Nantasket Beach Coastal Storm Damage Reduction Project
Hull, MA

Phase 2: Beach Nourishment

Massachusetts Environmental Policy Act: Expanded Notice of Project Change

EEA# 12688

Massachusetts Department of Conservation and Recreation

March 15, 2018

Cover photo: Nantasket Beach in front of the Mary Jeanette Murray Bath House at high tide during a hot summer day.

dcr
Massachusetts

Hand-delivered / Receipt Requested

March 15, 2018

Secretary Matthew A. Beaton
Executive Office of Energy and Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

RE: Nantasket Beach Coastal Storm Damage Reduction Project
Phase 2: Beach Nourishment
Expanded Notice of Project Change with a Request for a Waiver for Mandatory EIR
EEA# 12668

Dear Secretary Beaton,

As the local sponsor for the United States Army Corps of Engineer (USACE)'s *Nantasket Beach Coastal Storm Damage Reduction Project* at the Nantasket Beach Reservation in Hull, Massachusetts, the Department of Conservation and Recreation (DCR) is hereby submitting an Expanded Notice of Project Change with a Request for a Waiver for Mandatory Environmental Impact Report (EIR) for Phase 2 of the project. Enclosed please find two hardcopies (one with original signature) and two CDs of the same document.

This Expanded NPC is requesting a waiver for an EIR, primarily in the interest of time to avoid the risk of losing a rare opportunity for clean, suitable source for nourishment of Nantasket Beach; the source is a site in the Piscataqua River, Maine that is scheduled to be dredged. To allow for a full review of the project by MEPA, the Expanded NPC provides incorporates all elements of the Scope for an EIR included in the original 2002 Certificate of the Secretary.

The habitat created by the beach fill at Nantasket Beach would remain largely unchanged from existing conditions. There would be no or negligible adverse long-term impacts to the marine ecosystem. On the other hand, the high tide beach created by the beach fill along Nantasket Beach would significantly enlarge potential habitat for the listed Piping Plover.

The beach nourishment would also have substantial benefits to human environmental resources. Beach nourishment would reduce overtopping during storm conditions, reducing flood damages to facilities and properties. The high tide beach would provide recreational opportunities for many beachgoers in the wider region. Nantasket Beach is unique for a beach in a metropolitan area as it has excellent water quality at all times of the year due to its open ocean conditions. More visitor, and visitors that stay longer due to a high tide beach created by the nourishment,

Department of Conservation and Recreation
251 Causeway Street, Suite 600
Boston MA 02114-2119
617-626-1250 617-626-1351 Fax
www.mass.gov/dcr

Charles D. Baker
Governor

Karyn E. Polito
Lt. Governor

Matthew A. Beaton, Secretary, Executive
Office of Energy & Environmental Affairs

Leo Roy, Commissioner
Department of Conservation & Recreation

would provide more economic opportunities for businesses on the Reservation and the Town of Hull. An additional economic multiplier effect would occur with the eventual implementation of DCR's Master Plan. The net effect of this implementation would be even more visitors and recreational and cultural opportunities, further adding to economic benefits. A nourished beach is critical to DCR's vision for this plan.

Dredging of the Piscataqua River source material could occur as early as this fall. The USACE requires permits to be in place by June to be eligible for this material. We apologize for the limited time for review, but greatly appreciate your efforts and collaboration to take advantage of this rare opportunity for a large volume of clean material in the region.

If there are any questions or comments, please contact Mike Galvin at (617) 626-1442 or at Mike.Galvin@state.ma.us.

Sincerely,

Priscilla Geigis
Deputy Commissioner for Conservation and Resource Stewardship

Enclosures

cc: Distribution List (See Chapter 3 of Expanded NPC)

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Acronyms and Abbreviations

ADA	Americans with Disabilities Act
BUAR	Massachusetts Board of Underwater Archaeological Resources
CCME	Canadian Council of Ministers of the Environment
CO	Carbon monoxide
CMR	Code of Massachusetts Regulations
CWP	Coastal Waterbird Program (a Massachusetts Audubon program)
cy	cubic yard(s)
CZM	Coastal Zone Management
DCR	Massachusetts Department of Conservation and Recreation
DDE	Dichlorodiphenyldichloroethylene (pesticide breakdown product)
DMF	Massachusetts Division of Marine Fisheries
EEA	Executive Office of Energy and Environmental Affairs
EFH	Essential Fish Habitat
EIR	Environmental Impact Report
ENF	Environmental Notification Form
EO	Executive Order
ERL	Effects Range Low (NOAA sediment quality guideline value)
ERM	Effect Range Median (NOAA sediment quality guideline value)
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps (FEMA)
FIS	Flood Insurance Study (FEMA)
FMC	Fishery Management Council
ft	foot or feet
ft/yr	foot (or feet) per year
GEV	Generalized Extreme Value
HA	Historic archaeological site
HRA	Hull Redevelopment Authority
ISQG	Interim sediment quality guideline
km	kilometer(s)
m	meter(s)
m^3/yr	cubic meter(s) per year
MassDEP	Massachusetts Department of Environmental Protection

MDC	Metropolitan District Commission
MEPA	Massachusetts Environmental Policy Act
MESA	Massachusetts Endangered Species Act
MHC	Massachusetts Historical Commission
MHW	Mean high water
mg/kg	milligram per kilogram (part per million)
M.G.L	Massachusetts General Law
MLLW	Mean lower low water
MLW	Mean low water
mm	millimeter(s)
MSCP	Massachusetts Shoreline Change Project
MSL	Mean sea level
MTL	Mean tide level
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NHESP	Massachusetts Natural Heritage and Endangered Species Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOS	National Ocean Service
NPC	Notice of Project Change
PNF	Project Notification Form
RCS	Reportable concentrations for soils
SHPO	State Historic Preservation Officer
sqft	square feet
STP	Seawall Toe Protection
TOY	Time of year
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WIS	Wave Information Study
WPA	Wetlands Protection Act
WQC	Water quality certification
yr	year

1. Notice of Project Change Form

This chapter consists of the Notice of Project Change (NPC) form for this Expanded NPC document.

Commonwealth of Massachusetts

Executive Office of Energy and Environmental Affairs ■ MEPA Office

For Office Use Only   ***Executive Office of Environmental Affairs***
MEPA Analyst:
Phone: 617-626-

Notice of Project Change *(Expanded)*

The information requested on this form must be completed to begin MEPA Review of a NPC in accordance with the provisions of the Massachusetts Environmental Policy Act and its implementing regulations (see 301 CMR 11.10(1)).

EEA # *12688*		
Project Name: *Nantasket Beach Coastal Storm Damage Reduction Project*		
Street Address: *Nantasket Beach*		
Municipality: *Hull*	Watershed: *Boston Harbor*	
Universal Transverse Mercator Coordinates: *4681641 (Northing); 346820 (Easting)*	Latitude: *42°16'19" N* Longitude: *70°51'27" W*	
Estimated commencement date: *October 15, 2018*	Estimated completion date: *May 1, 2019*	
Project Type: *Beach Nourishment (Phase 2)*	Status of project design: *50* % complete	
Proponent: *Massachusetts Department of Conservation and Recreation (DCR)*		
Street Address: *251 Causeway Street*		
Municipality: *Boston*	State: *MA*	Zip Code: *02114*
Name of Contact Person: *Michael Galvin*		
Firm/Agency: *DCR*	Street Address: *251 Causeway Street*	
Municipality: *Boston*	State: *MA*	Zip Code: *02114*
Phone: *(617) 626-1442*	Fax: *(617) 626-1351*	E-mail: *mike.galvin@state.ma.us*

With this Notice of Project Change, are you requesting:

a Single EIR? (see 301 CMR 11.06(8))	☐Yes	☒No
a Special Review Procedure? (see 301CMR 11.09)	☐Yes	☒No
a Waiver of mandatory EIR? (see 301 CMR 11.11)	☒Yes	☐No
a Phase I Waiver? (see 301 CMR 11.11)	☐Yes	☒No

Which MEPA review threshold(s) does the project meet or exceed (see 301 CMR 11.03)?
The project is subject to MEPA review because it meets or exceeds review thresholds and requires state agency permits, and involves state agency funding. The entire project is subject to an Environmental Impact Report (EIR) because the proposed beach nourishment (Phase 2) would impact 10 acres or more of coastal beach. This Notice of Project Change (NPC) is being submitted as an Expanded NPC with a Request for a Waiver of mandatory EIR (a waiver was previously granted in a Final Record of Decision dated January 12, 2007).

ENF Thresholds

301 CMR 11.03(3)(b)(1)(a) alteration of a coastal beach/barrier beach – *The project would alter approximately 75 acres by placement of beach fill.*

301 CMR 11.03(3)(b)(e) expansion of existing fill or structure in a velocity zone or regulatory floodway *- The project is located within Land Subject to Coastal Storm Flowage.*

301 CMR 11.03 (3)(b)(f) alteration of one-half or more acres of any other wetlands - *The project would result in temporary and permanent alteration of Land Subject to Coastal Storm Flowage and coastal beach.*

EIR Thresholds

301 CMR 11.03(3)(a)(1)(b) alteration of ten or more acres of any other wetlands - *Phase 2 of the project (beach nourishment) would exceed the above threshold because nourishment of the entire beach, along the full length of seawall (6,800 linear feet), would alter 10 acres or more of coastal beach and Land Subject to Coastal Storm Flowage.*

Which State Agency Permits will the project require? Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:

The project requires the following state and municipal permits and review:

- *Chapter 91 Waterways License (MassDEP)*
- *Federal Coastal Zone Management Consistency Review (MA CZM)*
- *Order of Conditions (Town of Hull, Conservation Commission)*

Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:
No financial assistance or land transfers are required from an Agency of the Commonwealth. It is noted that the land between the northern end of the seawall and DCR's David Cook Comfort Station is owned by the Town of Hull. There is currently no lease; DCR would pursue a construction easement, easement to build, or other agreement.

Financial Assistance
Total costs for nourishing Nantasket Beach are a function of the volume of available material and funding. For example, for a volume of 300,000 cy (currently expected to be the maximum available volume from the Piscataqua River for Nantasket Beach), total costs for transportation and placement would be approximately $12 million (assuming $40/cy). Financial assistance options would be as follows:

- *Section 1122 funding: Costs could be cost-shared with the U.S Army Corps of Engineers (USACE). This assumes approval of a proposal for Section 1122 funding under the Water Resources Development Act (WRDA), Beneficial Use of Dredged*

Material, submitted through MA CZM on March 12, 2018. If the proposal is approved, costs for 300,000 cy of material would be approximately $200,000 for DCR, with $11.8 million contributed by the USACE.

- *Section 103 funding: The second option is the current Section 103 program with the USACE for the Nantasket Beach Coastal Storm Damage Reduction Project. The agreement of this program is a 2:1 cost split between USACE and DCR. Approximately $6 million remain available from the USACE, with $3 million to be provided by the DCR. The total of $9 million would allow for 225,000 cy of material from the Piscataqua River source. (Another funding source would have to be identified before Nantasket Beach could receive the additional available 75,000 cy from the Piscataqua River.)*
- *Subsequent to nourishing Nantasket Beach with up to 300,000 cy of Piscataqua River material, funding sources for additional nourishment to reach a beach fill volume of up 700,000 cy have not yet been determined. The funding source(s) (and potential financial assistance) for the additional material would depend on factors such as the type of source, its location, timing of availability of the material, and budgetary constraints for DCR and the Commonwealth at the time.*

PROJECT INFORMATION

In 25 words or less, what is the project change? The project change involves . . .

…a *request for a waiver from an EIR to allow for receiving clean, suitable dredged material for beach fill this year, a rare opportunity.*

See full project change description beginning on page 3.

Date of publication of availability of the ENF in the Environmental Monitor:
(Date: *ENF noticed 12/26/2001, most recent NPC noticed 11/08/2006*)

Was an EIR required? ☒Yes ☐No; if yes,
was a Draft EIR filed? ☐Yes (Date:) ☒No
was a Final EIR filed? ☐Yes (Date:) ☒No
was a Single EIR filed? ☐Yes (Date:) ☒No

An EIR was required for the entire project. The project was granted a Waiver allowing Phase 1 (seawall toe protection [STP]) to proceed to permitting prior to completion of an EIR for the entire project (most recent Record of Decision, January 12, 2007).

Have other NPCs been filed? ☒Yes (Date(s):) ☐No

- *NPC with Request for Phase 1 Waiver (Dec. 2004): A Certificate on the NPC/Request for Phase 1 Waiver was issued January 21, 2005 and a Final Record of Decision on March 03, 2005 granting a Phase 1 Waiver.*

- *NPC with Request for Phase 1 Waiver (Nov. 2006): A Certificate on the NPC and Request for Phase 1 Waiver was issued on December 15, 2006 and a Final Record of Decision, granting a Phase 1 Waiver, on January 12, 2007.*

If this is a NPC solely for lapse of time (see 301 CMR 11.10(2)) proceed directly to **ATTACHMENTS & SIGNATURES**.

This Expanded NPC is for a request for a waiver for a mandatory EIR.

PERMITS / FINANCIAL ASSISTANCE / LAND TRANSFER

List or describe all new or modified state permits, financial assistance, or land transfers not previously reviewed: **dd w/ list of State Agency Actions (e.g., Agency Project, Financial Assistance, Land Transfer, List of Permits)**

No new or modified state permits, financial assistance or land transfers are required that were not previously reviewed.

Are you requesting a finding that this project change is insignificant? A change in a Project is ordinarily insignificant if it results solely in an increase in square footage, linear footage, height, depth or other relevant measures of the physical dimensions of the Project of less than 10% over estimates previously reviewed, provided the increase does not meet or exceed any review thresholds. A change in a Project is also ordinarily insignificant if it results solely in an increase in impacts of less than 25% of the level specified in any review threshold, provided that cumulative impacts of the Project do not meet or exceed any review thresholds that were not previously met or exceeded. (see 301 CMR 11.10(6)) ☒**Yes** ☐**No; if yes, provide an explanation of this request in the Project Change Description below.**

The original NPC involved a beach fill of 280,000 cy. As explained in Chapter 7 of the Expanded NPC, the preferred alternative consists of placement of up to 700,000 cy. Other alternatives considered were for volumes up to 226,000 cy and up to 378,000 cy. A beach fill of up to 700,000 cy would provide the overall highest benefit to the natural and socio-economic environment for the Nantasket Beach Reservation. No permanent structures would be installed as part of Phase 2.

The material for nourishment would come from the Piscataqua River in Maine or other source providing material that meets the compatibility gradation and is similarly clean. The final volume received would depend the timing of dredging and available funding (see section on "Financial Assistance" above). The volume of 378,000 cy was considered by the USACE in 2014 for stabilizing the mid-section of the seawall. The volume of 226,000 cy was considered by the USACE in 2002 in the initial environmental assessment and was therefore included in the alternatives analysis for this Expanded NPC. The current preferred alternative of up to 700,000 cy would allow for additional nourishment of Nantasket Beach in the future (as suitable sources become available).

The beach fill material available from the Piscataqua River source is chemically clean and has a similar grain size composition as the existing material on Nantasket Beach. This implies that the habitat created by the beach fill would remain largely unchanged from existing conditions. Therefore, while benthic organisms on the footprint of the nourishment would be buried in the short-term, there would be negligible long-term impacts as benthic organisms would be expected to rapidly and fully recolonize the new beach fill. Instead there would be beneficial impacts to the natural environment. The high tide beach recreated by the beach fill along Nantasket Beach would substantially enlarge potential habitat for Piping Plover along Nantasket Beach. According to the Massachusetts Natural Heritage & Endangered Species Program (NHESP), Division of Fisheries & Wildlife, the northern end of the proposed project area is mapped habitat for this rare species of shorebird. Currently, a high tide beach no longer exists along much of Nantasket Beach.

Beach fill would also have substantial benefits to several human environmental resources:

- *Beach fill would reduce overtopping during storm conditions, reducing flood damages to facilities and properties owned by DCR, the Town of Hull, and private owners. Some of DCR's properties are eligible for listing on the National Register of Historic Places as a contributing structure within a potential Nantasket Beach Reservation Historic District.*

- *While the completion of the implementation of Phase 1 (seawall toe protection) in May 2018 will provide most of the added support for the seawall, beach nourishment would further protect the seawall, thereby further reducing the risk of damages of upland properties and facilities.*

- *The high tide beach would provide recreational opportunities for many beachgoers in the wider region, not just for residents of the Town of Hull. Nantasket Beach is unique for a beach in a metropolitan area as it has excellent water quality at all times of the year due to its open ocean conditions without being impacted by stormdrains, streams, and other potentially contaminated point sources. Furthermore, Nantasket Beach has good access and ample parking allowing residents from communities in the region without a waterfront a valuable opportunity for recreation in the ocean without long travel distances.*

- *More visitor, and visitors that stay longer due to a high tide beach created by the nourishment, provide more economic opportunities for businesses on the Reservation and the Town of Hull. Many of these businesses have been struggling due to the seasonal nature of visitors. An additional economic multiplier effect would occur with the eventual implementation of DCR's Master Plan from 2016. The net effect of this implementation would be even more visitors and recreational and cultural opportunities, further adding to economic benefits. A nourished beach is critical to DCR's vision for this plan.*

FOR PROJECTS SUBJECT TO AN EIR

If the project requires the submission of an EIR, are you requesting that a Scope in a previously issued Certificate be rescinded?
☐**Yes** ☒**No** (*)**; if yes, provide an explanation of this request**_____**.**
(*) See explanation below.

If the project requires the submission of an EIR, are you requesting a change to a Scope in a previously issued Certificate?
☒**Yes** (*) ☐**No; if yes, provide an explanation of this request.**
(*) See explanation below.

The most recent Scope for the EIR is from a Secretary's Certificate issued in 2002. Since that time, there have been two NPCs, further work on alternatives analysis, and some seawall repair and stabilization work completed under the 2007 Phase 1 Waiver. A Coastal Engineering and Shore Protection Alternatives Assessment has been completed by the Woods Hole Group and Louis Berger (2010) and a Feasibility Report and Environmental Assessment (EA) by the U.S. Army Corps of Engineers (2014).

This Expanded NPC is requesting a Waiver for an EIR, primarily in the interest of time to avoid the risk of losing this rare opportunity for clean, suitable material from the Piscataqua River. Nevertheless, the Expanded NPC provides additional information that incorporates all elements of the Scope for an EIR described in the 2002 Certificate of the Secretary.

SUMMARY OF PROJECT CHANGE PARAMETERS AND IMPACTS *(includes Phases 1 and 2)*

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
LAND			
Total site acreage	*36 acres (based on 280,000 cy in 2001 ENF)* *(includes Phase 1 and Phase 2 as the beach fill covers up the toe protection)*	*Alt. D (up to 700,000 cy: Preferred Alternative): +39 acres* *Alt. C (up to 378,000 cy): +19 acres* *Alt. B (up to 226,000 cy): - 5 acres*	*Alt. D (up to 700,000 cy: Preferred Alternative): 75 acres* *Alt. C (up to 378,000 cy): 55 acres* *Alt. B up to (226,000 cy): 31 acres*

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
Note: The following rows only consider Alternative D for Phase 2 (Preferred Alternative: 700,000 cy)			
Acres of land altered	***Phase 1**: approx. 3 acres* ***Phase 2:** 36 acres*	***Phase 1:** No change* ***Phase 2**: +39 acres*	***Phase 1**: approx. 3 acres[1]* ***Phase 2**: 75 acres*
Acres of impervious area	***Phase 1:** 0.43 acres* ***Phase 2:** None*	*No change*	***Phase 1:** 0.43 acres[2]* ***Phase 2:** None*
Square feet of bordering vegetated wetlands alteration	*N/A*	*N/A*	*N/A*
Square feet of other wetland alteration *Coastal Beach and Land Subject to Coastal Storm Flowage*	***Phase 1:** 118,000 square feet (sqft)[3]* ***Phase 2:** 36 acres (includes area of Phase 1)*	***Phase 1:** -2,000 sqft* ***Phase 2:** +39 acres (includes area of Phase 1)*	***Phase 1:** 116,000 sqft Limit of work* ***Phase 2:** 75 acres (includes area of Phase 1)*
Acres of non-water dependent use of tidelands or waterways	*N/A*	*N/A*	*N/A*

1 Approximately 3 acres, including previously completed 170-ft section at Mary J. Murray Bath House.
2 Impervious areas associated with beach access improvements - ADA ramps and stairs for pedestrian access.
3 The 2006 NPC form indicated 32,235 sqft (above material portion of STP only).Total alteration previously reviewed was approximately 118,000 sqft (2,000 x 59-ft) including permanent and temporary impacts.

