBRS Unit MA-14P is designated as an OPA which is not subject to Federal spending prohibitions except for the receipt of Federal flood insurance. Therefore, the proposed action of beach nourishment will not violate provisions of the CBRA. Nourishment of Town Neck Beach will provide protection for and enhance the CBRS unit by addressing erosion caused by the Canal FNP jetties. Beach nourishment will ensure that the marsh and the portion of Town Neck Beach that is within the CBRS unit are stable and available for recreation and bird habitat.

6.10 Recreation and Scenic Resources

No Action Alternative

The project area will continue to erode and be impacted by coastal storm events over the life of the project which will impact recreational and scenic resources by narrowing Town Neck Beach and threatening the salt marsh. The Town of Sandwich will continue to pursue nourishment and shoreline stabilization actions to prevent further damages to residences on Town Neck Beach. This will affect recreational and scenic resources with the temporary and sporadic addition of construction equipment to the project area.

Proposed Action
The proposed action will have short-term, localized impacts to recreation and scenery in the project area due to construction-related disturbances (e.g., noise, equipment on the beach, etc.). Construction will take place outside of peak beach season which will minimize these impacts. Over the long-term, the proposed project will have beneficial effects due to the wider berm and dune system which will provide a larger area for recreation and for scenic enjoyment of the beach.

6.11 Air Quality

No Action Alternative
The no action alternative may have negative, short-term impacts to air quality as construction may occur more often due to repairs to property from continued erosion causing flood damages. No long-term impacts to air quality are expected under the no action alternative.

Proposed Action
Barnstable County is in attainment with the NAAQS for all NAAQS priority pollutants (EPA, 2018). The proposed action will produce temporarily localized emission increases from the diesel-powered construction equipment working onsite. These localized emission increases will last only during the project's construction period and end when the project is over, thus any potential impacts will be temporary in nature. Based on a qualitative assessment of the construction requirements, it is anticipated that this project will be within the de minimis levels in any one construction year. The draft Record of Non-Applicability and its supporting documentation are contained in Appendix A4. Coordination with the U.S. Environmental Protection Agency on this project's impacts as they apply to the Clean Air Act are on-going.

6.12 Greenhouse Gases

No Action Alternative
The project area will continue to be impacted by coastal storm events over the life of the project which may cause GHG-emitting construction methods to occur more often due to repairs to property from continued erosion and subsequent flooding damages. However, a significant increase in the amount GHGs, as a result of the increased use of diesel-fueled engines (which emits CO_2), is not expected under the no action alternative.

Proposed Action
The primary GHG emitted by diesel-fueled engines is CO_2. The project is estimated to generate a total of approximately 5,000 mt CO_2-e (see EPA Greenhouse Gas Equivalent Calculator, www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator, website accessed 9 Sep 2020). The GHG emissions associated with the project are temporary and insignificant compared to the total of approximately 19,000,000 mt CO_2-e generated in Massachusetts during 2015 (latest reporting period) (MADEP, 2015).

6.13 Hazardous, Toxic and Radioactive Waste

No Action Alternative
The no action alternative will have no temporary or permanent, direct or indirect impacts to HTRW.

Proposed Action
Given that no HTRW sites or USTs exist within or adjacent to the project area, the proposed action will have no impacts to HTRW.

6.14 Noise

No Action Alternative
Under the no action alternative there may be negative, but temporary impacts from noise due to construction activities associated with storm and flooding damage repairs because of continued erosion of Town Neck Beach. No short-term or long-term impacts from noise are expected as a result of the no action alternative.

Proposed Action
Implementation of the proposed action will have minor, negative, short-term impacts to noise levels in the project area. The dredge as well as construction vehicles and equipment to grade the placed sand on Town Neck Beach will increase local noise levels temporarily. Existing noise levels in the project area are in the 54-64 dBA range (AECOM, 2017). Residences along Town Neck Beach adjacent to the nourishment footprint will likely experience higher levels of noise than typical during construction. However, construction is not anticipated to cause major, disruptive increases in noise. Construction will most likely be limited to daytime hours which will serve to minimize noise disturbance to the residences. Furthermore, construction will take place outside of the beach’s peak recreation season and the time of year for bird migrations thereby minimizing impacts to visitors and species that utilize the beach.

6.15 Environmental Justice

No Action

Environmental justice factors will not change with no action. The area is currently ranked in the highest percentile ranges for environmental justice indices and this is not expected to change with no action.

Proposed Action

The proposed action will not affect environmental justice factors. As reported by the EPA's EJSCREEN, vulnerable populations in the area have a low exposure to environmental hazards relative to the State (EPA, 2020). The project is not anticipated to reduce or increase that exposure level.

7. Coordination & Compliance with Environmental Requirements

7.1 Compliance Summary

Table 7-1. Summary of Federal Laws and Regulations

Item	Citation	Compliance
Federal Statutes		
Archaeological Resources Protection Act of 1979	16 U.S.C. 470aa et seq.	Not applicable to this project.
American Indian Religious Freedom Act of 1978	42 U.S.C. 1996	This project will not impede access by Native Americans to sacred sites, possession of sacred objects, and the freedom to worship through ceremonials and traditional rites.
Bald and Golden Eagle Protection Act	16 U.S.C. 668 et seq.	No bald or golden eagles will be impacted by the proposed project.
Clean Air Act	42 U.S.C. §§ 7401 et seq.	A Record of Non-Applicability (RONA) is provided in Appendix A4.
Clean Water Act	33 U.S.C. 1251 et seq.	A Clean Water Act, Section 401 Water Quality Certificate will be sought from the MADEP during the design phase of the project. A Clean Water Act Section 404 evaluation is incorporated into this report as Appendix A6.
Coastal Barrier Resources Act	16 U.S.C. 3501 et seq.	Coastal Barrier Resources Act Unit MA-14P is located within the project area and is designated as an Otherwise Protected Area (OPA). The only Federal spending prohibition within OPAs is the prohibition on Federal flood insurance.
Coastal Zone Management Act	16 U.S.C. §§ 1451-1464 CT Gen Stat § 22a-90 Chapter 444, as amended	A preliminary CZM Determination was prepared and is located in Appendix A2. Final CZM concurrence will be sought from the Massachusetts Office of Coastal Zone Management during the design phase of the project.
Endangered Species Act of 1973	16 U.S.C. 1531 et seq.	Section 7 coordination with the USFWS is on-going.
Estuarine Areas Act	16 U.S.C. 1221 et seq.	Not applicable.
Federal Water Project Recreation Act	16 U.S.C. 460l-12 et seq.	Public notice of availability to the project report to the National Park Service (NPS) and Office of Statewide Planning relative to the Federal and

		State comprehensive outdoor recreation plans signifies compliance with this Act.
Fish and Wildlife Coordination Act	16 U.S.C. 661 et seq.	The project will be coordinated with the USFWS, NMFS, and State fish and wildlife agencies.
Land and Water Conservation Fund Act of 1965	54 U.S.C. 200301 et seq.	Public notice of the availability of this report to the National Park Service (NPS) and the Office of Statewide Planning relative to the Federal and State comprehensive outdoor recreation plans signifies compliance with this Act.
Magnuson-Stevens Act Fishery Conservation and Management Act	16 U.S.C. 1855(b)(2)	An EFH Assessment has been prepared and is present in Appendix A3. Coordination with the NMFS is on-going to ensure compliance with this Act.
Marine Mammal Protection Act of 1972	16 U.S.C. 1361-1407.	The project has been designed to avoid impacts to marine mammals.
Marine Protection, Research, and Sanctuaries Act of 1972	33 U.S.C. 1401 et seq.	Not applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-712 et seq.	Migratory birds will not be impacted by the proposed project.
National Environmental Policy Act of 1969	42 U.S.C. 432 et seq.	Signature of the Finding of No Significant Impact (FONSI) will fulfill the requirement of this act. A draft FONSI is contained in Appendix A7.
National Historic Preservation Act of 1966	16 U.S.C. 470 et seq.	This project has been coordinated with the Massachusetts State Historic Preservation Officer, the Massachusetts Board of Underwater Archaeological Resources, the Sandwich Historical Commission, and the Wampanoag Tribe of Gay Head (Aquinnah) and Mashpee Wampanoag Tribal Historic Preservation Officers. SHPO concurrence indicates compliance.
Native American Graves Protection & Repatriation Act	25 U.S.C. 3001-3013, 18 U.S.C. 1170	Not applicable to this project.
Preservation of Historic and Archeological Data Act of 1974	54 U.S.C. 312501 et seq.	No historical or archaeological data will be irrevocably lost or destroyed by the project.
Rivers and Harbors Act of 1899	33 U.S.C. 401 et seq.	No requirements for projects or programs authorized by Congress. The proposed project is

		being conducted pursuant to the Congressionally-approved authority.
Watershed Protection and Flood Prevention Act	16 U.S.C 1001 et seq.	Not applicable.
Wild and Scenic Rivers Act	16 U.S.C. 1271 et seq.	Not applicable.
Executive Orders		
Protection and Enhancement of the Cultural Environment, 13 May 1971	EO 11593	Coordination with the State Historic Preservation Officer signifies compliance.
Floodplain Management, 24 May 1977	EO 11988 and amendments	See Section 9.2 below.
Protection of Wetlands, 24 May 1977	EO 11990	Circulation of this report for public and agency review fulfills the requirements of this order.
Environmental Effects Abroad of Major Federal Actions, 4 January 1979	EO 12114	Not applicable.
Environmental Justice, 11 February 1994	EO 12898	The project is not expected to have a significant impact on minority or low-income population, or any other population in the United States.
Accommodation of Sacred Sites, 24 May 1996	EO 13007	Access to and ceremonial use of Indian sacred sites by Indian religious practitioners will be allowed and accommodated. No adverse effects to the physical integrity of such sacred sites will occur.
Protection of Children from Environmental Health Risks and Safety Risks. 21 April, 1997	EO 13045	The project will not create a disproportionate environmental health or safety risk for children.
Federal Support of Community Efforts Along American Heritage Rivers	EO 13061, and Amendments	The project is not located along an American Heritage River.
Federal Agencies may not authorize, fund, or carry out actions likely to cause or promote the introduction or spread of invasive species	EO 13112	The project will not promote or cause the introduction or spread of invasive species.
Consultation and Coordination with Indian Tribal Governments, 6 November 2000	EO 13175	Consultation with Indian Tribal Governments, where applicable, and consistent with executive memoranda, DOD Indian policy, and USACE Tribal Policy Principles signifies compliance.