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
STRUCTURES			
Gross square footage	***Phase 1:*** *75,100 sqft*[4] ***Phase 2:*** *N/A*	***Phase 1:*** *Minor change* ***Phase 2:*** *N/A*	***Phase 1:*** *73,340 sqft*[5] *(STP 1,930-ft x 38-ft)* ***Phase 2:*** *N/A*
Number of housing units	*N/A*	*N/A*	*N/A*
Maximum height (in feet)	***Phase 1:*** *10 ft (NGVD29)* ***Phase 2:*** *12 ft (NGVD29)*	***Phase 1:*** *No change* ***Phase 2:*** *No change*	***Phase 1:*** *10 ft (NGVD29)* ***Phase 2:*** *12 ft (NGVD29)*
TRANSPORTATION			
Vehicle trips per day	*N/A*	*N/A*	*N/A*
Parking spaces	*N/A*	*N/A*	*N/A*
WATER/WASTEWATER			
Gallons/day (GPD) of water use	*N/A*	*N/A*	*N/A*
GPD water withdrawal	*N/A*	*N/A*	*N/A*
GPD wastewater generation/ treatment	*N/A*	*N/A*	*N/A*
Length of water/sewer mains (in miles)	*N/A*	*N/A*	*N/A*

4 Based on approx. 2,000-ft x 37.55-ft width (extent seaward) = 75,100 sqft (should be 2,100 x 38-ft)

5 Difference from "previously reviewed" reflects the 170-ft section completed at Mary J. Murray (MJM) Bath House and corrected dimensions. Gross square footage, including MJM component, is approximately 79,800 sqft

Does the project change involve any new or modified:

1. conversion of public parkland or other Article 97 public natural resources to any purpose not in accordance with Article 97? ☐**Yes** ☒**No**

2. release of any conservation restriction, preservation restriction, agricultural preservation restriction, or watershed preservation restriction? ☐**Yes** ☒**No**

3. impacts on Rare Species**?** ☒**Yes** ☐**No** (*) Beneficial impact

4. demolition of all or part of any structure, site or district listed in the State Register of Historic Place or the inventory of Historic and Archaeological Assets of the Commonwealth? ☐**Yes** ☒**No**

5. impact upon an Area of Critical Environmental Concern? ☐**Yes** ☒**No**

If you answered 'Yes' to any of these 5 questions, explain below:

(*) It is noted, as stated above, that the northern end of the project area is mapped habitat for the listed species Piping Plover. The proposed beach fill would create potential plover habitat along the full length of Nantasket Beach Reservation, i.e., would have a beneficial environmental impact.

PROJECT CHANGE DESCRIPTION (attach additional pages as necessary). The project change description should include:

(a) a brief description of the project as most recently reviewed

(b) a description of material changes to the project as previously reviewed,

(c) if applicable, the significance of the proposed changes, with specific reference to the factors listed 301 CMR 11.10(6), and

(d) measures that the project is taking to avoid damage to the environment or to minimize and mitigate unavoidable environmental impacts. If the change will involve modification of any previously issued Section 61 Finding, include a draft of the modified Section 61 Finding (or it will be required in a Supplemental EIR).

(a) Project as most recently reviewed by MEPA:

The project, as most recently reviewed by MEPA, and as described in the NPC/Request for Phase 1 Waiver submitted by DCR in November 2006, consisted of construction of an approximately 2,000-ft long STP revetment, seaward of the existing seawall, along with improved beach access and minor repairs to the existing seawall over a 4,380- ft length of the beach. With the construction of the toe protection in the mid-section of the seawall, this Phase 1 will be completed by the end of May 2018.

For Phase 2, the original ENF from 2001 included beach fill of 280,000 cy, impacting 36 acres. According to the Certificate from the Secretary, dated December 15, 2006, beach fill requires a mandatory EIR.

(b) Material changes to the Project:

As stated, construction of Phase 1 of the project is about to be completed. Therefore, the description below pertains to Phase 2 (beach nourishment).

Three nourishment alternatives were considered (up to 700,000 cy, up to 378,000 cy, up to 226,000 cy). The preferred alternative is up to 700,000 cy, as it offers the greatest amount of environmental (natural and socio-economic) benefit and at the same time allows for the most flexibility to manage beach nourishment along the Reservation.

(c) *Significance of Proposed Changes:*

Following is an evaluation of criteria for the Secretary's consideration of environmental consequences (301CMR11.10(6)):

- *<u>Expansion of the project and generation of further impacts</u>: The acreage under the preferred alternative (up to 700,000 cy) would change from 36 acres to 75 acres (an increase of 108%), which according to the definition in 301CMR 11.10(6) is significant. For comparison, the acreage under the up to 378,000 cy alternative would change the footprint to 55 acres (an increase of 53%); the acreage under the up to 226,000 cy alternative would change the footprint to 31 acres (a decrease of 14%).*

  However, the larger footprint of the preferred alternative would be insignificant in terms of environmental impacts. The project site does not have eelgrass beds. While short-term benthic organisms would be buried by the material placement, the benthic habitat would remain similar as the material placed is similar to the material on the beach currently. Therefore, benthic organisms would be expected to rapidly and fully recolonize to beach fill area. On the other hand, an upland beach would provide a beneficial impact by providing potential habitat for the listed Piping Plover. Furthermore, there would be a wide range of substantial benefits to several human environmental resources, as described in the section on "PERMITS / FINANCIAL ASSISTANCE / LAND TRANSFER" above. In essence, the benefits to plover habitat and socio-economic resources would be greatest with the largest beach fill alternative (i.e., the preferred alternative of up to 700,000 cy).

- *<u>Change in expected date of commencement or completion of construction</u>: DCR is submitting this Expanded NPC to expedite the permitting process to allow for receiving Piscataqua River material in 2018, should the USACE receive federal funding to start the dredging the site on October 15, 2018. If that is the case, and if DCR does not have permits for receiving the material in place by June, this rare and unique material source would be lost for nourishing Nantasket Beach.*

- *<u>Change of the project site</u>: The project site has not changed.*

- *<u>New application for a permit or new request for financial assistance or land transfer</u>: Not applicable; there are no new permit requirements or funding requests for the Phase 2.*

- *Change that delays realization of net benefits to environmental quality and resources or public health: The proposed beach fill would provide flood protection benefits as well as other natural and socio-economic benefits. Further delay in permitting could jeopardize availability of this material source.*

- *Change in ambient environment or information on the ambient environment: Climate change, and associated sea level rise and increased storm activity, is an important consideration for all projects, especially along the coast. The Nantasket Beach Reservation is vulnerable to flooding from overtopping. Sea level rise was considered in the design of the beach fill as part of the Coastal Engineering and Shore Protection Alternatives Assessment (Woods Hole Group and Louis Berger, 2010). DCR has continued to monitor beach elevations since 2007. The project's purpose is to provide flood protection and reduced storm damage effects to DCR-owned infrastructure and the community in the vicinity of Nantasket Beach.*

(d) Measures to avoid damage to the environment or to minimize and mitigate unavoidable damage

The Phase 1 STP project includes the following measures to avoid and minimize impacts:

- *Time of Year Restrictions: No in-water work shall occur from April 1 – October 1 to minimize adverse effects to fish habitat and potentially nesting Piping Plovers. This window is consistent with the approved dredging window at the Piscataqua River site of October 15 – April 15, allowing for approximately 2 weeks of mobilization at Nantasket Beach prior to the earliest arrival of material.*
- *Turbidity: In general, work would be performed during periods of low tide or in a manner where in-water work could be avoided through appropriate material berms. Construction would be conducted in a manner that minimizes turbidity from dewatering of the material slurry pumped onto the beach from the scows carrying the dredged material.*
- *Storm Damage Prevention: The contractor shall time work to avoid storms, high tides, and other factors that could result in adverse impacts to the resource areas.*
- *Equipment Maintenance: There shall be no servicing, fueling or maintenance or storage of equipment on the beach or within 25 feet of access points.*
- *Material Storage/Stockpile: No construction material storage or stockpiling would be permitted on the beach except for pipes needed to transport the dredged material slurry. The staging area would be located on one of the many DCR parking lots.*
- *Beach Profile Survey: DCR would provide 5 years of beach profile surveys. Surveys would be done twice a year at a minimum (as also required by MassDEP Superseding Order from August 31, 2017).*

- *<u>Piping Plover monitoring:</u> DCR would conduct annual monitoring for Piping Plover and appropriately protect nesting areas, if and when identified during the monitoring.*

ATTACHMENTS & SIGNATURES

Attachments:
1. Secretary's most recent Certificate on this project:
Provided in Attachment A of the Expanded NPC

2. Plan showing most recent previously-reviewed proposed build condition
Provided in Attachment A of the Expanded NPC

3. Plan showing currently proposed build condition
Provided in Chapter 4 of the Expanded NPC

4. Original U.S.G.S. map or good quality color copy (8-1/2 x 11 inches or larger) indicating the project location and boundaries
Provided in Chapter 2 of the Expanded NPC

5. List of all agencies and persons to whom the proponent circulated the NPC, in accordance with 301 CMR 11.10(7)
Provided in Chapter 3 of the Expanded NPC

6. Additional Attachments
Chapters 6 to 10 of the Expanded NPC present a detailed analysis of the project, its impacts, and mitigation measures. These chapters are designed to provide the level of detail of an EIR, and accordingly address the scope for the EIR identified in the original Certificate of the Secretary from January 25, 2002.

7. Appendices to the Expanded NPC

Appendix A. Previous MEPA Certificates and RODs
Appendix B. Nantasket Beach DCR Reservation, Hull, MA Coastal Engineering and Shore Protection Alternatives Assessment (2010)
Appendix C. Feasibility Report and Environmental Assessment (2014)
Appendix D. Suitability Assessment of Piscataqua River Material Source for Nourishment of Nantasket Beach (2018)
Appendix E. Benthic Invertebrates from the Nantasket Beach Fill Project (1996)
Appendix F. Surf Clam Survey (2006)
Appendix G. 2017 Beach Nesting Bird Summary Report Audubon (provided by Conservation Commission, Town of Hull)
Appendix H. Nantasket Beach Reservation Master Plan
Appendix I. Relevant Past Agency Coordination

Commonwealth of Massachusetts

Executive Office of Energy and Environmental Affairs ■ MEPA Office

For Office Use Only   ***Executive Office of Environmental Affairs***
MEPA Analyst:
Phone: 617-626-

Notice of Project Change *(Expanded)*

The information requested on this form must be completed to begin MEPA Review of a NPC in accordance with the provisions of the Massachusetts Environmental Policy Act and its implementing regulations (see 301 CMR 11.10(1)).

EEA # *12688*		
Project Name: *Nantasket Beach Coastal Storm Damage Reduction Project*		
Street Address: *Nantasket Beach*		
Municipality: *Hull*	Watershed: *Boston Harbor*	
Universal Transverse Mercator Coordinates: *4681641 (Northing); 346820 (Easting)*	Latitude: *42°16'19" N* Longitude: *70°51'27" W*	
Estimated commencement date: *October 15, 2018*	Estimated completion date: *May 1, 2019*	
Project Type: *Beach Nourishment (Phase 2)*	Status of project design: *50* % complete	
Proponent: *Massachusetts Department of Conservation and Recreation (DCR)*		
Street Address: *251 Causeway Street*		
Municipality: *Boston*	State: *MA*	Zip Code: *02114*
Name of Contact Person: *Michael Galvin*		
Firm/Agency: *DCR*	Street Address: *251 Causeway Street*	
Municipality: *Boston*	State: *MA*	Zip Code: *02114*
Phone: *(617) 626-1442*	Fax: *(617) 626-1351*	E-mail: *mike.galvin@state.ma.us*

With this Notice of Project Change, are you requesting:

a Single EIR? (see 301 CMR 11.06(8))	☐Yes	☒No
a Special Review Procedure? (see 301CMR 11.09)	☐Yes	☒No
a Waiver of mandatory EIR? (see 301 CMR 11.11)	☒Yes	☐No
a Phase I Waiver? (see 301 CMR 11.11)	☐Yes	☒No

Which MEPA review threshold(s) does the project meet or exceed (see 301 CMR 11.03)?
The project is subject to MEPA review because it meets or exceeds review thresholds and requires state agency permits, and involves state agency funding. The entire project is subject to an Environmental Impact Report (EIR) because the proposed beach nourishment (Phase 2) would impact 10 acres or more of coastal beach. This Notice of Project Change (NPC) is being submitted as an Expanded NPC with a Request for a Waiver of mandatory EIR (a waiver was previously granted in a Final Record of Decision dated January 12, 2007).

ENF Thresholds

301 CMR 11.03(3)(b)(1)(a) alteration of a coastal beach/barrier beach – *The project would alter approximately 75 acres by placement of beach fill.*

301 CMR 11.03(3)(b)(e) expansion of existing fill or structure in a velocity zone or regulatory floodway *- The project is located within Land Subject to Coastal Storm Flowage.*

301 CMR 11.03 (3)(b)(f) alteration of one-half or more acres of any other wetlands - *The project would result in temporary and permanent alteration of Land Subject to Coastal Storm Flowage and coastal beach.*

EIR Thresholds

301 CMR 11.03(3)(a)(1)(b) alteration of ten or more acres of any other wetlands - *Phase 2 of the project (beach nourishment) would exceed the above threshold because nourishment of the entire beach, along the full length of seawall (6,800 linear feet), would alter 10 acres or more of coastal beach and Land Subject to Coastal Storm Flowage.*

Which State Agency Permits will the project require? Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:

The project requires the following state and municipal permits and review:

- *Chapter 91 Waterways License (MassDEP)*
- *Federal Coastal Zone Management Consistency Review (MA CZM)*
- *Order of Conditions (Town of Hull, Conservation Commission)*

Identify any financial assistance or land transfer from an Agency of the Commonwealth, including the Agency name and the amount of funding or land area in acres:
No financial assistance or land transfers are required from an Agency of the Commonwealth. It is noted that the land between the northern end of the seawall and DCR's David Cook Comfort Station is owned by the Town of Hull. There is currently no lease; DCR would pursue a construction easement, easement to build, or other agreement.

Financial Assistance
Total costs for nourishing Nantasket Beach are a function of the volume of available material and funding. For example, for a volume of 300,000 cy (currently expected to be the maximum available volume from the Piscataqua River for Nantasket Beach), total costs for transportation and placement would be approximately $12 million (assuming $40/cy). Financial assistance options would be as follows:

- *Section 1122 funding: Costs could be cost-shared with the U.S Army Corps of Engineers (USACE). This assumes approval of a proposal for Section 1122 funding under the Water Resources Development Act (WRDA), Beneficial Use of Dredged*

Material, submitted through MA CZM on March 12, 2018. If the proposal is approved, costs for 300,000 cy of material would be approximately $200,000 for DCR, with $11.8 million contributed by the USACE.

- *Section 103 funding: The second option is the current Section 103 program with the USACE for the Nantasket Beach Coastal Storm Damage Reduction Project. The agreement of this program is a 2:1 cost split between USACE and DCR. Approximately $6 million remain available from the USACE, with $3 million to be provided by the DCR. The total of $9 million would allow for 225,000 cy of material from the Piscataqua River source. (Another funding source would have to be identified before Nantasket Beach could receive the additional available 75,000 cy from the Piscataqua River.)*
- *Subsequent to nourishing Nantasket Beach with up to 300,000 cy of Piscataqua River material, funding sources for additional nourishment to reach a beach fill volume of up 700,000 cy have not yet been determined. The funding source(s) (and potential financial assistance) for the additional material would depend on factors such as the type of source, its location, timing of availability of the material, and budgetary constraints for DCR and the Commonwealth at the time.*

PROJECT INFORMATION

In 25 words or less, what is the project change? The project change involves . . .

…a *request for a waiver from an EIR to allow for receiving clean, suitable dredged material for beach fill this year, a rare opportunity.*

See full project change description beginning on page 3.

Date of publication of availability of the ENF in the Environmental Monitor:
(Date: *ENF noticed 12/26/2001, most recent NPC noticed 11/08/2006*)

Was an EIR required? ☒Yes ☐No; if yes,
was a Draft EIR filed? ☐Yes (Date:) ☒No
was a Final EIR filed? ☐Yes (Date:) ☒No
was a Single EIR filed? ☐Yes (Date:) ☒No

An EIR was required for the entire project. The project was granted a Waiver allowing Phase 1 (seawall toe protection [STP]) to proceed to permitting prior to completion of an EIR for the entire project (most recent Record of Decision, January 12, 2007).

Have other NPCs been filed? ☒Yes (Date(s):) ☐No

- *NPC with Request for Phase 1 Waiver (Dec. 2004): A Certificate on the NPC/Request for Phase 1 Waiver was issued January 21, 2005 and a Final Record of Decision on March 03, 2005 granting a Phase 1 Waiver.*

- *NPC with Request for Phase 1 Waiver (Nov. 2006): A Certificate on the NPC and Request for Phase 1 Waiver was issued on December 15, 2006 and a Final Record of Decision, granting a Phase 1 Waiver, on January 12, 2007.*

If this is a NPC solely for lapse of time (see 301 CMR 11.10(2)) proceed directly to **ATTACHMENTS & SIGNATURES**.

This Expanded NPC is for a request for a waiver for a mandatory EIR.

PERMITS / FINANCIAL ASSISTANCE / LAND TRANSFER

List or describe all new or modified state permits, financial assistance, or land transfers not previously reviewed: **dd w/ list of State Agency Actions (e.g., Agency Project, Financial Assistance, Land Transfer, List of Permits)**

No new or modified state permits, financial assistance or land transfers are required that were not previously reviewed.

Are you requesting a finding that this project change is insignificant? A change in a Project is ordinarily insignificant if it results solely in an increase in square footage, linear footage, height, depth or other relevant measures of the physical dimensions of the Project of less than 10% over estimates previously reviewed, provided the increase does not meet or exceed any review thresholds. A change in a Project is also ordinarily insignificant if it results solely in an increase in impacts of less than 25% of the level specified in any review threshold, provided that cumulative impacts of the Project do not meet or exceed any review thresholds that were not previously met or exceeded. (see 301 CMR 11.10(6)) ☒**Yes** ☐**No; if yes, provide an explanation of this request in the Project Change Description below.**

The original NPC involved a beach fill of 280,000 cy. As explained in Chapter 7 of the Expanded NPC, the preferred alternative consists of placement of up to 700,000 cy. Other alternatives considered were for volumes up to 226,000 cy and up to 378,000 cy. A beach fill of up to 700,000 cy would provide the overall highest benefit to the natural and socio-economic environment for the Nantasket Beach Reservation. No permanent structures would be installed as part of Phase 2.

The material for nourishment would come from the Piscataqua River in Maine or other source providing material that meets the compatibility gradation and is similarly clean. The final volume received would depend the timing of dredging and available funding (see section on "Financial Assistance" above). The volume of 378,000 cy was considered by the USACE in 2014 for stabilizing the mid-section of the seawall. The volume of 226,000 cy was considered by the USACE in 2002 in the initial environmental assessment and was therefore included in the alternatives analysis for this Expanded NPC. The current preferred alternative of up to 700,000 cy would allow for additional nourishment of Nantasket Beach in the future (as suitable sources become available).

The beach fill material available from the Piscataqua River source is chemically clean and has a similar grain size composition as the existing material on Nantasket Beach. This implies that the habitat created by the beach fill would remain largely unchanged from existing conditions. Therefore, while benthic organisms on the footprint of the nourishment would be buried in the short-term, there would be negligible long-term impacts as benthic organisms would be expected to rapidly and fully recolonize the new beach fill. Instead there would be beneficial impacts to the natural environment. The high tide beach recreated by the beach fill along Nantasket Beach would substantially enlarge potential habitat for Piping Plover along Nantasket Beach. According to the Massachusetts Natural Heritage & Endangered Species Program (NHESP), Division of Fisheries & Wildlife, the northern end of the proposed project area is mapped habitat for this rare species of shorebird. Currently, a high tide beach no longer exists along much of Nantasket Beach.

Beach fill would also have substantial benefits to several human environmental resources:

- *Beach fill would reduce overtopping during storm conditions, reducing flood damages to facilities and properties owned by DCR, the Town of Hull, and private owners. Some of DCR's properties are eligible for listing on the National Register of Historic Places as a contributing structure within a potential Nantasket Beach Reservation Historic District.*

- *While the completion of the implementation of Phase 1 (seawall toe protection) in May 2018 will provide most of the added support for the seawall, beach nourishment would further protect the seawall, thereby further reducing the risk of damages of upland properties and facilities.*

- *The high tide beach would provide recreational opportunities for many beachgoers in the wider region, not just for residents of the Town of Hull. Nantasket Beach is unique for a beach in a metropolitan area as it has excellent water quality at all times of the year due to its open ocean conditions without being impacted by stormdrains, streams, and other potentially contaminated point sources. Furthermore, Nantasket Beach has good access and ample parking allowing residents from communities in the region without a waterfront a valuable opportunity for recreation in the ocean without long travel distances.*

- *More visitor, and visitors that stay longer due to a high tide beach created by the nourishment, provide more economic opportunities for businesses on the Reservation and the Town of Hull. Many of these businesses have been struggling due to the seasonal nature of visitors. An additional economic multiplier effect would occur with the eventual implementation of DCR's Master Plan from 2016. The net effect of this implementation would be even more visitors and recreational and cultural opportunities, further adding to economic benefits. A nourished beach is critical to DCR's vision for this plan.*

FOR PROJECTS SUBJECT TO AN EIR

If the project requires the submission of an EIR, are you requesting that a Scope in a previously issued Certificate be rescinded?
☐**Yes** ☒**No** (*)**; if yes, provide an explanation of this request**_____**.**
(*) See explanation below.

If the project requires the submission of an EIR, are you requesting a change to a Scope in a previously issued Certificate?
☒**Yes** (*) ☐**No; if yes, provide an explanation of this request.**
(*) See explanation below.

The most recent Scope for the EIR is from a Secretary's Certificate issued in 2002. Since that time, there have been two NPCs, further work on alternatives analysis, and some seawall repair and stabilization work completed under the 2007 Phase 1 Waiver. A Coastal Engineering and Shore Protection Alternatives Assessment has been completed by the Woods Hole Group and Louis Berger (2010) and a Feasibility Report and Environmental Assessment (EA) by the U.S. Army Corps of Engineers (2014).

This Expanded NPC is requesting a Waiver for an EIR, primarily in the interest of time to avoid the risk of losing this rare opportunity for clean, suitable material from the Piscataqua River. Nevertheless, the Expanded NPC provides additional information that incorporates all elements of the Scope for an EIR described in the 2002 Certificate of the Secretary.

SUMMARY OF PROJECT CHANGE PARAMETERS AND IMPACTS *(includes Phases 1 and 2)*

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
LAND			
Total site acreage	*36 acres (based on 280,000 cy in 2001 ENF)* *(includes Phase 1 and Phase 2 as the beach fill covers up the toe protection)*	*Alt. D (up to 700,000 cy: Preferred Alternative): +39 acres* *Alt. C (up to 378,000 cy): +19 acres* *Alt. B (up to 226,000 cy): - 5 acres*	*Alt. D (up to 700,000 cy: Preferred Alternative): 75 acres* *Alt. C (up to 378,000 cy): 55 acres* *Alt. B up to (226,000 cy): 31 acres*

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
Note: The following rows only consider Alternative D for Phase 2 (Preferred Alternative: 700,000 cy)			
Acres of land altered	***Phase 1**: approx. 3 acres* ***Phase 2:** 36 acres*	***Phase 1:** No change* ***Phase 2**: +39 acres*	***Phase 1**: approx. 3 acres[1]* ***Phase 2**: 75 acres*
Acres of impervious area	***Phase 1:** 0.43 acres* ***Phase 2:** None*	*No change*	***Phase 1:** 0.43 acres[2]* ***Phase 2:** None*
Square feet of bordering vegetated wetlands alteration	*N/A*	*N/A*	*N/A*
Square feet of other wetland alteration *Coastal Beach and Land Subject to Coastal Storm Flowage*	***Phase 1:** 118,000 square feet (sqft)[3]* ***Phase 2:** 36 acres (includes area of Phase 1)*	***Phase 1:** -2,000 sqft* ***Phase 2:** +39 acres (includes area of Phase 1)*	***Phase 1:** 116,000 sqft Limit of work* ***Phase 2:** 75 acres (includes area of Phase 1)*
Acres of non-water dependent use of tidelands or waterways	*N/A*	*N/A*	*N/A*

1 Approximately 3 acres, including previously completed 170-ft section at Mary J. Murray Bath House.
2 Impervious areas associated with beach access improvements - ADA ramps and stairs for pedestrian access.
3 The 2006 NPC form indicated 32,235 sqft (above material portion of STP only).Total alteration previously reviewed was approximately 118,000 sqft (2,000 x 59-ft) including permanent and temporary impacts.

Summary of Project Size & Environmental Impacts	Previously reviewed	Net Change	Currently Proposed
STRUCTURES			
Gross square footage	***Phase 1:*** *75,100 sqft*[4] ***Phase 2:*** *N/A*	***Phase 1:*** *Minor change* ***Phase 2:*** *N/A*	***Phase 1:*** *73,340 sqft*[5] *(STP 1,930-ft x 38-ft)* ***Phase 2:*** *N/A*
Number of housing units	*N/A*	*N/A*	*N/A*
Maximum height (in feet)	***Phase 1:*** *10 ft (NGVD29)* ***Phase 2:*** *12 ft (NGVD29)*	***Phase 1:*** *No change* ***Phase 2:*** *No change*	***Phase 1:*** *10 ft (NGVD29)* ***Phase 2:*** *12 ft (NGVD29)*
TRANSPORTATION			
Vehicle trips per day	*N/A*	*N/A*	*N/A*
Parking spaces	*N/A*	*N/A*	*N/A*
WATER/WASTEWATER			
Gallons/day (GPD) of water use	*N/A*	*N/A*	*N/A*
GPD water withdrawal	*N/A*	*N/A*	*N/A*
GPD wastewater generation/ treatment	*N/A*	*N/A*	*N/A*
Length of water/sewer mains (in miles)	*N/A*	*N/A*	*N/A*

4 Based on approx. 2,000-ft x 37.55-ft width (extent seaward) = 75,100 sqft (should be 2,100 x 38-ft)

5 Difference from "previously reviewed" reflects the 170-ft section completed at Mary J. Murray (MJM) Bath House and corrected dimensions. Gross square footage, including MJM component, is approximately 79,800 sqft

Does the project change involve any new or modified:

1. conversion of public parkland or other Article 97 public natural resources to any purpose not in accordance with Article 97? ☐**Yes** ☒**No**

2. release of any conservation restriction, preservation restriction, agricultural preservation restriction, or watershed preservation restriction? ☐**Yes** ☒**No**

3. impacts on Rare Species**?** ☒**Yes** ☐**No** (*) Beneficial impact

4. demolition of all or part of any structure, site or district listed in the State Register of Historic Place or the inventory of Historic and Archaeological Assets of the Commonwealth? ☐**Yes** ☒**No**

5. impact upon an Area of Critical Environmental Concern? ☐**Yes** ☒**No**

If you answered 'Yes' to any of these 5 questions, explain below:

(*) It is noted, as stated above, that the northern end of the project area is mapped habitat for the listed species Piping Plover. The proposed beach fill would create potential plover habitat along the full length of Nantasket Beach Reservation, i.e., would have a beneficial environmental impact.

PROJECT CHANGE DESCRIPTION (attach additional pages as necessary). The project change description should include:

(a) a brief description of the project as most recently reviewed

(b) a description of material changes to the project as previously reviewed,

(c) if applicable, the significance of the proposed changes, with specific reference to the factors listed 301 CMR 11.10(6), and

(d) measures that the project is taking to avoid damage to the environment or to minimize and mitigate unavoidable environmental impacts. If the change will involve modification of any previously issued Section 61 Finding, include a draft of the modified Section 61 Finding (or it will be required in a Supplemental EIR).

(a) Project as most recently reviewed by MEPA:

The project, as most recently reviewed by MEPA, and as described in the NPC/Request for Phase 1 Waiver submitted by DCR in November 2006, consisted of construction of an approximately 2,000-ft long STP revetment, seaward of the existing seawall, along with improved beach access and minor repairs to the existing seawall over a 4,380- ft length of the beach. With the construction of the toe protection in the mid-section of the seawall, this Phase 1 will be completed by the end of May 2018.

For Phase 2, the original ENF from 2001 included beach fill of 280,000 cy, impacting 36 acres. According to the Certificate from the Secretary, dated December 15, 2006, beach fill requires a mandatory EIR.

(b) Material changes to the Project:

As stated, construction of Phase 1 of the project is about to be completed. Therefore, the description below pertains to Phase 2 (beach nourishment).

Three nourishment alternatives were considered (up to 700,000 cy, up to 378,000 cy, up to 226,000 cy). The preferred alternative is up to 700,000 cy, as it offers the greatest amount of environmental (natural and socio-economic) benefit and at the same time allows for the most flexibility to manage beach nourishment along the Reservation.

(c) *Significance of Proposed Changes:*

Following is an evaluation of criteria for the Secretary's consideration of environmental consequences (301CMR11.10(6)):

- *<u>Expansion of the project and generation of further impacts</u>: The acreage under the preferred alternative (up to 700,000 cy) would change from 36 acres to 75 acres (an increase of 108%), which according to the definition in 301CMR 11.10(6) is significant. For comparison, the acreage under the up to 378,000 cy alternative would change the footprint to 55 acres (an increase of 53%); the acreage under the up to 226,000 cy alternative would change the footprint to 31 acres (a decrease of 14%).*

  However, the larger footprint of the preferred alternative would be insignificant in terms of environmental impacts. The project site does not have eelgrass beds. While short-term benthic organisms would be buried by the material placement, the benthic habitat would remain similar as the material placed is similar to the material on the beach currently. Therefore, benthic organisms would be expected to rapidly and fully recolonize to beach fill area. On the other hand, an upland beach would provide a beneficial impact by providing potential habitat for the listed Piping Plover. Furthermore, there would be a wide range of substantial benefits to several human environmental resources, as described in the section on "PERMITS / FINANCIAL ASSISTANCE / LAND TRANSFER" above. In essence, the benefits to plover habitat and socio-economic resources would be greatest with the largest beach fill alternative (i.e., the preferred alternative of up to 700,000 cy).

- *<u>Change in expected date of commencement or completion of construction</u>: DCR is submitting this Expanded NPC to expedite the permitting process to allow for receiving Piscataqua River material in 2018, should the USACE receive federal funding to start the dredging the site on October 15, 2018. If that is the case, and if DCR does not have permits for receiving the material in place by June, this rare and unique material source would be lost for nourishing Nantasket Beach.*

- *<u>Change of the project site</u>: The project site has not changed.*

- *<u>New application for a permit or new request for financial assistance or land transfer</u>: Not applicable; there are no new permit requirements or funding requests for the Phase 2.*

- *Change that delays realization of net benefits to environmental quality and resources or public health: The proposed beach fill would provide flood protection benefits as well as other natural and socio-economic benefits. Further delay in permitting could jeopardize availability of this material source.*

- *Change in ambient environment or information on the ambient environment: Climate change, and associated sea level rise and increased storm activity, is an important consideration for all projects, especially along the coast. The Nantasket Beach Reservation is vulnerable to flooding from overtopping. Sea level rise was considered in the design of the beach fill as part of the Coastal Engineering and Shore Protection Alternatives Assessment (Woods Hole Group and Louis Berger, 2010). DCR has continued to monitor beach elevations since 2007. The project's purpose is to provide flood protection and reduced storm damage effects to DCR-owned infrastructure and the community in the vicinity of Nantasket Beach.*

(d) Measures to avoid damage to the environment or to minimize and mitigate unavoidable damage

The Phase 1 STP project includes the following measures to avoid and minimize impacts:

- *Time of Year Restrictions: No in-water work shall occur from April 1 – October 1 to minimize adverse effects to fish habitat and potentially nesting Piping Plovers. This window is consistent with the approved dredging window at the Piscataqua River site of October 15 – April 15, allowing for approximately 2 weeks of mobilization at Nantasket Beach prior to the earliest arrival of material.*
- *Turbidity: In general, work would be performed during periods of low tide or in a manner where in-water work could be avoided through appropriate material berms. Construction would be conducted in a manner that minimizes turbidity from dewatering of the material slurry pumped onto the beach from the scows carrying the dredged material.*
- *Storm Damage Prevention: The contractor shall time work to avoid storms, high tides, and other factors that could result in adverse impacts to the resource areas.*
- *Equipment Maintenance: There shall be no servicing, fueling or maintenance or storage of equipment on the beach or within 25 feet of access points.*
- *Material Storage/Stockpile: No construction material storage or stockpiling would be permitted on the beach except for pipes needed to transport the dredged material slurry. The staging area would be located on one of the many DCR parking lots.*
- *Beach Profile Survey: DCR would provide 5 years of beach profile surveys. Surveys would be done twice a year at a minimum (as also required by MassDEP Superseding Order from August 31, 2017).*

- *<u>Piping Plover monitoring:</u> DCR would conduct annual monitoring for Piping Plover and appropriately protect nesting areas, if and when identified during the monitoring.*

ATTACHMENTS & SIGNATURES

Attachments:
1. Secretary's most recent Certificate on this project:
Provided in Attachment A of the Expanded NPC

2. Plan showing most recent previously-reviewed proposed build condition
Provided in Attachment A of the Expanded NPC

3. Plan showing currently proposed build condition
Provided in Chapter 4 of the Expanded NPC

4. Original U.S.G.S. map or good quality color copy (8-1/2 x 11 inches or larger) indicating the project location and boundaries
Provided in Chapter 2 of the Expanded NPC

5. List of all agencies and persons to whom the proponent circulated the NPC, in accordance with 301 CMR 11.10(7)
Provided in Chapter 3 of the Expanded NPC

6. Additional Attachments
Chapters 6 to 10 of the Expanded NPC present a detailed analysis of the project, its impacts, and mitigation measures. These chapters are designed to provide the level of detail of an EIR, and accordingly address the scope for the EIR identified in the original Certificate of the Secretary from January 25, 2002.

7. Appendices to the Expanded NPC

Appendix A. Previous MEPA Certificates and RODs
Appendix B. Nantasket Beach DCR Reservation, Hull, MA Coastal Engineering and Shore Protection Alternatives Assessment (2010)
Appendix C. Feasibility Report and Environmental Assessment (2014)
Appendix D. Suitability Assessment of Piscataqua River Material Source for Nourishment of Nantasket Beach (2018)
Appendix E. Benthic Invertebrates from the Nantasket Beach Fill Project (1996)
Appendix F. Surf Clam Survey (2006)
Appendix G. 2017 Beach Nesting Bird Summary Report Audubon (provided by Conservation Commission, Town of Hull)
Appendix H. Nantasket Beach Reservation Master Plan
Appendix I. Relevant Past Agency Coordination

Signatures:

3/12/18

Date Signature of Responsible Officer or Proponent

3/14/2018

Date Signature of person preparing NPC (if different from above)

Priscilla Geigis
Name (print or type)

Bernward Hay
Name (print or type)

DCR
Firm/Agency

Louis Berger
Firm/Agency

251 Causeway Street
Street

117 Kendrick Street, Suite 400
Street

Boston, MA 02114
Municipality/State/Zip

Needham, MA 02494
Municipality/State/Zip

617-626-1442
Phone

781-707-7428
Phone

2. USGS Map

The project area for the Nantasket Beach Coastal Storm Damage Reduction Project consists of the Massachusetts Department of Conservation and Recreation's (DCR) Nantasket Beach Reservation (Reservation), located in the southeastern part of the Town of Hull, Plymouth County, Massachusetts (Figure 2-1).

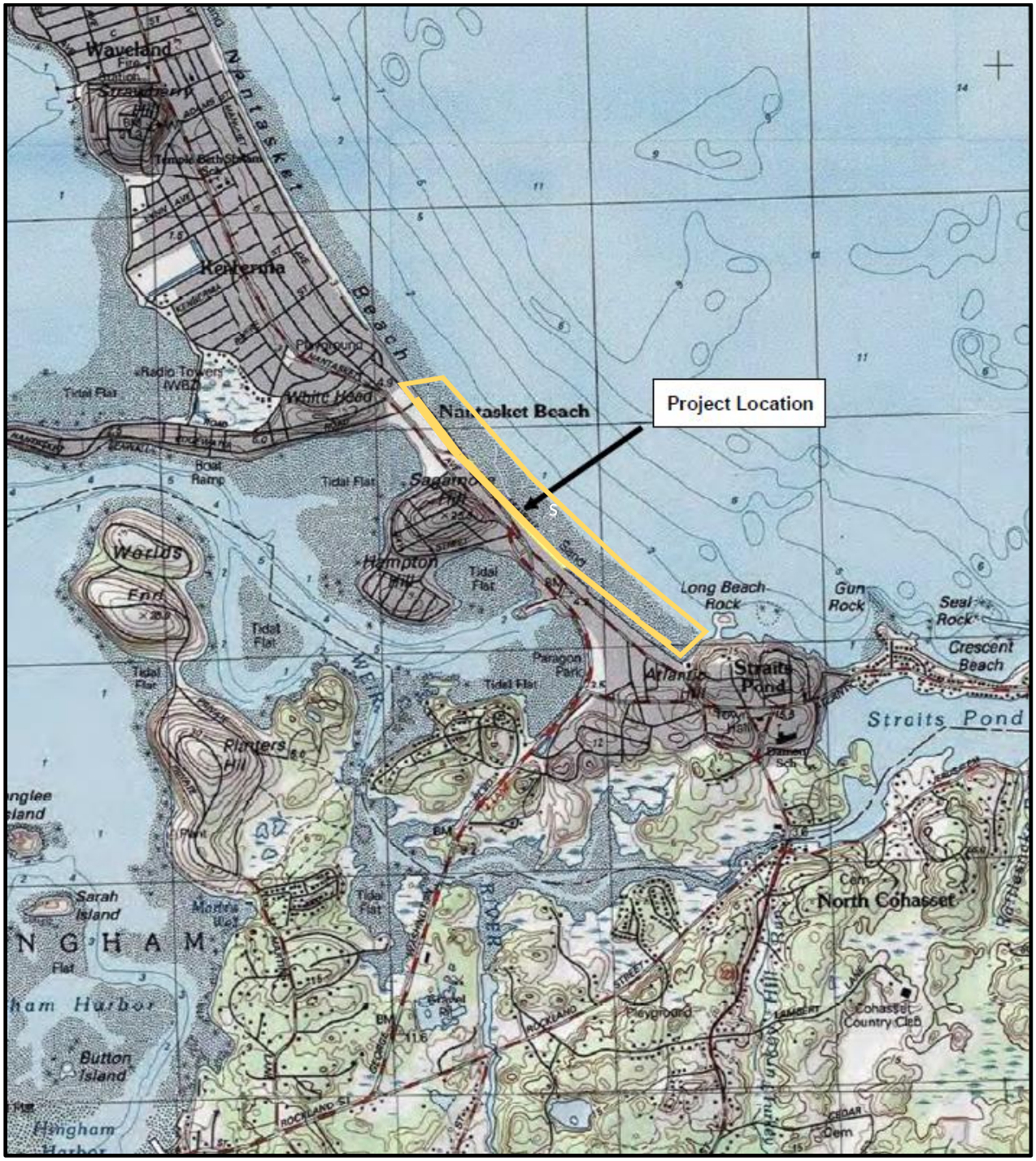


Figure 2-1. Project location (Scale: 1 inch = approximately 2,000 feet) Source of map: USGS

3. Distribution List for Expanded NPC

3.1 Executive Office of Energy and Environmental Affairs – Secretary's Office

Secretary Matthew Beaton
Executive Office of Energy and Environmental Affairs
Attn: MEPA Office
100 Cambridge Street, Suite 900
Boston, MA 02114

3.2 State Senators/Congressman

Senator Robert Hedlund
24 Beacon Street,
State House, Room 313C
Boston, MA 02133

Senator Elizabeth Warren
2400 JFK Building
15 New Sudbury Street
Boston, MA 02203

Senator Ed Markey
975 JFK Federal Building
15 New Sudbury Street
Boston, MA 02203

Congressman Stephen Lynch
1245 Hancock Street, Suite 41
Quincy, MA 02169

3.3 State Agencies

Massachusetts Department of
Environmental Protection
Commissioner's Office
Attn: MEPA Coordinator
1 Winter Street
Boston, MA 02108

Massachusetts Department of
Environmental Protection
Southeast Regional Office
Attn: Dave Hill, Chapter 91 Program
20 Riverside Drive
Lakeville, MA 02347

Massachusetts Department of
Environmental Protection
Southeast Regional Office
Attn: Greg DeCesare, 401 WQC Program
20 Riverside Drive
Lakeville, MA 02347

Massachusetts Department of
Environmental Protection
Southeast Regional Office
Attn: Jim Mahala, Chief, Wetlands and
Waterways Program
20 Riverside Drive
Lakeville, MA 02347

Jason Burtner
CZM South Shore Regional Coordinator
Massachusetts Office of Coastal Zone
Management
c/o Stellwagen Bank National Marine
Sanctuary
175 Edward Foster Road
Scituate, MA 02066

Bruce Carlisle, Director
Massachusetts Office of Coastal Zone Management
251 Causeway Street, Suite 800
Boston, MA 02114-2138

Bob Boeri, Project Review Coordinator
Massachusetts Office of Coastal Zone Management
251 Causeway Street, Suite 800
Boston, MA 02114-2138

David Pierce, Director
Massachusetts Division of Marine Fisheries
251 Causeway Street, Suite 400
Boston, MA 02114-2138

MA Division of Marine Fisheries
Annisquam River Marine Fisheries Field Station
Attn: Environmental Reviewer
30 Emerson Ave
Gloucester, MA 01930

Misty-Anne Marold
Senior Endangered Species Review Biologist, Massachusetts Division of Fisheries and Wildlife
Natural Heritage and Endangered Species Program
1 Rabbit Hill Road
Westborough, MA 01581

Priscilla Geigis
Deputy Commissioner for Conservation and Resource Stewardship
Massachusetts Department of Conservation and Recreation
251 Causeway Street, Suite 600
Boston, MA 02114

Mike Galvin
Project Engineer
Massachusetts Department of Conservation and Recreation
251 Causeway Street, Suite 600
Boston, MA 02114

Andy Backman
Director of Regional Planning
Massachusetts Department of Conservation and Recreation
251 Causeway Street, Suite 600
Boston, MA 02114

Massachusetts Historical Commission
Attn: MEPA Coordinator
220 William T Morrissey Boulevard
Dorchester, MA 02125

Secretary Stephanie Pollock
Massachusetts Department of Transportation
10 Park Plaza, Suite 4160
Boston, MA 02116

Jeff DeCarlo
Administrator
Aeronautics Division
Massachusetts Department of Transportation
10 Park Plaza, Suite 4160
Boston, MA 02116

Lionel Lucien
Manager, Public/Private Development Unit
Massachusetts Department of Transportation
10 Park Plaza, Suite 4160
Boston, MA 02116

Mary-Jo Perry
District Highway Director
Massachusetts Department of Transportation, District 5
1000 County Street
Taunton, MA 02780

Andrew Brennan
Director of Environmental Affairs
Massachusetts Bay Transit Authority
10 Park Plaza, Suite 3910
Boston, MA 02116

Marc Draisen
Executive Director
Metropolitan Area Planning Commission
60 Temple Place
Boston, MA 02111

Monica Bharel
Commissioner
Massachusetts Department of Public Health
250 Washington Street
Boston, MA 02108

Massachusetts Water Resource Authority
Attn: Environmental Reviewer
Charlestown Navy Yard
100 First Ave, Building 39
Boston, MA 02129

Karl Quackenbush
Executive Director, Central Transportation Planning Staff
Boston Regional Metropolitan Planning Organization
10 Park Plaza, Suite 2150
Boston, MA 02116

3.4 Municipal Government

3.4.1 Town of Hull

Kevin Richardson
Chairman, Board of Selectmen
Hull Town Hall
253 Atlantic Avenue
Hull, MA 02045

Joyce Sullivan
Public Health Director
Hull Town Hall
253 Atlantic Avenue
Hull, MA 02045

Chris Krahforst
Conservation Administrator
Hull Town Hall
253 Atlantic Avenue
Hull, MA 02045

Rhoda Kanet
Chairman
Hull Beach Management Committee
Hull Town Hall
253 Atlantic Avenue
Hull, MA 02045

Chris Dilorio
Director of Community Development and Planning
Hull Town Hall
253 Atlantic Avenue
Hull, MA 02045

3.4.2 Town of Cohasset

Kevin McCarthy
Chairman, Board of Selectmen
Cohasset Town Hall
41 Highland Avenue
Cohasset, MA 02025