Executive Memorandum		
Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980		Not applicable; the project does not involve or impact agricultural lands.
White House Memorandum, Government-to-Government Relations with Indian Tribes, 29 April 1994.		Consultation with Federally Recognized Indian Tribes signifies compliance.

7.2 Compliance with Executive Order (EO) 11988

Executive Order 11988 requires that Federal agencies avoid, to the extent possible, adverse impacts associated with the occupancy and modification of flood plains and to avoid support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in ER 1165-2-26, requires an eight-step process that agencies should carry out as part of their decision-making on projects that have potential impacts to, or are within the floodplain. The eight steps and project-specific responses to them are summarized below.

EO 11988 Step	Project-Specific Response
Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).	The proposed action is within the base floodplain.
If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.	Practicable measures and alternatives were formulated and evaluated against USACE guidance.
If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments.	The Draft Integrated Feasibility Report and Environmental Assessment will be released for public review, and coordination with agency officials have been held throughout the feasibility study process.

Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified.	The anticipated impacts associated with the proposed action are summarized in Section 7 of this report. The project will not adversely impact the natural or beneficial flood plain values.
If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists.	The project will not encourage development in the floodplain because all properties available for development have been developed. The project provides benefits solely for existing development.
As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the “no action” alternative.	The project will not induce development in the flood plain. Section 5 of this report summarizes the alternative identification, screening and selection process. The “no action” alternative was included in the plan formulation phase.
If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.	The Final Integrated Feasibility Report and Environmental Assessment will document the final determination.
Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.	The proposed action is the most responsive to all of the study objectives and the most consistent with the Executive Order.

7.3 List of Environmental Assessment Report Preparers

Individual	**Responsibility**
Grace Moses	Biologist; NEPA
Marcos Paiva	Archaeologist: NHPA, Sec. 106
Michael Riccio	Project Manager

8. Recommended Plan

8.1 Recommended Plan

Alternative 1A was identified in the alternatives analysis as the alternative that will most effectively address the problem, can be constructed for under $12.5 million dollars and does not rely on a separate navigation project being conducted at the same time in order for it to be successfully constructed. An environmental assessment concluded that Alternative 1A will not have any significant adverse impacts to environmental, cultural, or historic resources. Consequently, Alternative 1A was determined to be the Recommended Plan. It includes the one-time construction of a 388,000 cubic yard engineered dune and berm beach along Town Neck Beach using material dredged from the nearshore at Scusset Beach, using a hydraulic dredge. Figures 8-1 through 8-3 depict the recommended plan and full-sized plans can be found in Appendix E.