Jeffrey Summers
Conservation Agent
Cohasset Town Hall
41 Highland Avenue
Cohasset, MA 02025

Margaret Chapman
Chairperson
Board of Health
Cohasset Town Hall
41 Highland Avenue
Cohasset, MA 02025

Jo-Ann M. Pilczak
Manager of Permitting and Inspections
Planning Board
Cohasset Town Hall
41 Highland Avenue
Cohasset, MA 02025

3.4.3 Town of Hingham

Judith S. Sneath
Chairperson, Planning Board
Hingham Town Hall
210 Central Street
Hingham, MA 02043

Loni Fournier
Hingham Town Hall
Senior Planner, Conservation Commission
210 Central Street
Hingham, MA 02043

Paul Gannon
Board of Selectmen
Hingham Town Hall
210 Central Street
Hingham, MA 02043

Bruce T. Capman
Executive Health Officer
Hingham Town Hall
210 Central Street
Hingham, MA 02043

3.4.4 Town of Scituate

Maura Curran
Chairperson, Board of Selectmen
Scituate Town Hall
600 Chief Justice Cushing Highway
Scituate, MA 02066

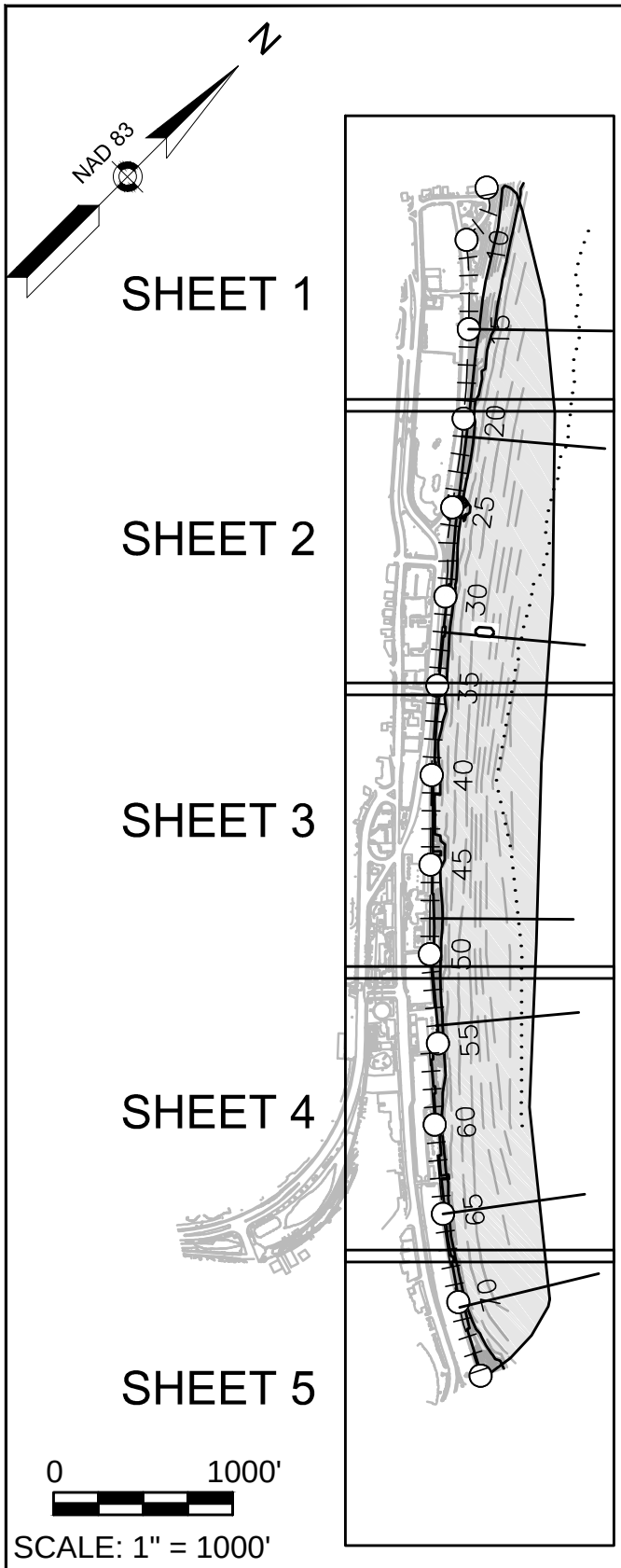
Brad Washburn
Director of Planning & Development
600 Chief Justice Cushing Highway
Scituate, MA 02066

Amy Walkey
Conservation Agent & Natural Resource Officer
Scituate Town Hall
600 Chief Justice Cushing Highway
Scituate, MA 02066

Jennifer Keefe
Director, Public Health
Scituate Town Hall
600 Chief Justice Cushing Highway
Scituate, MA 020

4. Preferred Alternative Design Plans

Plans attached in the chapters consist of 50% design plans for the Preferred Alternative, with plan views and selected cross-sections of beach fill.



NOTES:
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ELEVATIONS BASED ON NAVD 1988
VERTICAL DATUM (FEET)
MLW ELEVATION −5.16 FEET NAVD88
MHW ELEVATION 4.33 FEET NAVD88

VOLUME OF PROPOSED SAND NOURISHMENT = 700,000 CY & 75± ACRES

PLAN BY: Louis Berger
117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781−444−3330 FAX|781−444−0099

APPLICATION BY: MASSACHUSETTS DEPARTMENT OF CONSERVATION AND RECREATION

NANTASKET BEACH COASTAL STORM DAMAGE REDUCTION PROJECT, PHASE 2: BEACH NOURISHMENT

DATE: MARCH 15, 2018

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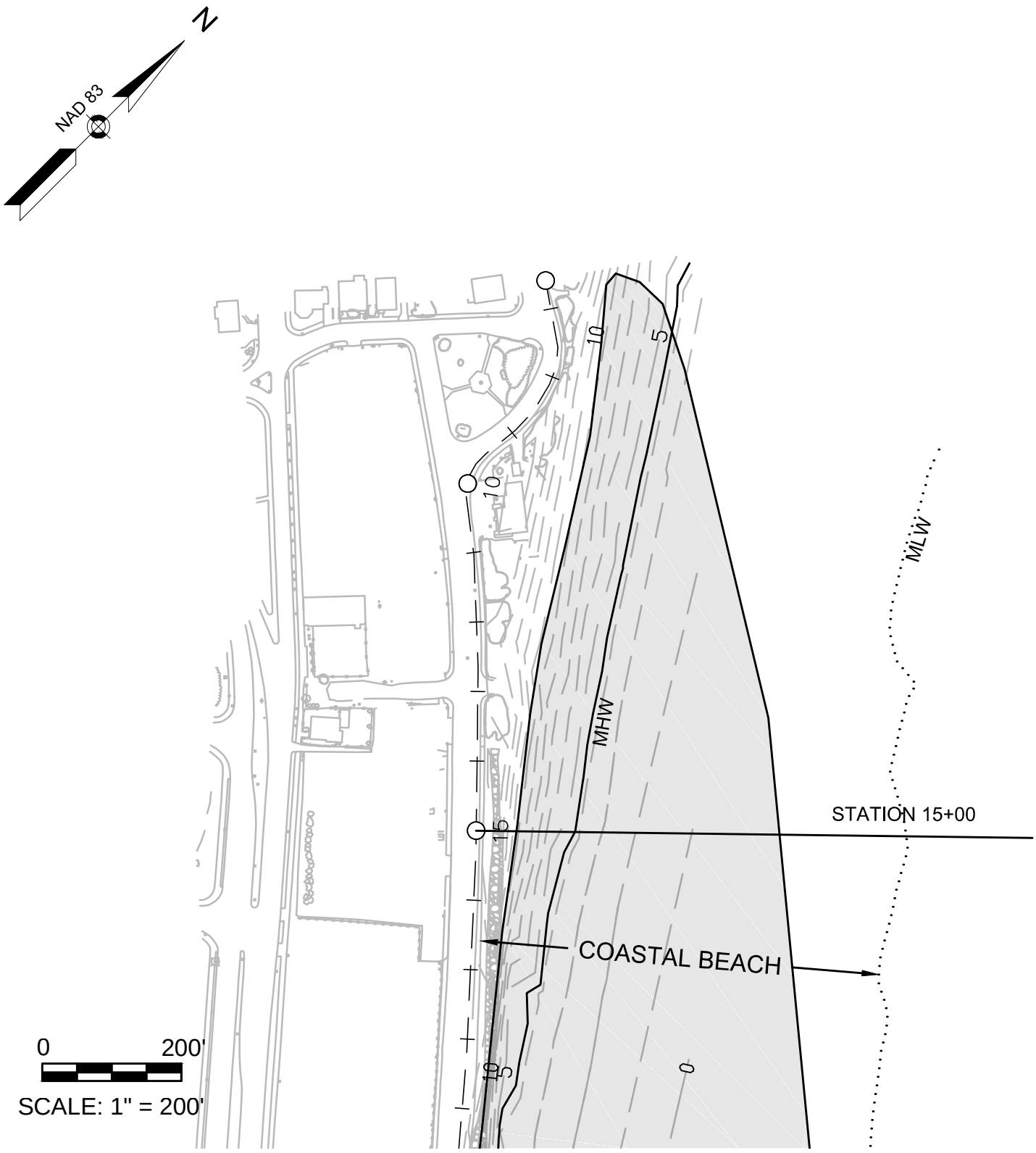

PLAN BY:

Louis Berger

117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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SHEET: 2 OF 10

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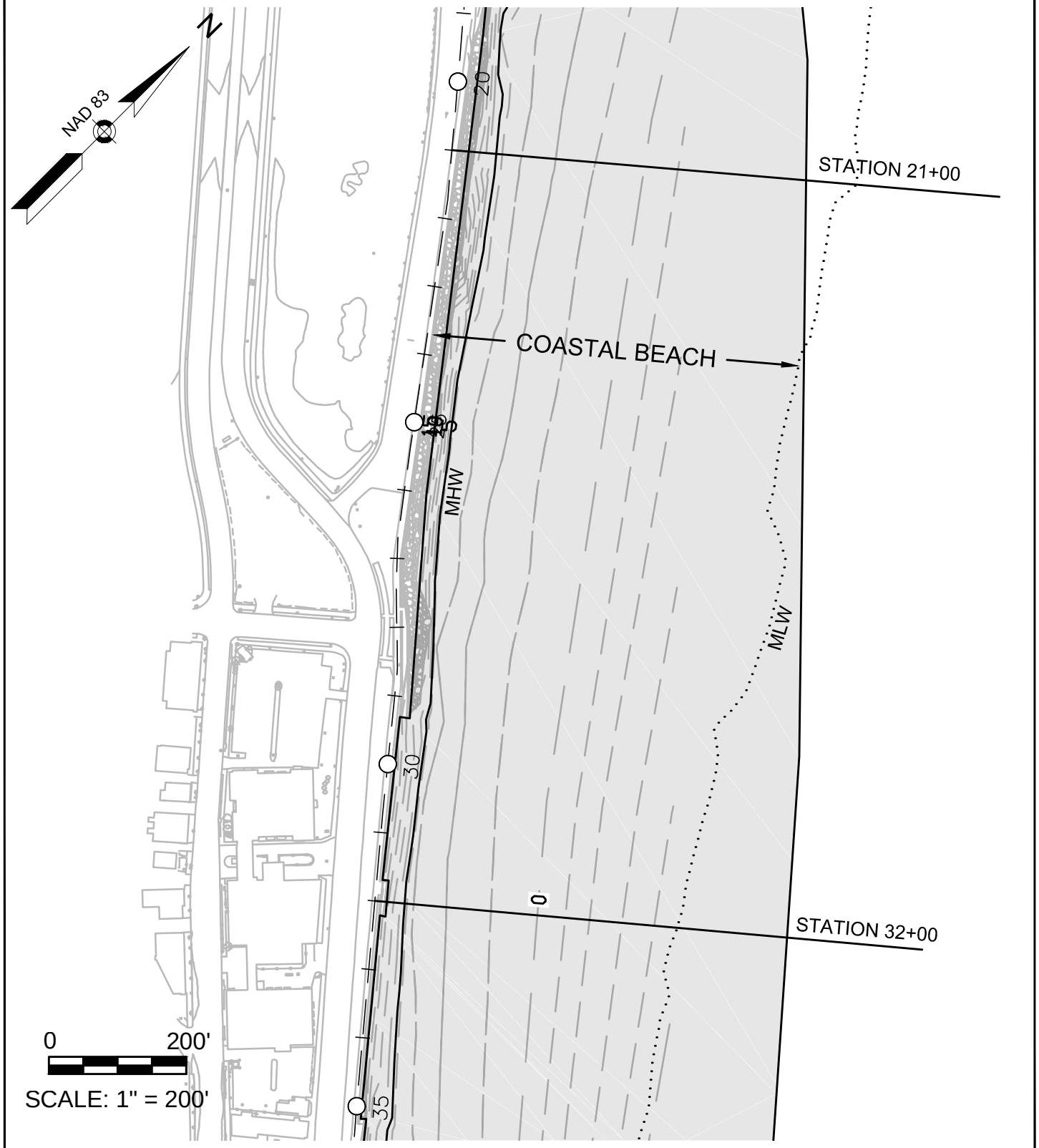

PLAN BY:

Louis Berger

117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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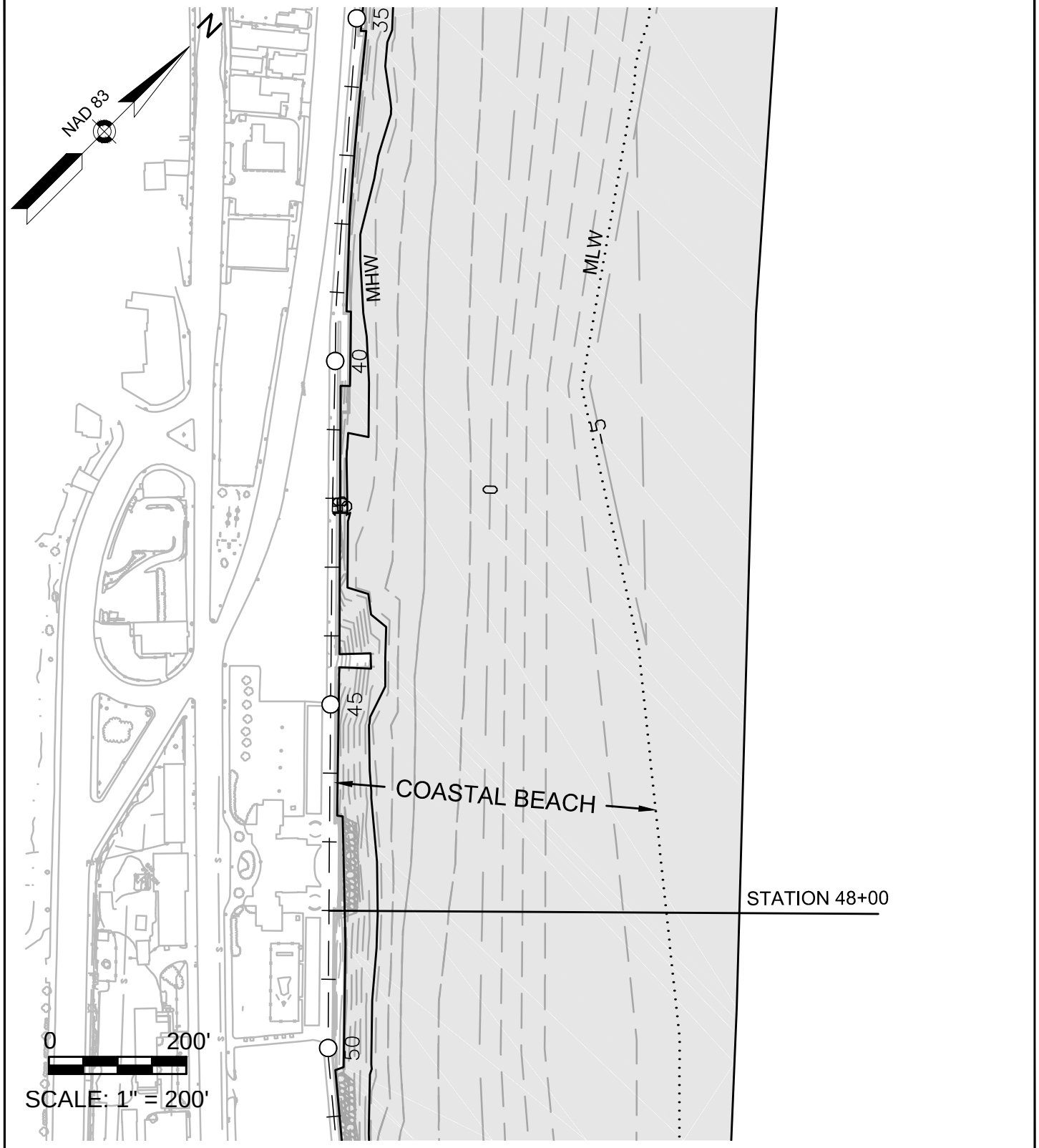

PLAN BY:

Louis Berger

117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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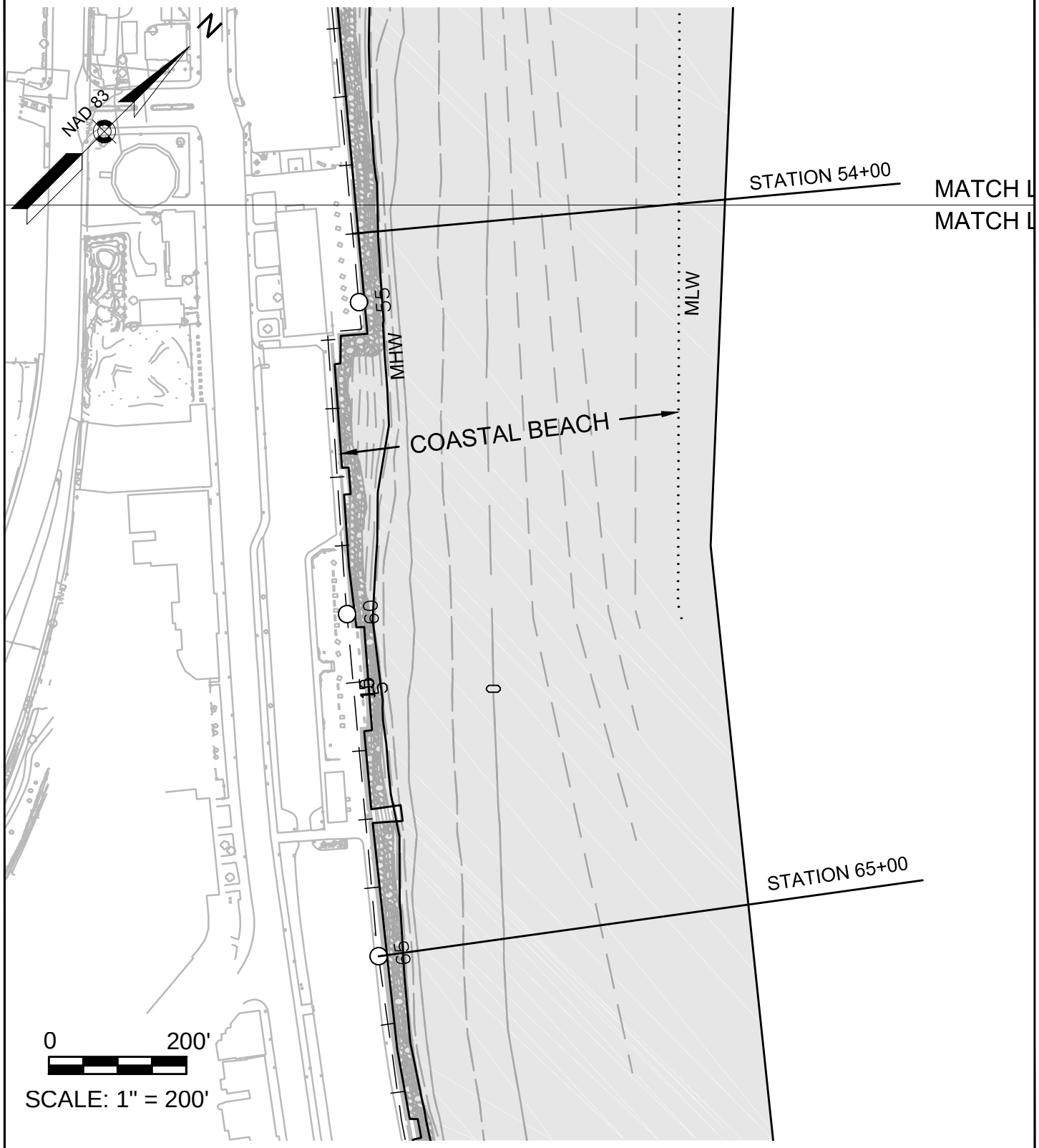

PLAN BY:

Louis Berger

117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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DATE: MARCH 15, 2018

SHEET: 5 OF 10

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SCALE: 1" = 200'

PLAN BY:

Louis Berger

117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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DATE: MARCH 15, 2018