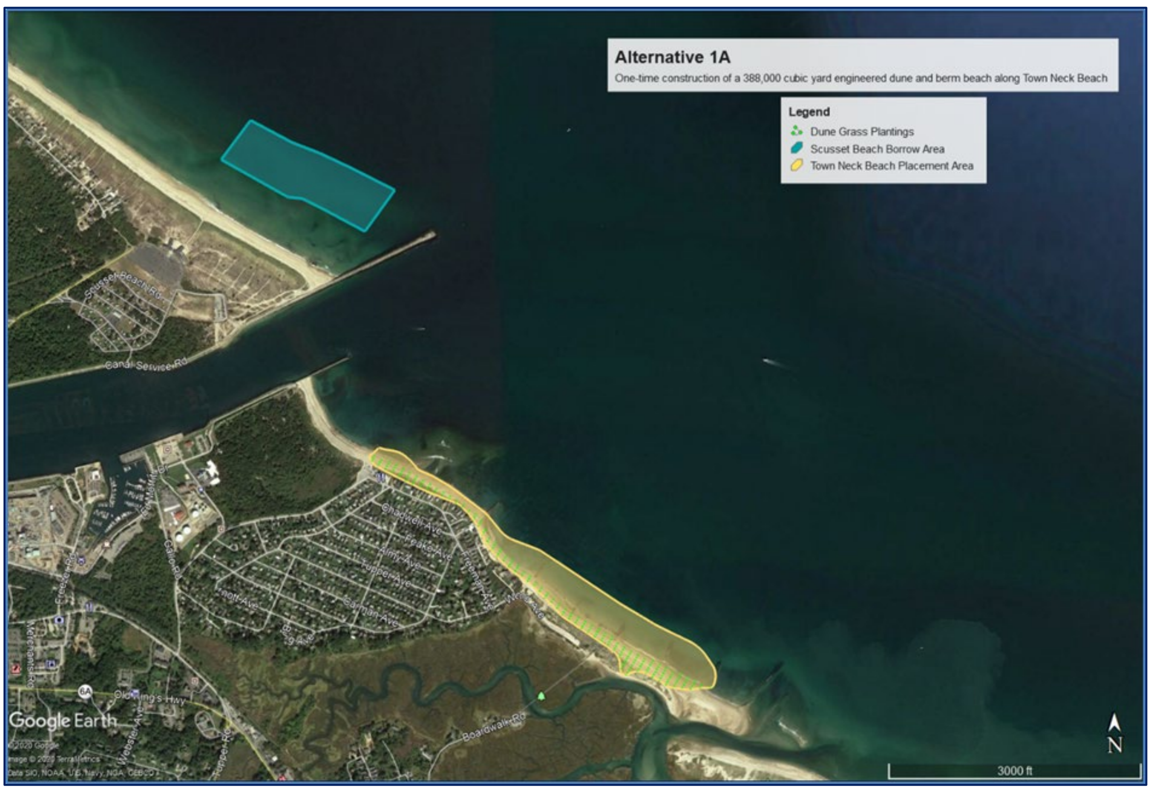

Figure 8-1: Overview of the Recommended Plan; Alternative 1A

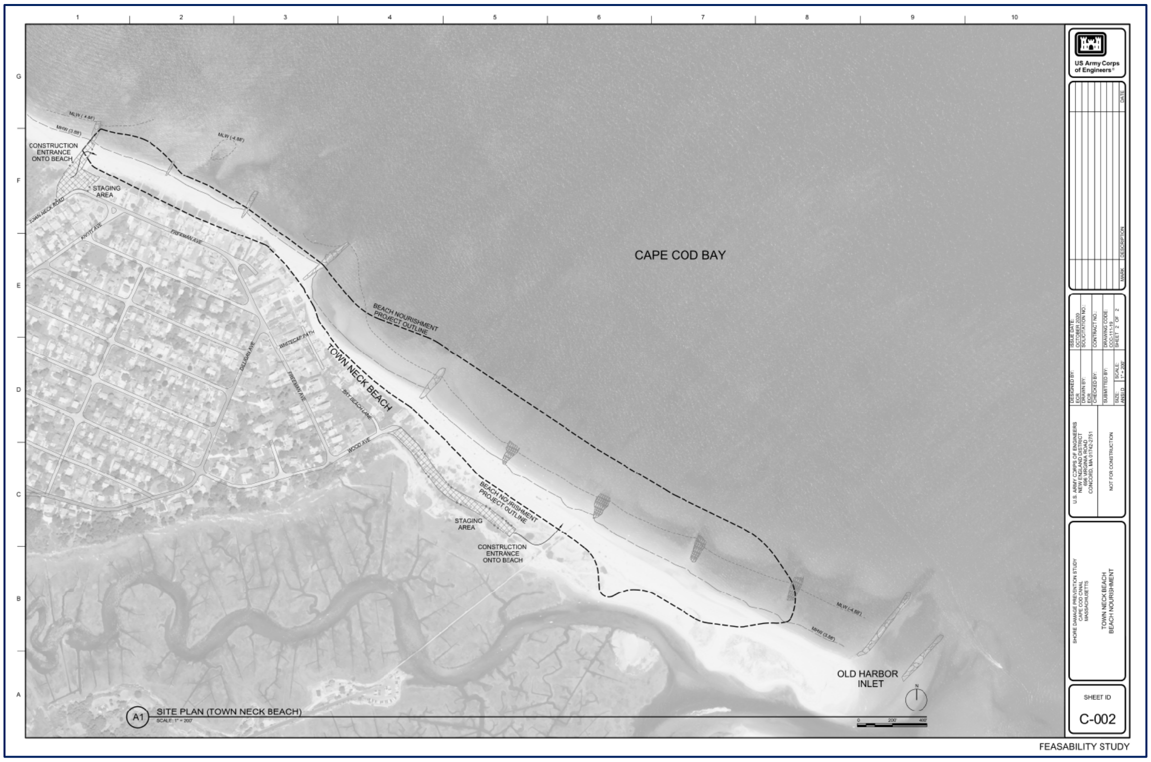

Figure 8-2: Alternative 1A, Town Neck Beach beach nourishment plans

Figure 8-3: Alternative 1A, Scusset Beach borrow area plans

8.2 Detailed Cost Estimate for Recommended Plan

After Alternative 1 A was identified as the Recommended Plan, a refined and more detailed cost estimate was prepared by the Cost Engineering Section, which could then be certified by the USACE's Cost Engineering Center of Expertise. The purpose of this cost estimate was to present a Total Project Cost (construction and non-construction costs) for the Recommended Plan at the current price level to be used for project justification/authorization and to project costs forward in time for budgeting purposes. The costing efforts were intended to produce a cost estimate that is reliable and accurate and that supports the definition of the Government's and the non-Federal sponsor's obligations. Upon completion of this exercise, Alternative 1A was estimated to have an initial construction cost of $11,636,000, as shown in Table 8-1. In addition to the initial construction costs, the total project cost includes all costs associated with the feasibility study. The study cost is estimated to cost $615,000. Therefore, the estimated total project cost of the Recommended Plan is **$12,251,000**. A more detailed explanation of this process and a complete breakdown of the cost estimate can be found in Appendix F.