SHEET: 6 OF 10

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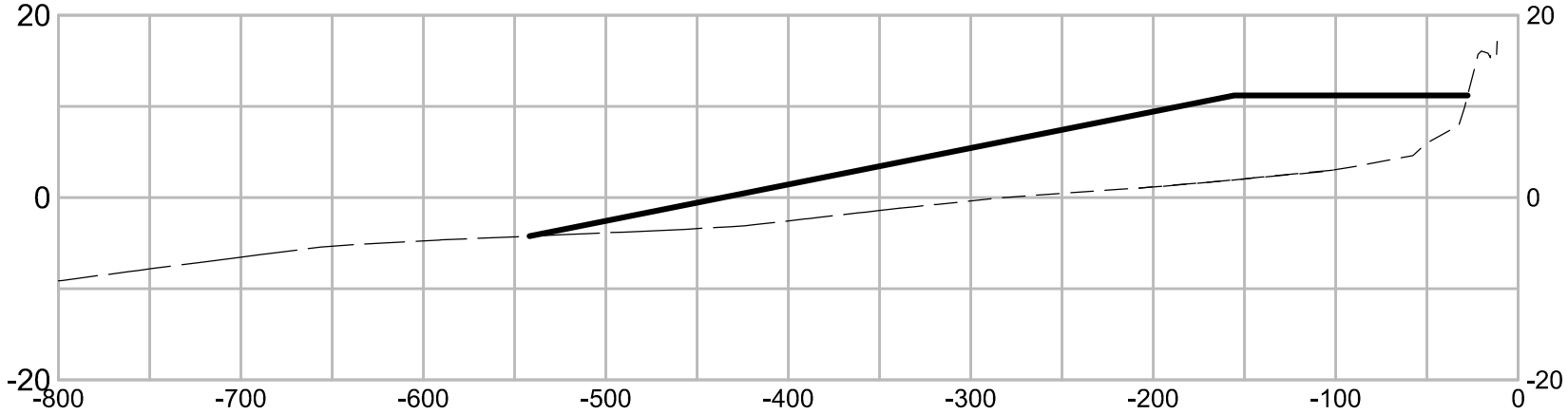

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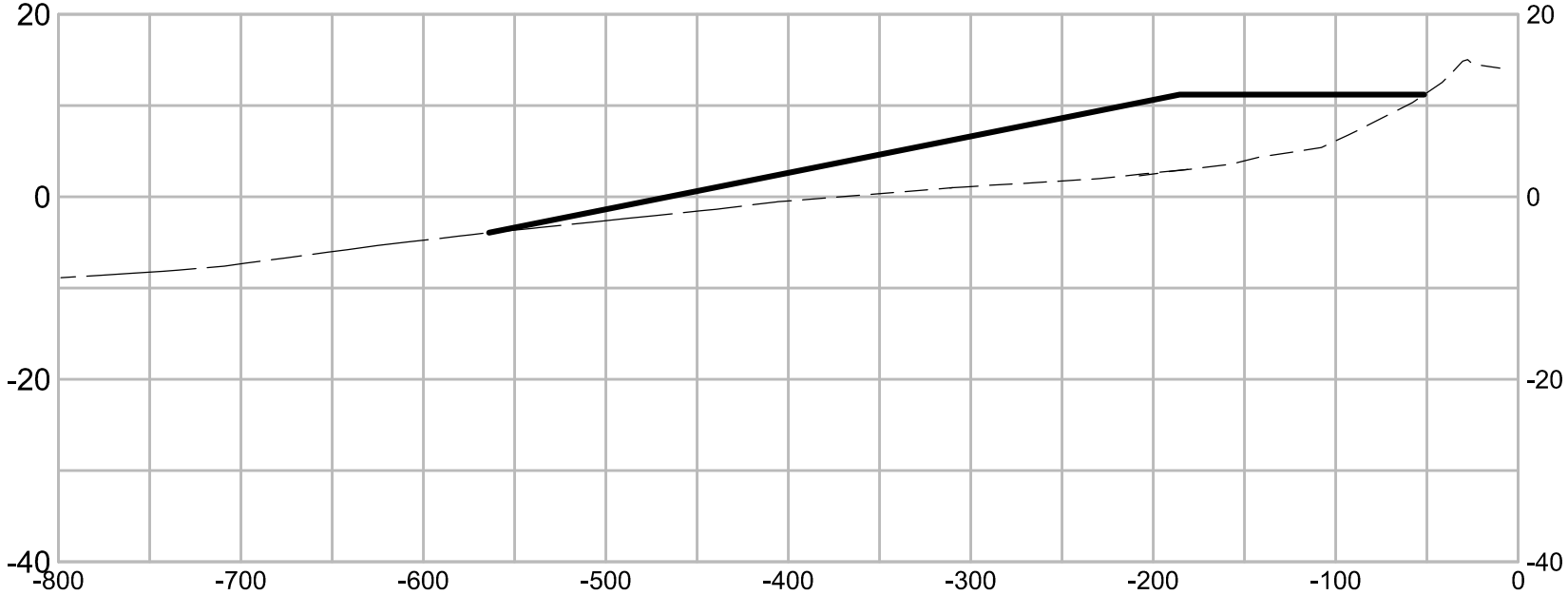

PLAN BY:
Louis Berger
117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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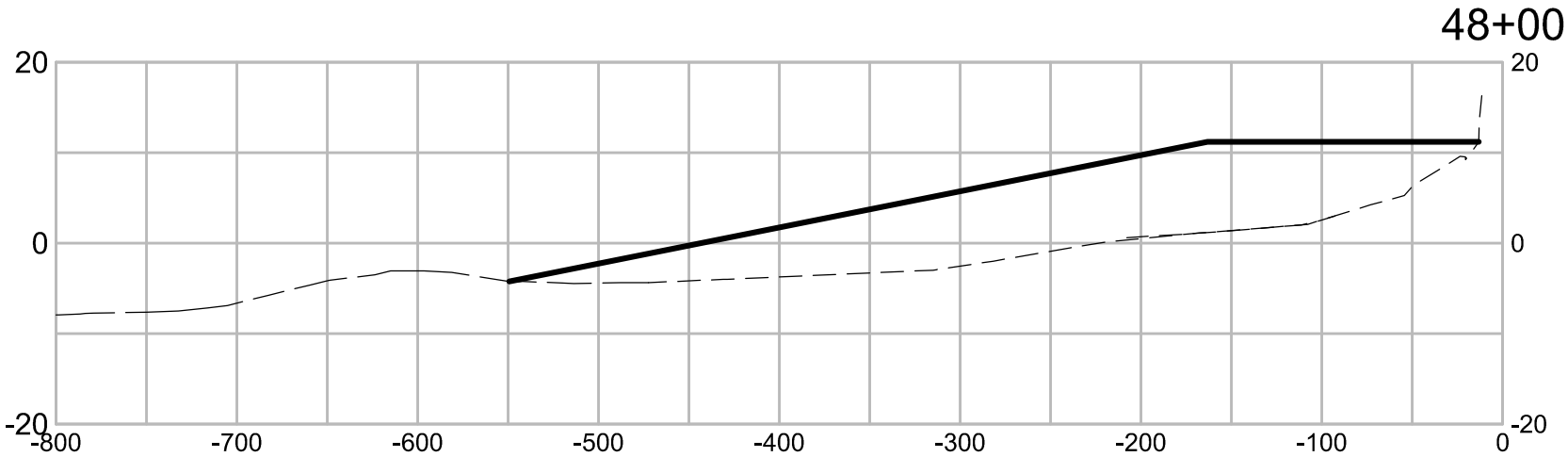

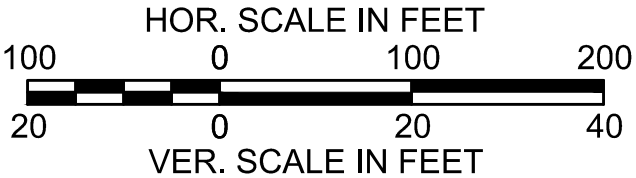

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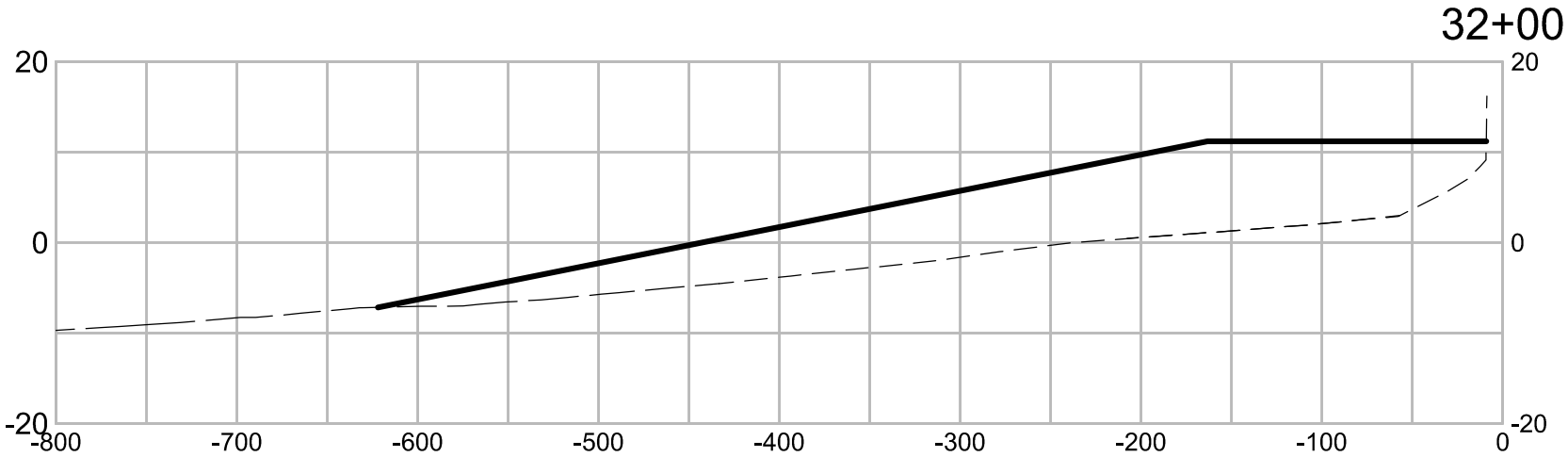

PLAN BY:
Louis Berger
117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

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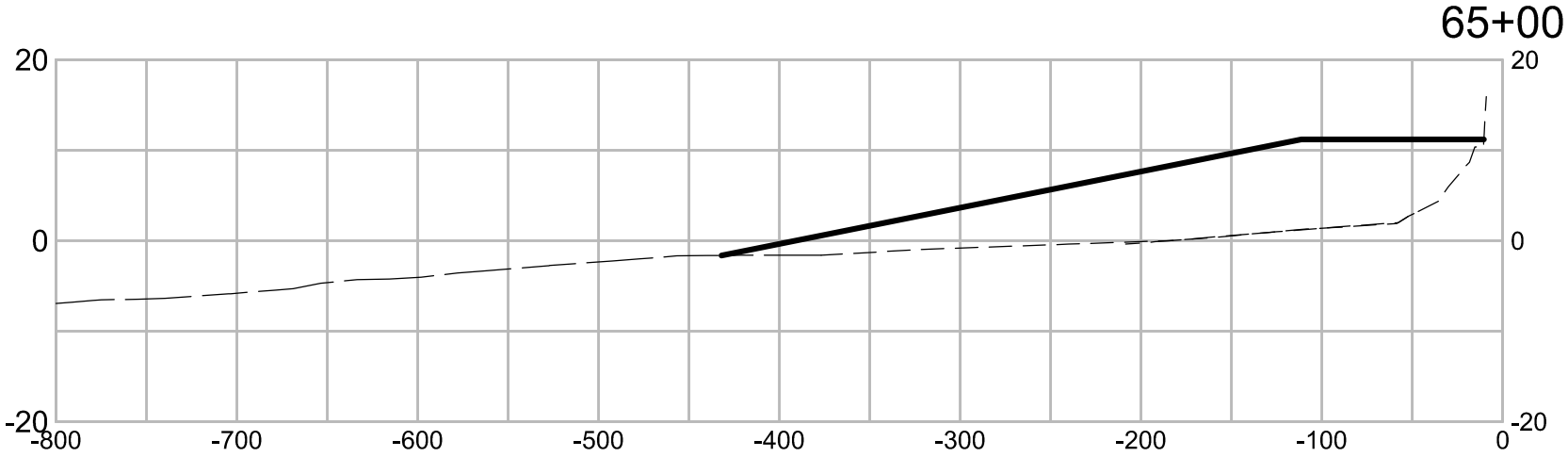

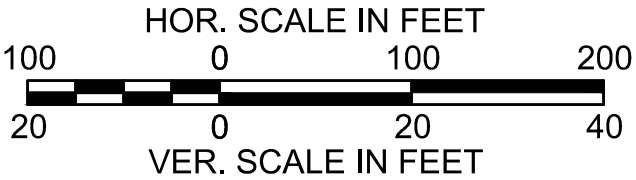

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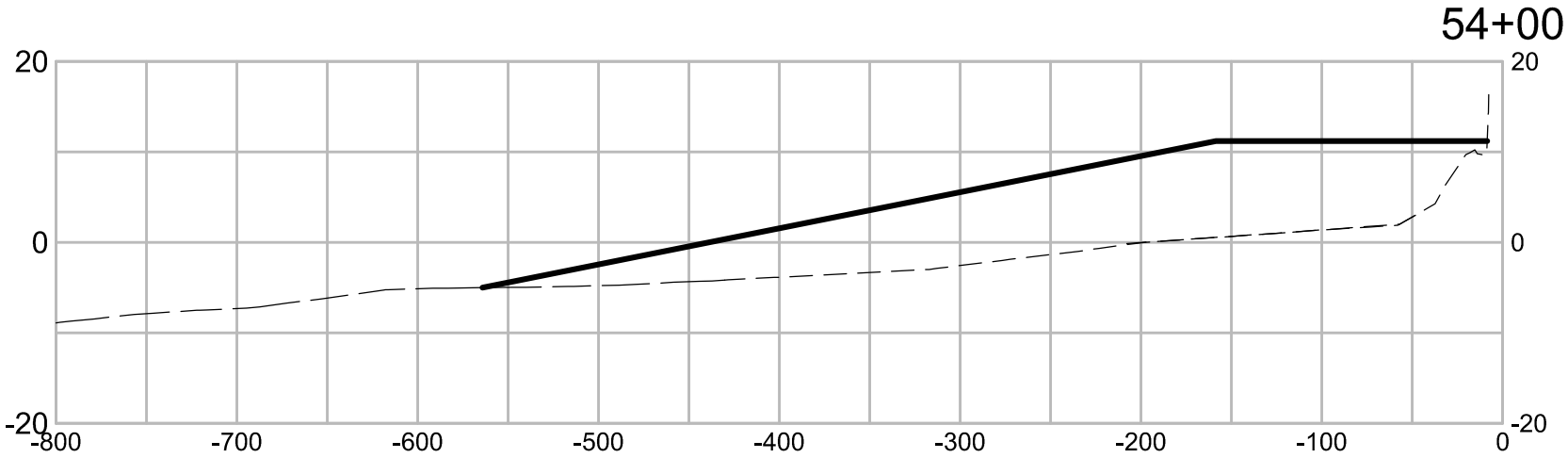

PLAN BY:
Louis Berger
117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

APPLICATION BY: MASSACHUSETTS DEPARTMENT OF CONSERVATION AND RECREATION

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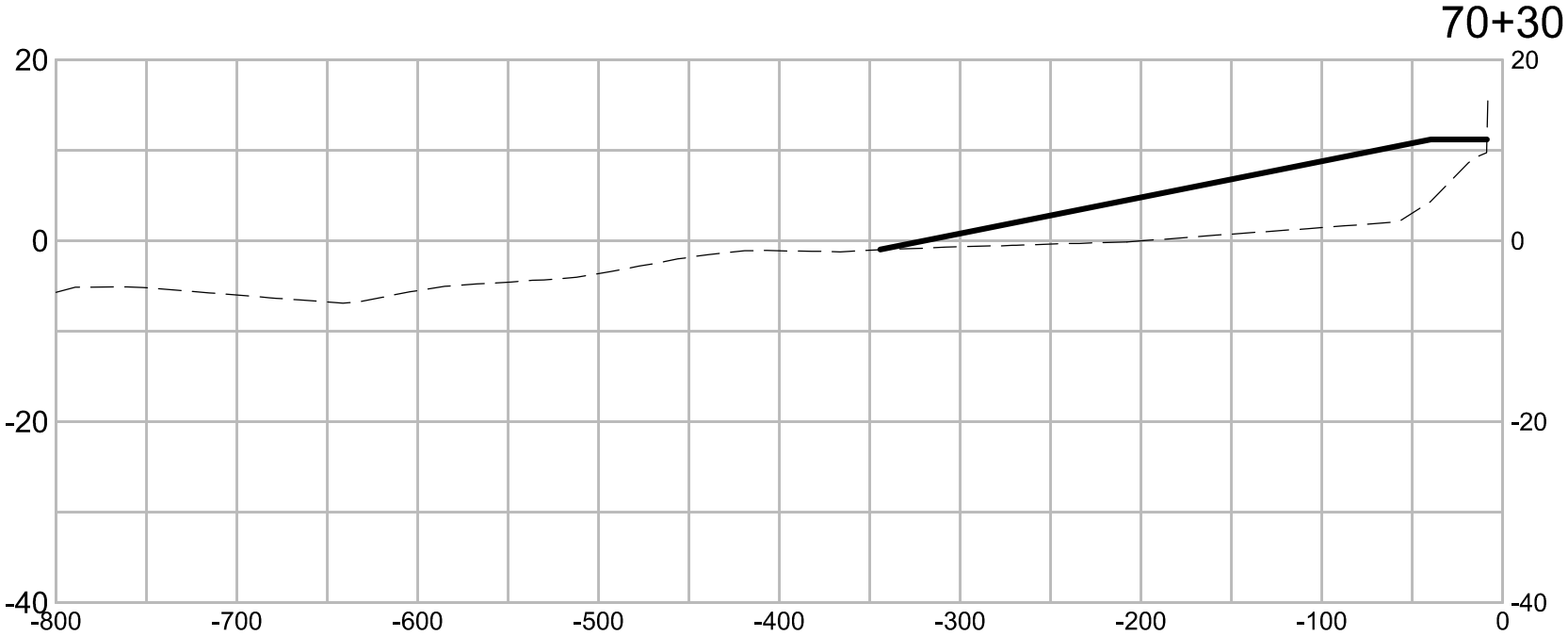

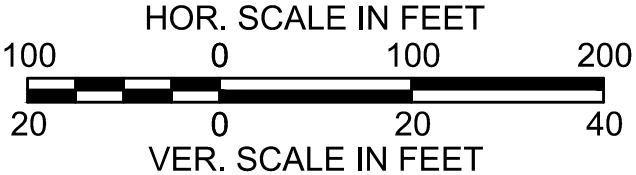

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PLAN BY:

Louis Berger
117 KENDRICK STREET, SUITE 400
NEEDHAM, MA 02494
P|781-444-3330 FAX|781-444-0099

APPLICATION BY: MASSACHUSETTS DEPARTMENT OF CONSERVATION AND RECREATION

NANTASKET BEACH COASTAL STORM DAMAGE REDUCTION PROJECT, PHASE 2: BEACH NOURISHMENT

DATE: MARCH 15, 2018

SHEET: 10 OF 10

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5. Introduction and Project Background

5.1 Project Background

The Nantasket Beach Coastal Storm Damage Reduction Project is located at DCR's Nantasket Beach Reservation (Reservation) in the Town of Hull, Plymouth County, Massachusetts. The Reservation is located along the southerly 6,800-foot (ft) long portion of the elongated peninsula in Hull that extends SE-NW into Massachusetts Bay (Figures 5-1 and 5-2). Beginning at its southern end, the Reservation contains a 5,400-ft long concrete seawall (Figures 5-3 to 5-5). The northern 1,400-ft end of the Reservation contains a rip rap revetment that transitions to an area of coastal dune and beach. The Reservation and its facilities are maintained by DCR. Public facilities include the seawall and revetment, a pavilion, a bathhouse, parking areas, and multiple structures from the days when the area was home to Paragon Park. Nantasket Beach is a popular destination for beachgoers in the summer, with the number of visitors in 2015 estimated to be 200,000. Many visitors also visit the Reservation in other seasons, for beach walks and ocean viewing.

Gradual erosion over time as a result of storm-driven waves from the east has resulted in a loss of beach material in front of the concrete seawall and consequent lowering of the beach elevation. As an example, beach elevation surveys conducted by DCR since 2006 show a gradual loss in beach elevation along the mid-section of the seawall (Figure 5-6). This has left the existing seawall vulnerable to damage and upland properties subject to an increased risk of storm damage and flooding due to overtopping during coastal storms. This increased flood risk and storm damage threatens public, commercial, and residential properties located landward of the seawall.

DCR has a long history of working cooperatively with the U.S. Army Corps of Engineers (USACE) on beach erosion control studies for Nantasket Beach. Early studies conducted by the USACE in 1949 and 1968 concluded that beach nourishment along the Reservation property should be pursued to create a protective and recreational beach. Unfortunately, the work was never completed. A subsequent Reconnaissance study by the USACE in 1993 found that a beach fill nourishment project constructed in front of the seawall was economically justified and that a Feasibility Study for the project was warranted. The Feasibility Report and Environmental Assessment for the Nantasket Beach DCR Reservation Coastal Storm Damage Reduction Project was completed in 2002 (USACE, 2002a). This study recommended proceeding with the engineering and design for a beach fill nourishment project, contingent upon a commitment by the DCR to reconstruct damaged portions of the seawall, ramps, and stairs prior to construction of the nourishment.

Following this recommendation by the USACE, the DCR filed an Environmental Notification Form (ENF) with the Massachusetts Environmental Policy Act (MEPA) in 2001 for the Nantasket Beach Coastal Storm Damage Reduction Protection Project. The work was proposed in two phases; Phase 1 included repairs to the seawall and Phase 2 included the placement of 280,000 cubic yards (cy) of material along the entire 6,800-ft long Reservation property (see original plan in Appendix A1), with the beach fill source to be identified at a later date. A Certificate of the Secretary of Environmental Affairs on the ENF was issued on January 25, 2002 requiring the preparation of an Environmental Impact Report (EIR) for both phases of the project (EOEA #12668; Appendix A2).

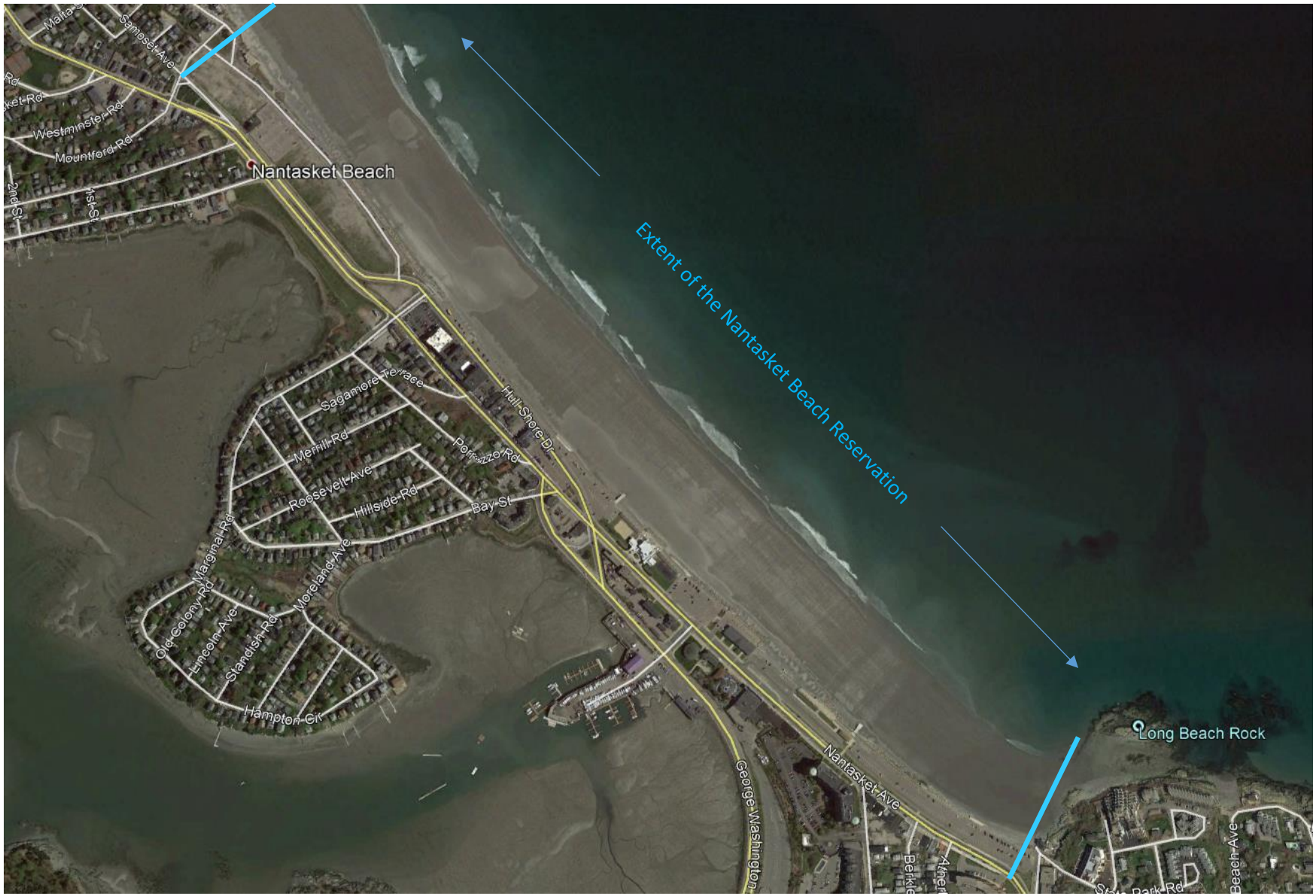


Figure 5-1. Aerial photograph of project area at low tide (Date of image: April 14, 2016) Source: Google Earth

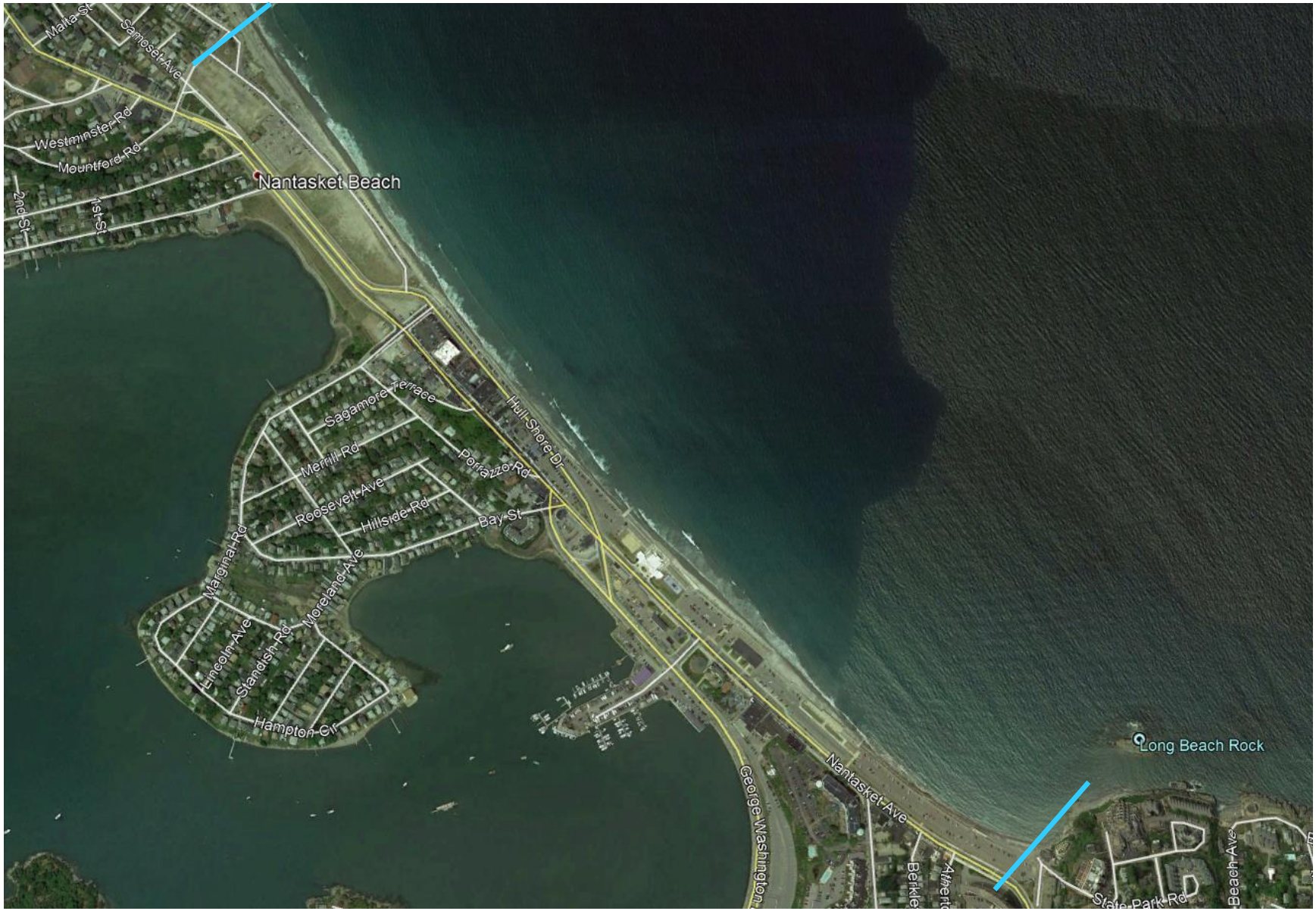


Figure 5-2. Aerial photograph of project area at high tide (Date of image: June 6, 2015) Source: Google Earth

Figure 5-3. Seawall along the southern section of the seawall with toe protection, at low tide *(top)* and high tide *(bottom)*. The high tide beach has been lost along the southern and mid-sections of the seawall because of long-term erosion.

Figure 5-4. Seawall along the mid-section of the seawall, still without toe protection (which is now under construction), at low tide *(top)* and high tide *(bottom)*

Figure 5-5. Shore protection along the northern section of the Reservation at high tide *(top)*, and along the 1,400-ft long section of riprap revetment with coastal dune and wider beach at the northern end of the Reservation *(bottom)*

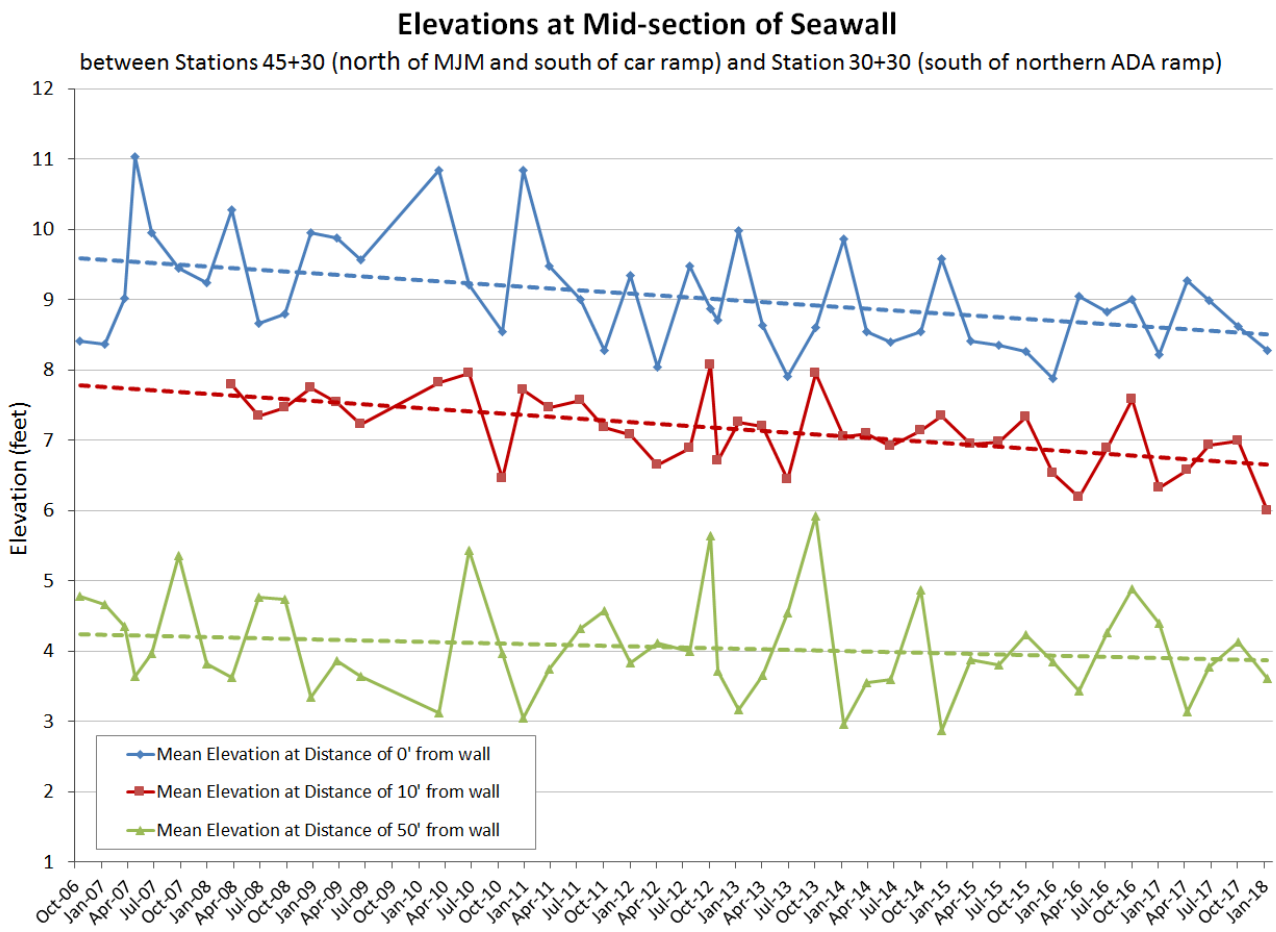


Figure 5-6. Beach elevations along the mid-section of the seawall. Elevations have been gradually decreasing.

Since this time, Notice of Project Change (NPC) applications were filed with MEPA in December 2004 and October 2006, requesting Phase 1 Waivers and changes to the designs for seawall and revetment improvements. The Phase 1 Waivers were granted in both cases, and Final Records of Decision (RODs) were issued in March 2005 and January 2007 (Appendix A3 and A4). The Secretary's Certificates on the NPCs indicated that the Phase 2 portion of the project for beach nourishment, as originally proposed in the 2001 ENF, was still subject to the preparation of a mandatory EIR.

DCR has been working since 2006 to implement repairs and improvements to the seawall, revetment, ramps and stairs as described in the various MEPA filings. A summary of the Phase 1 work completed to date is included in the following Section 5.2. During this same time, DCR continued to evaluate additional alternatives for shore protection at Nantasket Beach. A coastal engineering and shore protection alternatives assessment was performed for DCR by Woods Hole Group and Louis Berger in February 2010 (Appendix B). This study evaluated a range of alternatives including structural changes to the existing seawall and revetment, and various beach

nourishment designs. The recommended alternative from this study included seawall toe protection in combination with a 700,000 cy beach nourishment project. Upland sources of beach fill were also evaluated for short-term smaller nourishment efforts, but a larger source of beach fill for long-term protection, potentially from offshore sources, needed to be identified. Following this recommendation for a larger source of beach fill for beach nourishment, DCR worked with the USACE to evaluate potential sources in the New England region. Fortunately, a source of beach-compatible material was identified recently from a USACE navigation project in the Piscataqua River in New Hampshire.

As a result of this work, the design for the Phase 2 nourishment at Nantasket Beach has been revised to include a larger volume, to be obtained from the USACE dredging in the Piscataqua River. The design includes a nourishment project with up to 700,000 cy of beach fill that extends along the entire 6,800-ft long Reservation, impacting approximately 75 acres of coastal beach and land under the ocean. This Expanded NPC has been prepared to describe the changes to the Phase 2 portion of the Nantasket Beach Coastal Storm Damage Reduction Protection Project. The new Phase 2 design exceeds the MEPA threshold 301 CMR 11.03(a)1.b for a mandatory EIR. However, as allowed under 301 CMR 11.11(3) the DCR is requesting a waiver from the mandatory EIR. The basis for the waiver request is provided in Section 5.4.

5.2 History of Phase 1 Activities to Date

Activities have been underway since 2007 that have advanced Phase 1 of the Nantasket Beach Coastal Storm Damage Reduction Project. Following is a brief summary of the work completed to date:

- **Beach Elevation Monitoring (2006 – ongoing):** Beach elevation monitoring along the entire seawall has been conducted continuously since 2006 on a quarterly basis to assess the performance of the beach.

- **Granite Stairs (2006 - 2007):** Granite stairs were designed and placed in front of all access point along the southern section of the seawall to allow for safe beach access by beachgoers (Figure 5-7). These stairs consist of multiple 400-lb granite blocks, tightly placed, with an underlayer of stones. Construction was completed in 2007.

- **Handicap-accessible Ramps (2007 - 2008):** Three ramps were designed and constructed in the middle section of the seawall (Figure 5-8). These ramps were designed to be compliant with the Americans with Disabilities Act (ADA). Construction was completed in 2008.

- **Emergency Stabilization of an approximately 170-ft Section in front of the DCR-owned Mary Jeanette Murray Bath House (2012 - 2013):** An assessment of the seawall in front of the bath house determined that the seawall was at risk, as cracks had developed on the upland side of the seawall and the footing of the seawall was getting increasingly exposed (Figure 5-9). A stone revetment was placed in 2013 for the protection of the seawall.

Figure 5-7. Granite stairs constructed along southern section of the seawall at access points

Figure 5-8. Americans with Disabilities Act (ADA) compliant ramps constructed in the middle and southern sections of the seawall

Figure 5-9. Emergency stabilization in front of the DCR-owned Mary Jeanette Murray Bath House in 2013

- **Current Construction Project – Seawall Toe Protection (STP) in the mid-section of the seawall:** This construction project will be completed at the end of May 2018. The STP is similar in design to the revetment along the southern part of the seawall (Figures 5-3 and 5-7). A cross-section of the STP design is provided in Figure 5-10. Completion of the STP will complete Phase 1 of the Coastal Storm Damage Reduction Project.

It is important to note that the Phase 2 beach nourishment was identified as a requirement in Massachusetts Department of Environmental Protection's (MassDEP) Superseding Order of Conditions (Special Condition 8), issued on August 31, 2017 for this portion of the Phase 1 work. The Special Condition states,

> *"Within six (6) months of the date of this Superseding Order, [DCR] shall submit a plan and schedule for MassDEP approval indicating all measures necessary to identify a source of material, plan and execute a beach nourishment project in the amount of at least 280,000 cubic yards along a 6,800 linear foot section of the seawall to provide additional storm damage protection and flood control as required by the Certificate of the Secretary, dated December 15, 2006 for Phase 2 of the project."*

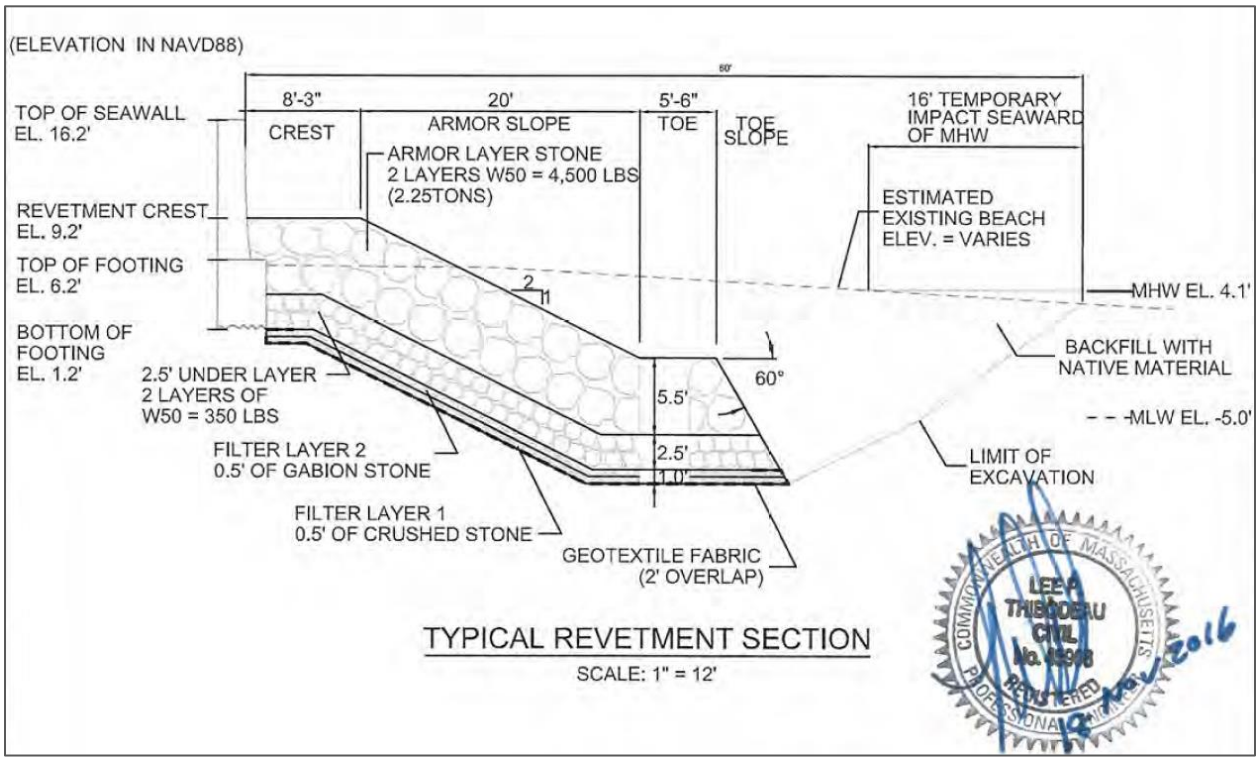


Figure 5-10. Cross-section of STP currently being placed in front of the mid-section of the seawall

5.3 Project Description

A number of engineering alternatives were evaluated to identify a beach nourishment design for Phase 2 of the Nantasket Beach Coastal Storm Damage Reduction Protection Project. Alternative D has been selected as the preferred alternative for the nourishment. A discussion of the other alternatives evaluated as part of this project is provided in Chapter 7 "Alternatives Analysis".

Alternative D includes the placement of up to 700,000 cy of clean beach compatible material along 6,800 linear ft of the shoreline at the DCR Nantasket Beach Reservation (Figure 5-11). The beach would be increased to an elevation of 11.2 ft (NAVD88) across a berm that extends out from the seawall and revetment by an average of 150 ft. This elevation would cover the revetment in the southern and mid-sections of the seawall by 2 ft. From the berm crest, the nourishment profile would slope gradually at a 1V:25H grade to meet the natural elevation of the existing nearshore profile. The nourishment footprint would occupy approximately 75.3 acres of existing coastal beach and land under the ocean. By widening and raising the elevation of the beach, the location of mean high water (MHW) would be pushed seaward by more than 300 ft. This would greatly increase the available recreational area for this public beach. The project would also reduce vulnerability to coastal storms, flooding, erosion, and sea level rise for public, commercial, and residential properties. In addition, the project would strengthen natural ecosystems for the benefit of state and federally listed shorebirds. Engineering plans, cross-sections and additional details of Alternative D are provided in Chapter 4.

A number of alternatives have also been considered and evaluated for sources of sand to nourish the beach. Both upland and offshore alternatives were considered and eliminated by the DCR. Fortunately, a viable source of material has been identified from the USACE navigation project to dredge the Piscataqua River along the border of New Hampshire and Maine. The volume of material to be dredged is approximately 728,000 cy of sand and gravel, which has been found to be compatible with the native Nantasket Beach sediments. In the spring of 2017, Nantasket Beach was added to the potential list of recipients for beneficial reuse of the dredged material. Consequently, Piscataqua River has been selected as a viable alternative for a source to nourish Nantasket Beach.