Table 8-1: Final Cost Estimate for the Tentatively Selected Plan; Alternative 1A

CWBS	Feature Account	ESTIMATED COST	PROJECT FIRST COST	FULLY FUNDED COST
CONSTRUCTION				
17	BEACH REPLENISHMENT	$10,443,000	$10,443,000	$11,065,000
	CONSTRUCTION SUBTOTAL	**$10,443,000**	**$10,443,000**	**$11,065,000**
NON-CONSTRUCTION				
01	LANDS AND DAMAGES	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$291,000	$291,000	$305,000
31	CONSTRUCTION MANAGEMENT (S&A)	$247,000	$247,000	$266,000
	NON-CONSTRUCTON SUBTOTAL	**$538,000**	**$538,000**	**$571,000**
	TOTAL	$10,981,000	$10,981,000	$11,636,000

It should be noted here that although Alternative 1A was determined to be the Recommended Plan, Alternative 1E was almost identical in both design and cost. The only difference between the two was the dredge type. Consequently, additional consideration will be given to Alternative 1E during the design phase of this project to ensure that the most cost effective and environmentally acceptable means of constructing a 388,000 cubic yard beach at Town Neck Beach is identified and implemented. It should also be noted here that it is possible the next operations and maintenance dredging of the Canal does in fact occur at the same time this proposed project is implemented. In the event that the two projects' schedules align, additional consideration will be given to incorporating beneficial use of the material dredged from the Canal into this project design as a means of reducing total project costs and reducing the total volume of material needed to be dredged from the nearshore area at Scusset Beach.

8.3 Cost Sharing and Non-Federal Sponsor Responsibilities

The costs of implementing a project under Section 111 of the CAP program must be shared in the same proportion as the cost sharing provisions applicable to the project causing the shore damage. In this case, the Canal FNP is the project causing the shore damage, which is and entirely Federally funded project. Therefore, the cost sharing responsibilities of implementing the Recommended Plan will be 100% Federal and 0% non-Federal, so long as the project does not exceed the $12.5 million per project Federal cost limit under Section 111 authority. The cost limit includes the Federal cost of studies, design, implementation, and any participation in future renourishment.

8.4 Design and Construction Considerations

The recommended plan was developed to a level of detail commensurate with determining whether a project can be implemented within the constraints of the study authority. More detailed plans and specifications for construction will need to be developed during the design and implementation phase.

Because the Town recently obtained federal, state and local permits for an identical beach nourishment template, the footprint of the recommended beach nourishment area is not likely to change significantly during the design and implementation phase. The source of beach nourishment material however, as well as the methods by which it will be obtained and placed on Town Neck Beach, will require more significant refinement and design consideration.

The proposed borrow area identified in this project is slightly larger than what the town recently received permits for. Consequently, additional federal, state and local permitting will be required in order to allow for the expanded borrow area to be used for the Recommended Plan. Additionally, as was suggested in Section 9.2 of this report, although the Recommended Plan specifies that 388,000 cubic yards of material will be obtained entirely from Scusset Beach, taking advantage of future operations and maintenance dredging of the Canal in the near future could still be a possibility. In the event that the timing of future dredging of the Canal aligns with implementation of the Recommended Plan, that material will need to be disposed of somewhere, and it intuitively make sense to beneficially reuse the material on Town Neck Beach instead of disposing of it offshore. Beneficially reusing that material reduces the total volume of material needed to be dredged from the Scusset Beach nearshore area and it could reduce the total project costs. In conclusion, details pertaining to the specific dredging, pumping, and grading methods associated with construction of the recommended plan still need to be refined during the design and implementation phase of the project.

8.5 Real Estate Requirements

The recommended plan includes the construction of an engineered beach profile with a footprint of approximately 41 acres. Approximately 40 acres of the 41-acre beach nourishment placement area are located on land currently owned by the town of Sandwich. Construction easements within this section of the project area must be provided by the Town to facilitate initial construction and any potential future maintenance and/or repair work. A small portion of the project footprint will extend onto seven privately owned parcels. Construction easements will also be required from those property owners to construct and maintain the proposed project. Non-standard easements must be provided by those property owners. Due to the mitigative nature of the Section 111 authority, as well as the incidental nature of material being placed on those properties, easements for those properties would not require public access for all uses, as would be required for a traditional Coastal Storm Risk Mitigation project per USACE Planning guidance (ER 1160-2-100).

The project will be 100% federally funded 100%, per Section 111 policy requirements. As such, the District will be responsible for obtaining and certifying acquisition of all Lands, Easements, and Rights of Way (LERs) required for the construction, operation, and maintenance of the project. The non-federal sponsor will not be responsible for obtaining and certifying LERs acquisition but has indicated a willingness to informally assist the District in its efforts to acquire LERs associated with this project.