Dredging work in the Piscataqua River is being permitted and constructed by the USACE and their selected contractor. As such, the dredging activities and barge transport to the pump-out location offshore of Nantasket Beach are not addressed in this Expanded NPC. Details regarding the expected barge operations and beach nourishment construction process are provided in Section 5.5.

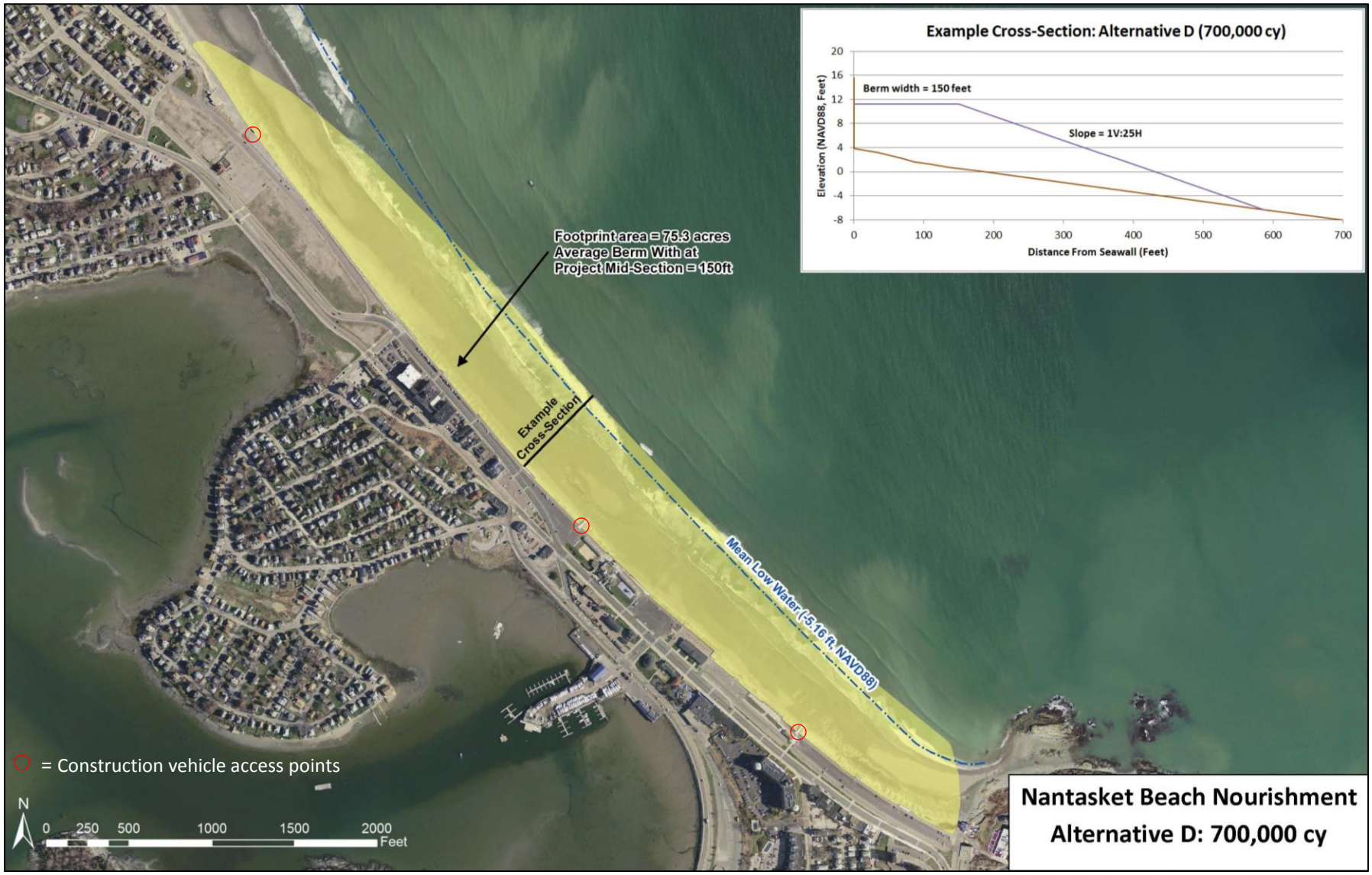


Figure 5-11. Beach nourishment Alternative D selected as the preferred alternative for Nantasket Beach

5.4 Request for Waiver from Mandatory EIR

Since the Phase 2 beach nourishment proposes to alter approximately 75 acres of resource area protected by the MEPA Regulations (301 CMR 11.00), a mandatory EIR is required. Specifically, the project exceeds the Land threshold of direct alteration of 50 or more acres of land (301 CMR 11.03(1)(a)1), and the Wetlands, Waterways, and Tidelands threshold of altering more than ten acres of a wetland (301 CMR 11.03(3)(a)1.b. However, as permitted by 301 CMR 11.11 a waiver from the requirement of the mandatory EIR is being requested. The basis for the waiver request is provided below.

301 CMR 11.11(1) Standards for all Waivers. The Secretary may waive any provision or requirements in 301 CMR 11.00 not specifically required by MEPA and may impose appropriate and relevant conditions or restrictions, provided that the Secretary finds that strict compliance with the provision or requirement would:

(a) Result in an undue hardship for the Proponent, unless based on delay in compliance by the Proponent.

Response: DCR was informed by the USACE in January 2018 that dredging could occur as early as October 2018, and DCR would need permits in place to be able to receive the sediment for beneficial use on Nantasket Beach. A clean, suitable source like the Piscataqua River source is rare in the region, as sediments of many dredging projects are often too fine-grained and may further be contaminated, and as offshore borrow sites do not currently exist. This sand source is ideal to address the mandatory condition under the Superseding Order from MassDEP from August 31, 2017 for implementing Phase 1.

In addition, a loss of this source would result in a loss of substantial benefits to the socio-economic resources, as follows:

- Beach fill would reduce overtopping during storm conditions, thereby reducing flood damages to facilities and properties owned by DCR, the Town of Hull, and private owners. Some of DCR's properties are eligible for listing on the National Register of Historic Places as a contributing structure within a potential Nantasket Beach Reservation Historic District.
- While the implementation of Phase 1 (STP) will provide most of the added support for the seawall, beach nourishment would further protect the seawall, thereby further reducing the risk of damages of upland properties and facilities.
- The high tide beach would provide recreational opportunities for many beachgoers in the wider region, not just for residents of the Town of Hull. Nantasket Beach is unique for a beach in a metropolitan area as it has excellent water quality at all times of the year due to its open ocean conditions, without being impacted by storm drains, streams, and other potentially contaminated point sources. Furthermore, Nantasket Beach has good access and ample parking allowing residents from communities in the region without a waterfront, a valuable opportunity for recreation in and along the ocean without long travel distances.

- More visitors, and visitors that stay longer due to a high tide beach created by the nourishment, would provide more economic opportunities for businesses on the Reservation and the Town of Hull. Many of these businesses have been struggling due to the seasonal nature of visitors. An additional economic multiplier effect would occur with the eventual implementation of DCR's Master Plan (DCR, 2016). The net effect of this implementation would be even more visitors and recreational and cultural opportunities, further adding to economic benefits. A nourished beach is critical to DCR's vision for this plan.

In summary, loss of this rare source for beach fill would constitute an undue hardship for DCR, and, considering DCR's mission *("To protect, promote and enhance our common wealth of natural, cultural and recreational resources for the well-being of all"),* loss of this source would also constitute an undue hardship to the residents and businesses of the Town of Hull and surrounding communities.

(b) Not serve to avoid or minimize Damage to the Environment

Response: Environmental resources and coastal processes in the project area are well understood. Since the initial 2001 ENF for this project, substantial information has been accumulated that is presented and analyzed in this Expanded NPC; study reports are included as Appendices C to F. DCR has also consulted state agencies such as the MEPA Office, MassDEP, Massachusetts Office of Coastal Zone Management (CZM), the Massachusetts Division of Marine Fisheries (DMF), and the Conservation Commission of the Town of Hull.

Existing environmental resources are described in Chapter 6 ("Existing Environment"). As specified in Chapter 8 ("Assessment of Impacts") of this Expanded NPC, the proposed project would have no to negligible long-term impact on the environment. Short-term, benthic organisms and some surf clams would be buried in the footprint of the nourishment. However, the habitat would be replaced with the same type of material, and the nourished area is expected to recolonize rapidly and fully (i.e., habitat would not be lost). No hard structures would be placed into the footprint under Phase 2 (i.e., there would no permanent alteration of the habitat). Instead, the high tide beach created by the beach fill would substantially enlarge potential habitat for listed Piping Plover by reestablishing a high tide beach along Nantasket Beach. According to the Massachusetts Natural Heritage & Endangered Species Program (NHESP), the northern end of the proposed project area is has been mapped habitat for the Piping Plover.

Preparation of this Expanded NPC integrated the scope for the EIR contained in the Certificate on the ENF issued on January 25, 2002. The Expanded NPC also addresses appropriate construction and post-construction management and monitoring measures to avoid or minimize damage to the environment. In summary, an EIR would not serve to further avoid or minimize damage to the environment.

301 CMR 11.11(3) <u>Determination for EIR Waiver</u>. In the case of a waiver of a mandatory EIRR review threshold, the Secretary shall at a minimum based the finding required in accordance with 301 CMR 11.11(1)(b) on a determination that:

(a) the Project is likely to cause no Damage to the Environment.

Response: Please see the Response above for 301 CMR 11.11(1)(b).

(b) ample and unconstrained infrastructure facilities and services exist to support the Project (in the case of a Project undertaken by an Agency or involving Financial Assistance) or those aspects of the Project within subject matter jurisdiction (in the case of a Project undertaken by a Person and requiring one or more Permits or involving a Land Transfer but not involving Financial Assistance).

Response: Ample and unconstrained infrastructure exists to support Phase 2 of the project. Phase 2 would be constructed on state property and reduce flooding of existing facilities and infrastructure resulting from overtopping during storms.

5.5 Construction Methodology and Timing

Construction would consist of: (a) dredging sediment from the Piscataqua River and placing the sediment in a barge, (b) transport of the barge to the pump out location offshore of Nantasket Beach, (c) pumping the material onto the beach from the barge moored offshore, (d) directing the slurry to facilitate settling of the sediment on the beach and runoff of supernatant water back to the Bay, and (e) regrading the sediment to the design specifications using land-based excavators and/or bulldozers. The USACE would be responsible for permitting and implementing the first three steps (a through c), while the DCR is permitting the last two steps (d and e) involving construction of the beach nourishment.

According to the USACE, dredging has been permitted to occur between October 15 and April 15 (a window of six months). Excavated sediment would be placed into scows with a capacity of 3,500 to 5,000 cy. Once filled to capacity, the loaded scows would be towed to a location approximately 2,600 ft offshore of Nantasket Beach. The scow mooring location would be in water depths greater than 24 ft mean lower low water (MLLW). It is estimated that up to two (2) scows of dredged material would be delivered to the offshore mooring site each day. The scows would be equipped with pump-out capability and would be used to fluidize the sediment so that it can be pumped hydraulically to the beach. A pipeline would be used to direct the material from the pump to the targeted nourishment locations on the beach.

Nourishment would likely start in the southernmost corner of Nantasket Beach, and gradually progress to the north. The length of the construction zone on the beach at any given time would be approximately 1,000 ft, including the discharge site and the regrading activities behind the pipeline. This zone would gradually move to the north, as additional pipeline is added to advance the beach nourishment to the north. Where necessary, sediment deposited from the discharge pipe would be regraded using land-based excavators and/or bulldozers to ensure the nourishment matches the design specifications and nourishment template. Surveys would be performed during construction to ensure the beach is built to the correct elevations and slopes.

The staging area for the land-based work would be located upland of the seawall. Only equipment needed for moving material and advancing the pipeline would be on the beach at any given time. Access to the beach for construction equipment would be via existing ramps shown in Figure 5-

11. There are multiple large parking lots along the entire length of the seawall that would available for use for staging equipment during the period of the nourishment. Space is available at DCR's nearby facility for administrative office requirements, including sanitary facilities.

DCR understands that Nantasket Bach is an active recreational beach and would work with the USACE contractor to minimize impacts to residents and beachgoers, such as safety, noise, aesthetics, and limits to the recreational zone and other blocked-off areas. Work by the USACE in the Piscataqua River is expected to occur during the mid-October to mid-April dredging season, during 2018/2019 or 2019/2020, or a subsequent year, pending available funding for the dredging project. At this time, the USACE is prepared to start dredging as soon as funds are available (i.e., as early as October 15, 2018). The planned fall/winter dredging season corresponds with typical time of year (TOY) construction windows for beach nourishment projects in Massachusetts designed to protect marine resources and state/federally listed species.

6. Existing Environment

6.1 Physical Conditions

6.1.1 Geology

Nantasket Beach formed from the erosion of several drumlin islands in the area (Johnson and Reed, 1910). Drumlins are glacially deposited landforms composed of silt, sand, gravel and boulders. Several of these drumlins were once located east of Nantasket Beach but have been completely eroded over time. Most of the sediment along Nantasket Beach was derived from the erosion of these drumlins. Other drumlins on the Hull peninsula (Strawberry Hill, Sagamore Head, and Whitehead) are now protected from marine erosion by the beaches in front of them. The existing drumlins in the area add little material to Nantasket Beach and it does not appear likely that a significant amount of material is being added from the sites of the destroyed drumlins (USACE, 2014).

6.1.2 Sediment Characteristics

The sediment in the vicinity of Nantasket Bach has been mapped as mostly sand by CZM-USGS (Figure 6-1). Approximately 3,000 ft offshore from the Reservation, the seafloor has been mapped as hard complex seafloor. Rock with gravel exists approximately 2,000 ft offshore the southernmost end of the Reservation.

In the fall of 2005, Ocean Surveys, Inc. conducted a characterization study of Nantasket Beach on behalf of the DCR and USACE (USACE, 2006). The study included the collection of vibracores and ponar grab samples along five beach transects, and subsequent grain size analyses of the collected samples. At each station, cores were split into an upper sample (upper 2 ft of the sediment column) and a lower sample (lower 2 ft). Three transects (#3, #5, and #7) were located adjacent to Nantasket Beach (Figure 6-2). These transects extended approximately 3,000 ft out to sea. Cores were collected at the following stations (elevations in NAVD88):

- *Dune (Transect #3 only):*
  - Base of dune (+12.3 ft)
  - Mid-berm (+8.2 ft)
  - Berm crest (+6.5 ft)

- *Beach and Intertidal Zone:*
  - Mean high water (MHW; +4.3 ft)
  - +2.0 ft
  - MSL (-0.3 ft)
  - -3.0 ft
  - Mean low water (MLW; -5.3 ft)

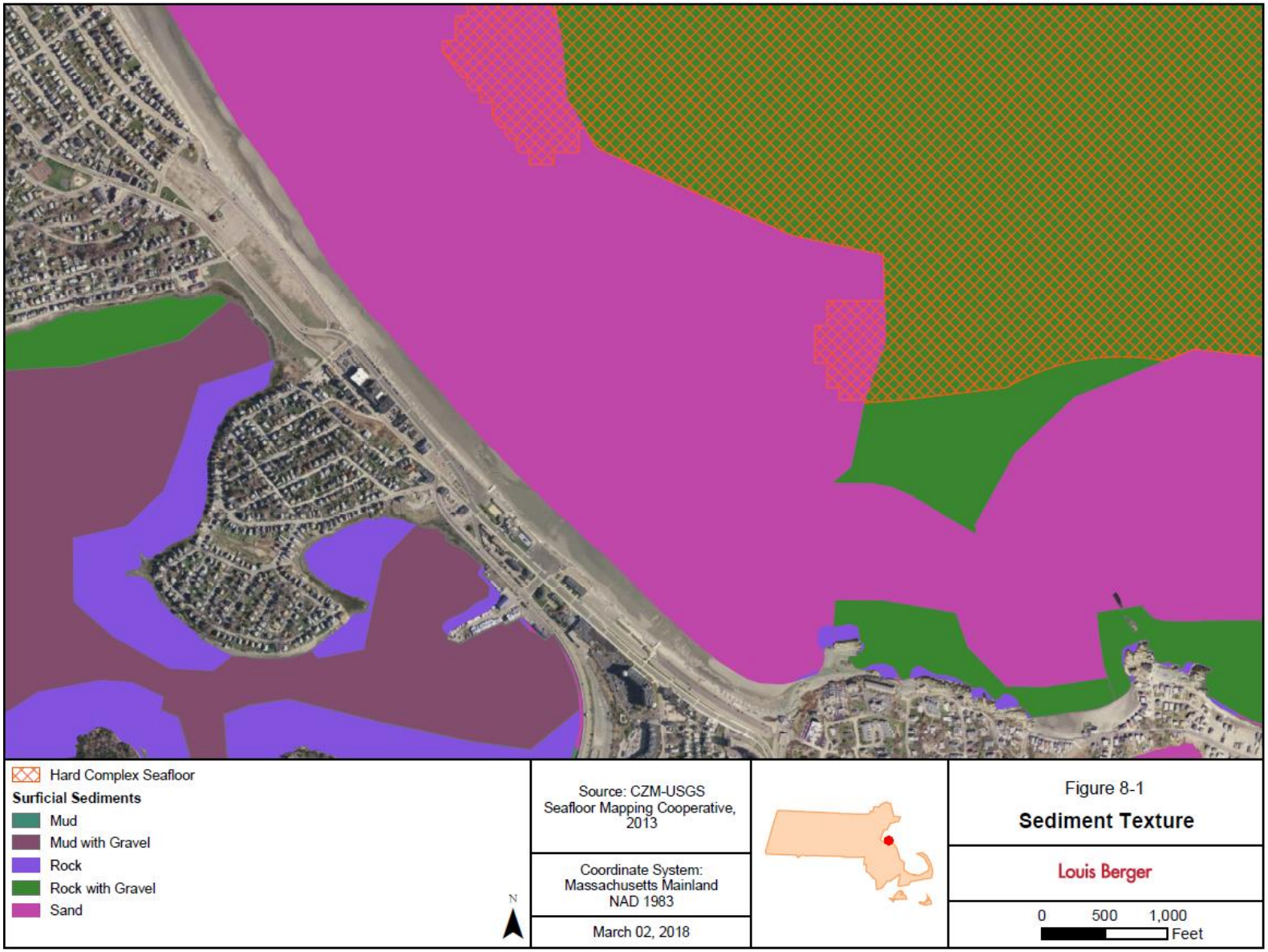


Figure 6-1. Sediment texture in the Nantasket Beach project area. Source of data: CZM-USGS, 2013

- *Subtidal Zone:*
    - -10 ft
    - -15 ft
    - -20 ft
    - -25 ft
    - -30 ft
    - -35 ft

Also included in USACE (2006) were geotechnical analyses of test pit samples collected during the summer of 2004 by the USACE and DCR (Figure 6-3). The test pits were located in the upper intertidal zone and were dug to a depth of approximately 3 to 4 ft below grade.

The grain size distribution found along Nantasket Beach was as follows (see Appendix D for a detailed analysis):

- **Transects*:*** Along the beach and intertidal zone, the sediment consisted predominantly of sand (Figures 6-2 and 6-4, and 6-5). The mean sand, gravel, and silt/clay concentrations were 86%, 13%, and 1%, respectively for the combined beach and intertidal zone. The upper part of the sediment column (0-2 ft) was generally finer-grained (mean sand and gravel concentrations of 93% and 7%, respectively) than the deeper (2-4 ft) part of the sediment column (mean sand, gravel and silt/clay concentrations of 79%, 20%, and 1%, respectively). The predominant sand fraction in the beach and intertidal zone was fine sand (mean of 77%), specifically in the size range of 0.15 to 0.25 mm (mean of 48%).

  In the subtidal zone, the grain size distribution was generally similar to the beach and intertidal zone, although the sediment was slightly finer-grained (Figures 6-2, 6-4, and 6-5). This was reflected by the higher concentration of the fine sand size fraction of 0.074 to 0.15 mm in this zone.

- **Test Pits:** Sediment in the test pits consisted of 1.6% cobble, 22.3% gravel, 75.6% sand, and 0.5% silt/clay (mean concentrations) (Figure 6-6). Most of the sand consisted of fine sand (66%), with the fine sand size fraction of 0.15 to 0.25 mm representing 41% of the total sample and the fine sand fraction of 0.25 to 0.42 mm representing 21% of the total sample. Gravel concentrations in test pit samples ranged from 3% to 44%, reflecting the dynamic nature of the beach's sediment environment. Cobble was only found in three of 15 pit samples.

Sediment samples in the test pits were described as gray-brown; the sediments along transects were described predominantly as gray, with same samples described as olive-brown to yellow-brown.