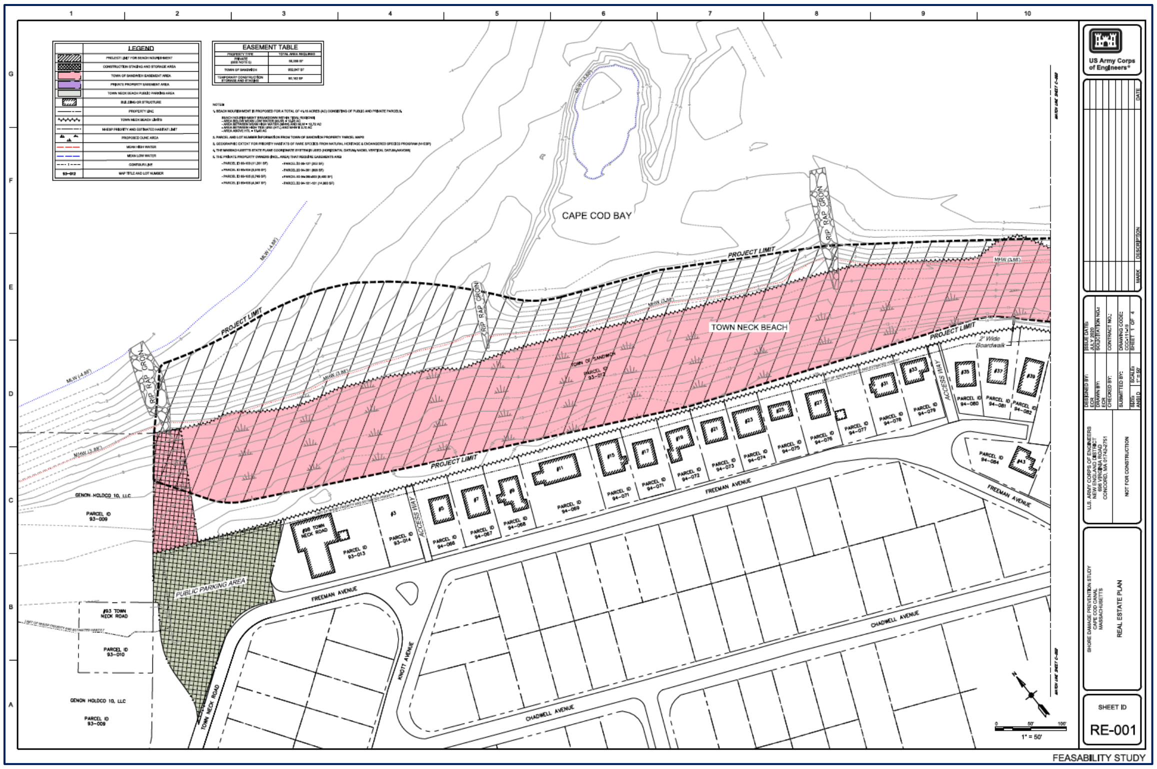

Figure 8-4: Real Estate Impacts of Recommended Plan sheet 1 of 4

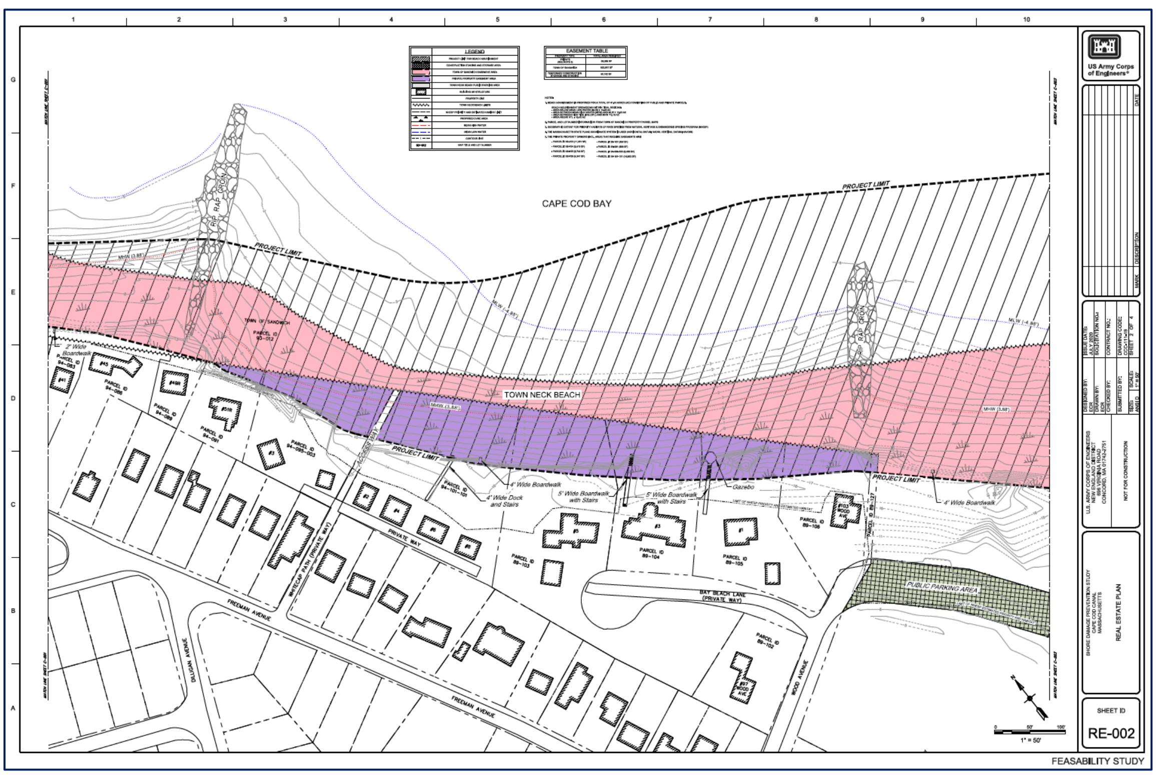

Figure 8-5: Real Estate Impacts of Recommended Plan sheet 2 of 4

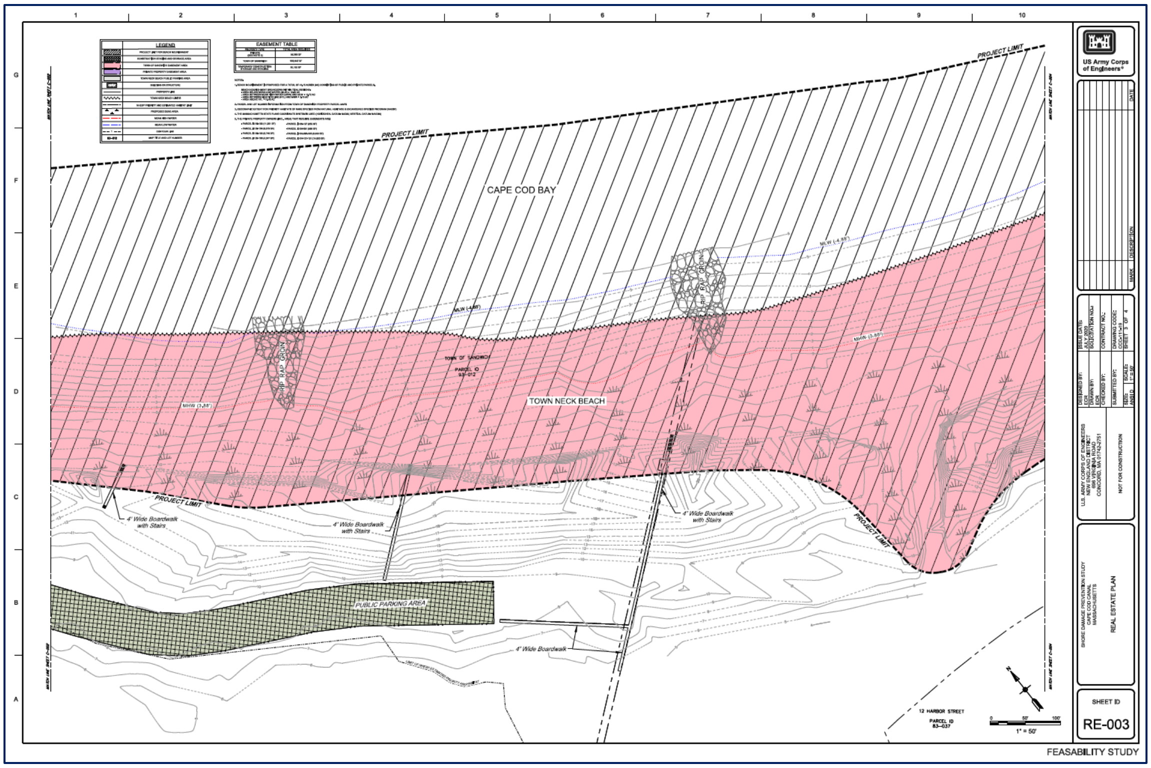

Figure 8-6: Real Estate Impacts of Recommended Plan sheet 3 of 4

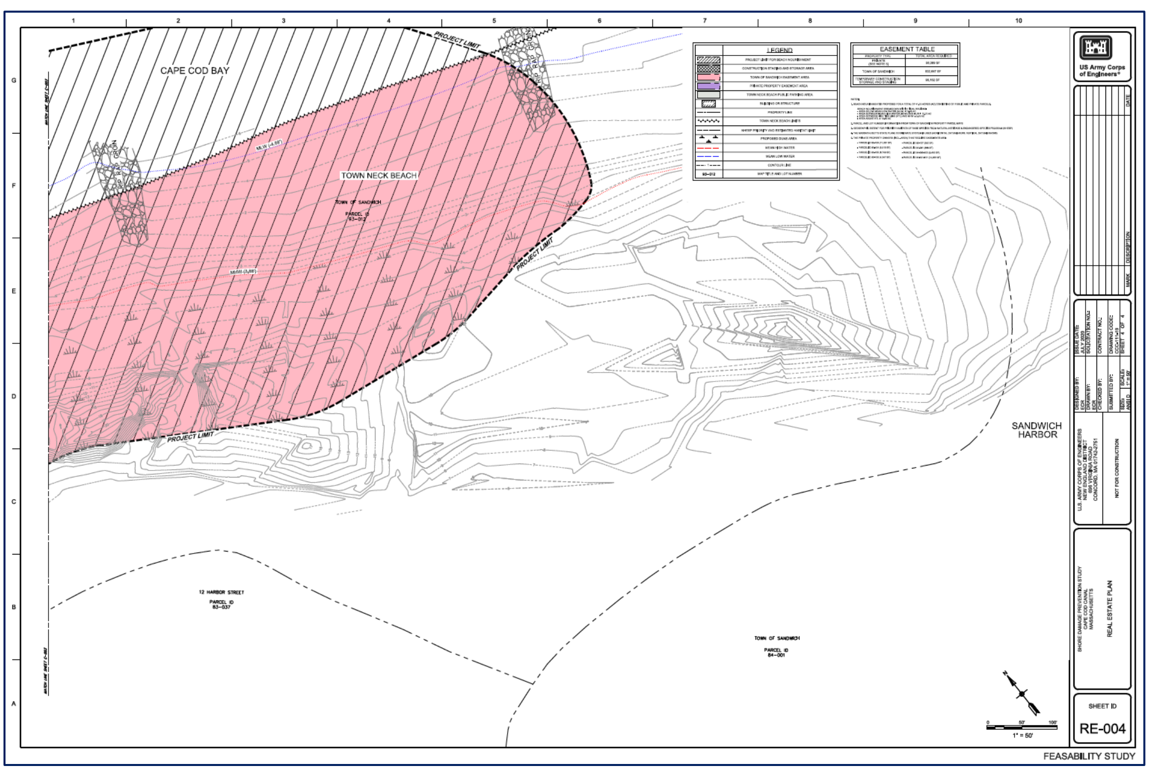

Figure 8-7: Real Estate Impacts of Recommended Plan sheet 4 of 4

8.6 Additional Recommendations

Erosion of the Sandwich shoreline downdrift of the Canal is expected to continue if the jetties at the east entrance continue to interrupt longshore sediment transport through the littoral system. There is no reason to expect that to change in the foreseeable future, thus the erosion is expected to continue in perpetuity. No alternative that could mitigate erosion impacts on a similar time scale could be implemented through the Section 111 authority due to high project costs relative to the $12.5 million Federal project cost limit. Consequently, the Recommended Plan does not adequately address the perpetual nature of erosion directly attributable to the Canal FNP. Although no solution was identified that would address the problem for the full 50-year period of analysis, there may be opportunities for the USACE to assist in mitigating erosion impacts on a more long-term scale.

The USACE routinely dredges the Canal for maintenance purposes, removing approximately 90,000 cubic yards of material every seven years. That material is typically disposed offshore at the Cape Cod Canal Disposal Site, as it is the least costly, environmentally acceptable means of disposing the material. If that material were beneficially reused at Town Neck Beach for supplemental beach nourishment purposes instead, it would substantially aid in mitigating long-term erosion of the shoreline and any resulting damage to public and private property and infrastructure. Erosion rates described in this report, project approximately 900,000 cubic yards of material being lost from Town Neck Beach and Springhill Beach over the next 50 years. That equates to 18,000 cubic yards of material per year and 126,000 over seven years. Although loss of 126,000 cubic yards would exceed the 90,000 cubic yards of material estimated to be available from the Canal every seven years, it would still provide substantial relief in the form of supplemental beach nourishment; conceptually offsetting erosion by 70%.

Evaluating the costs and benefits of beneficially reusing material dredged from the Canal was beyond the scope of this study but a feasibility study conducted by the USACE in 2015 through Section 204 of the CAP program did attempt to do so. That study evaluated the reduction in damages to shorefront properties, not including Great Marsh or the Route 6A/Downtown Sandwich areas (i.e. the evaluation underestimated the benefits of the project), and it preliminarily justified such a project. There is currently no plan in place to beneficially reuse material from the Canal thought, which risks missing a relatively low-cost opportunity to significantly reduce coastal storm risk to the community. Therefore, in addition to recommending the one-time construction of an engineered beach at Town Neck Beach via Alternative 1A, this report also recommends that the USACE consider developing a more strategic, regionally beneficial disposal plan for future operations and maintenance dredging of the east entrance to the Canal.

9. Recommendations

In making the following recommendations, I have given consideration to all significant aspects in the overall public interest, including environmental, social and economic effects, engineering feasibility and compatibility of the project with the policies, desires and capabilities of the town of Sandwich and other non-Federal interests.

I recommend that mitigating erosion impacts to the Sandwich shoreline, directly attributable to the Cape Cod Canal Federal Navigation Project, as fully detailed in this Integrated Detailed Project Report and Environmental Assessment, be authorized for construction as a Federal project, subject to such modifications as may be prescribed by the Division Engineer for the North Atlantic Division.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of highest review levels within the North Atlantic Division. Consequently, the recommendations may be modified (by the Division Engineer) before they are authorized for implementation. The town of Sandwich, interested Federal agencies and other parties will be advised of any such modifications and will be afforded an opportunity to comment further prior to final authorization.

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