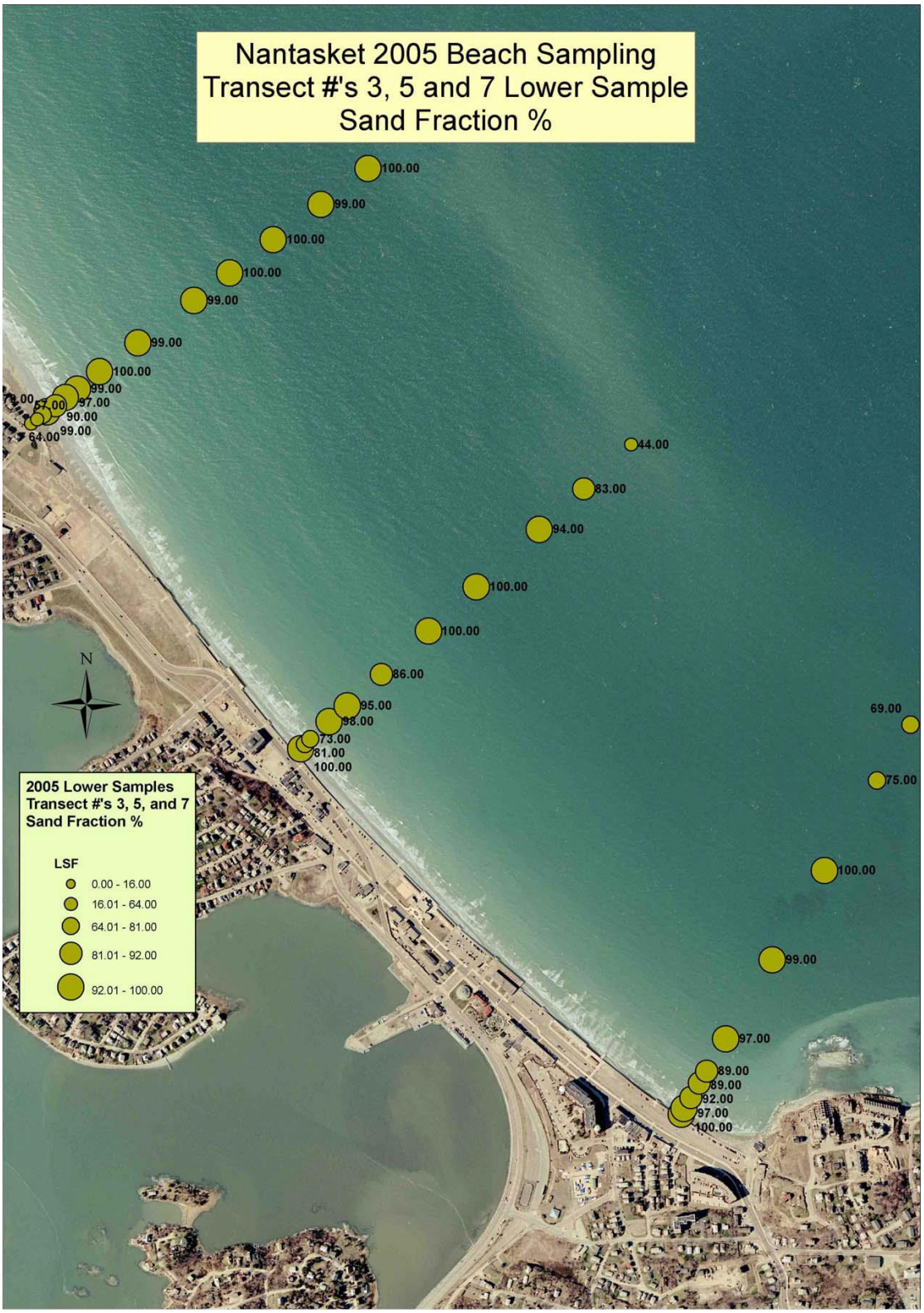


Figure 6-2. Core and grab sample stations along transects perpendicular to Nantasket Beach, including sand concentrations. Source: USACE, 2006

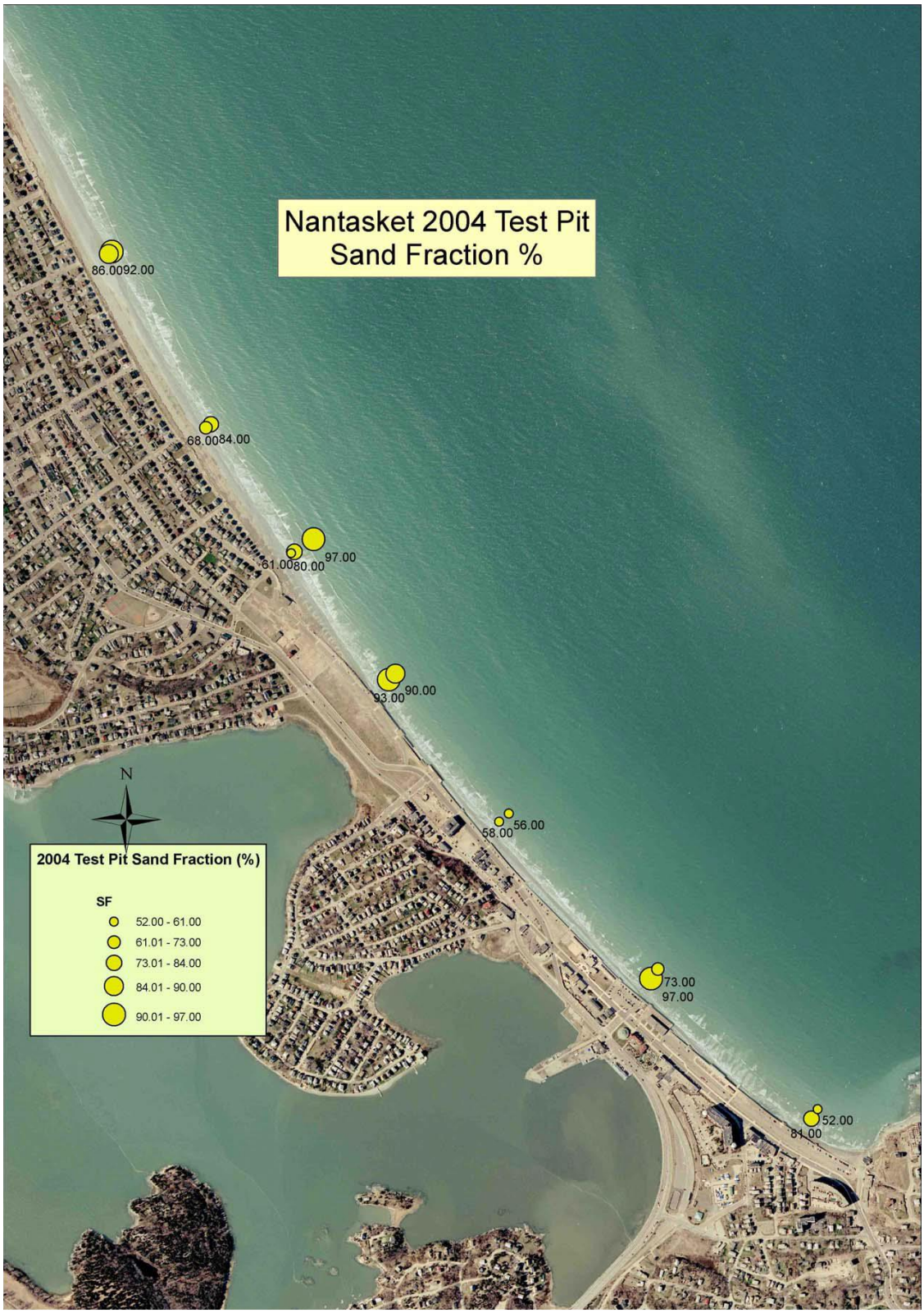


Figure 6-3. Sediment sampling test pits along Nantasket Beach from 2004, including sand concentrations. Source: USACE, 2006

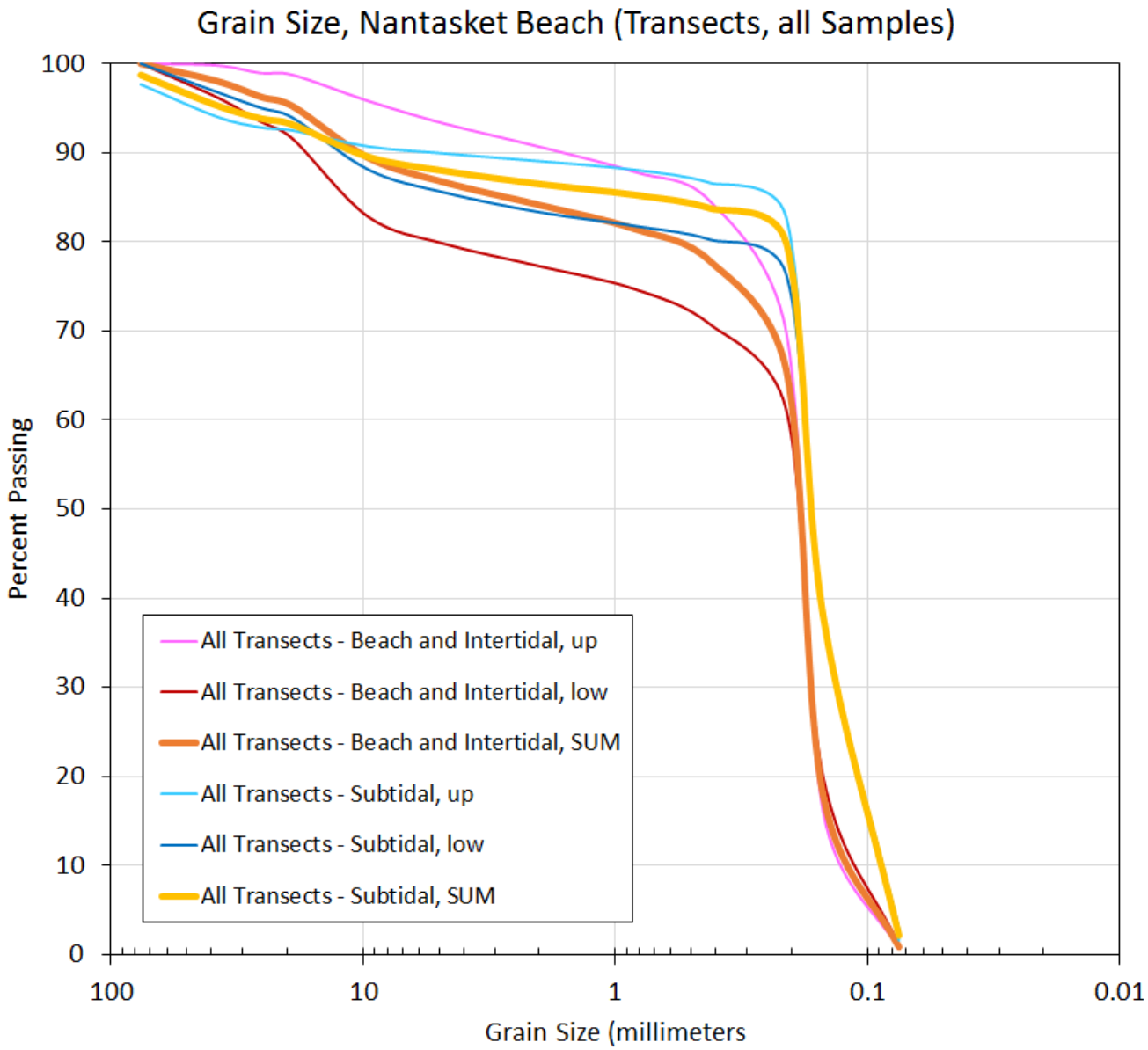
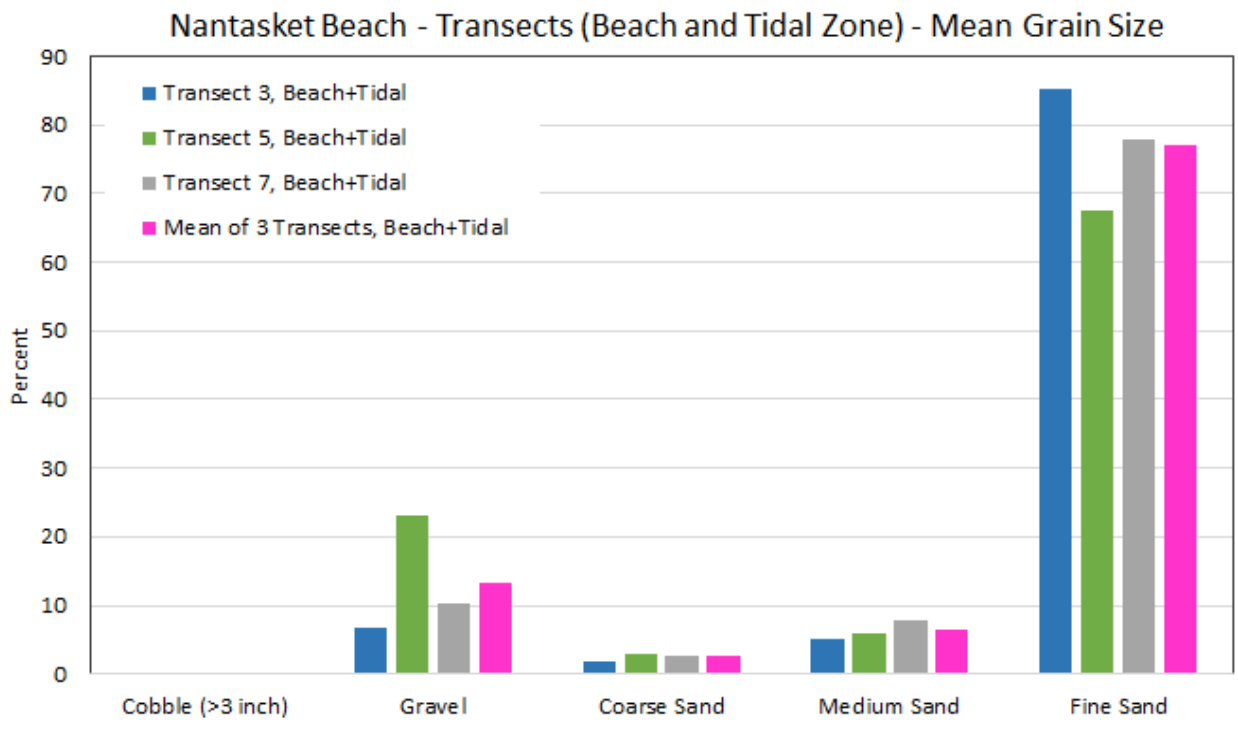


Figure 6-4. Mean grain size distributions for all samples from the 2005 transects at Nantasket Beach for the beach and intertidal zone, and the subtidal zone (upper sample, lower sample, and both samples combined). Source: Louis Berger, 2018



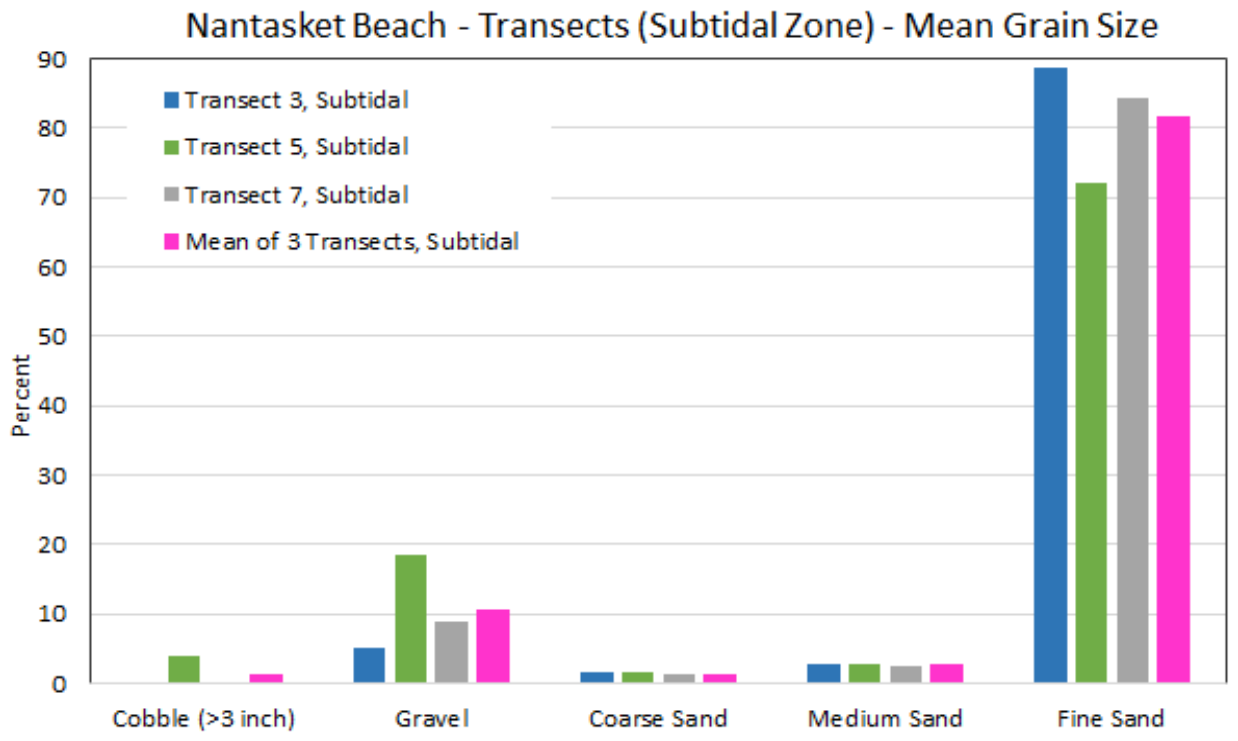


Figure 6-5. Mean grain size distribution along transects on Nantasket Beach for the beach and intertidal zone *(top)*, and the subtidal zone *(bottom).* Transects are arranged on the graph from north (Transect #3 on the left) to south (Transect #7 on the right). Source: Louis Berger, 2018

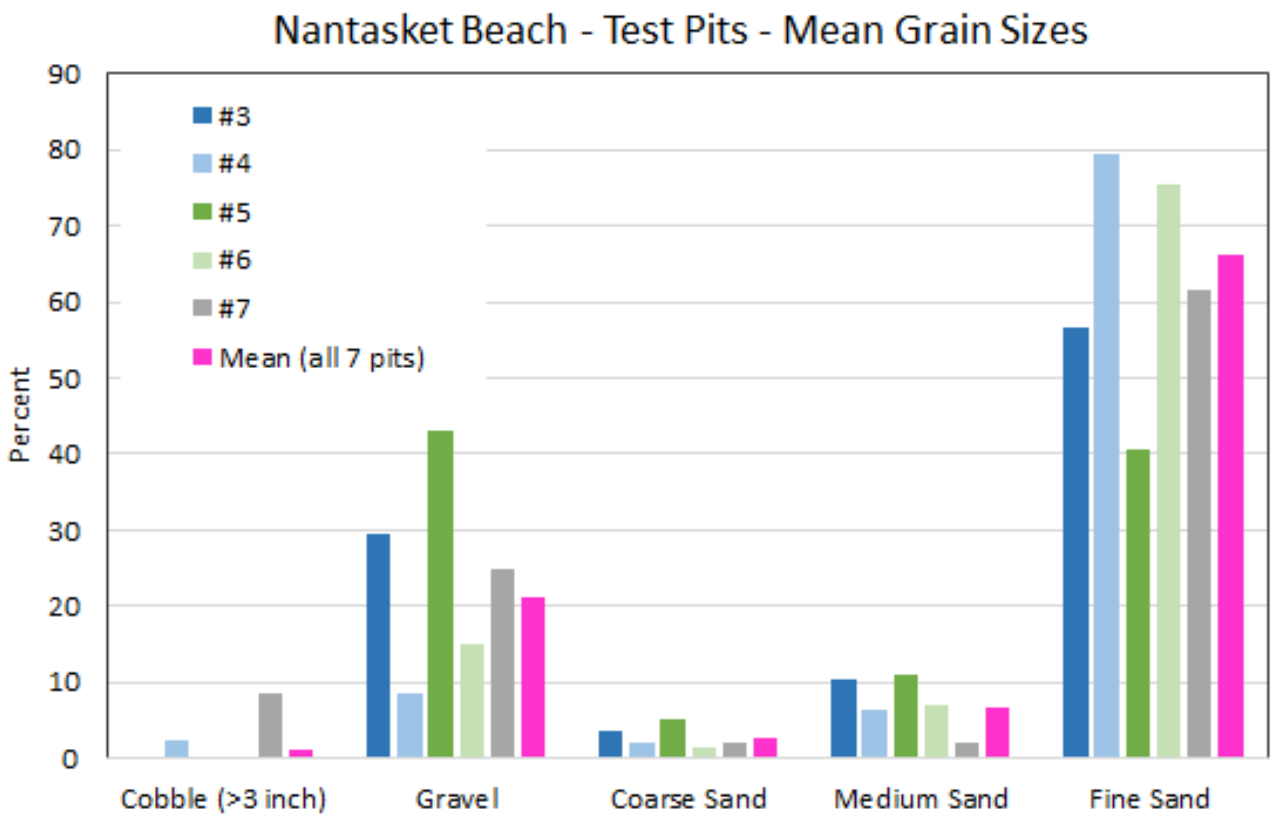


Figure 6-6. Mean grain size distribution for each test pit along Nantasket Beach. Test pits are arranged on the graph from north (Station #3 on the left) to south (Station #7 on the right). Source: Louis Berger, 2018

6.1.3 Topography and Bathymetry

Existing bathymetric data in the vicinity of the Town of Hull were acquired from two government sources (the National Oceanographic and Atmospheric Administration [NOAA], and the USACE. In addition, data from the most recent beach elevation survey conducted by DCR (January 2018) in the nearshore region was used to supplement the NOAA/USACE data. DCR's survey includes transects out to 200 ft from the seawall at 100-ft intervals alongshore (i.e., a total of 68 transects along the Reservation).

To illustrate the topographic and bathymetric characteristics of the site, three representative transects (A, B, and C) were established in the locations shown in Figure 6-7. The transects start at the existing shore protection structures (seawall or revetment), and extend out a distance of 2,000 ft. The transects extend approximately 1,300 ft seaward of the toe of the proposed beach nourishment and include much of the sandy substrata mapped by CZM-USGS in Figure 6-1. The topography and bathymetry along Transects A, B, and C are shown in Figure 6-8, respectively. The data show a narrow high tide beach, ranging from 40 ft wide at the southern end of the beach (Transect C) to 150 ft wide at the northern end of the beach (Transect A). The location of MLW extends approximately 500 to 600 ft offshore, creating an extensive intertidal zone. The profile seaward of MLW slopes very gradually, ranging from 1V:70H to 1V:85H.

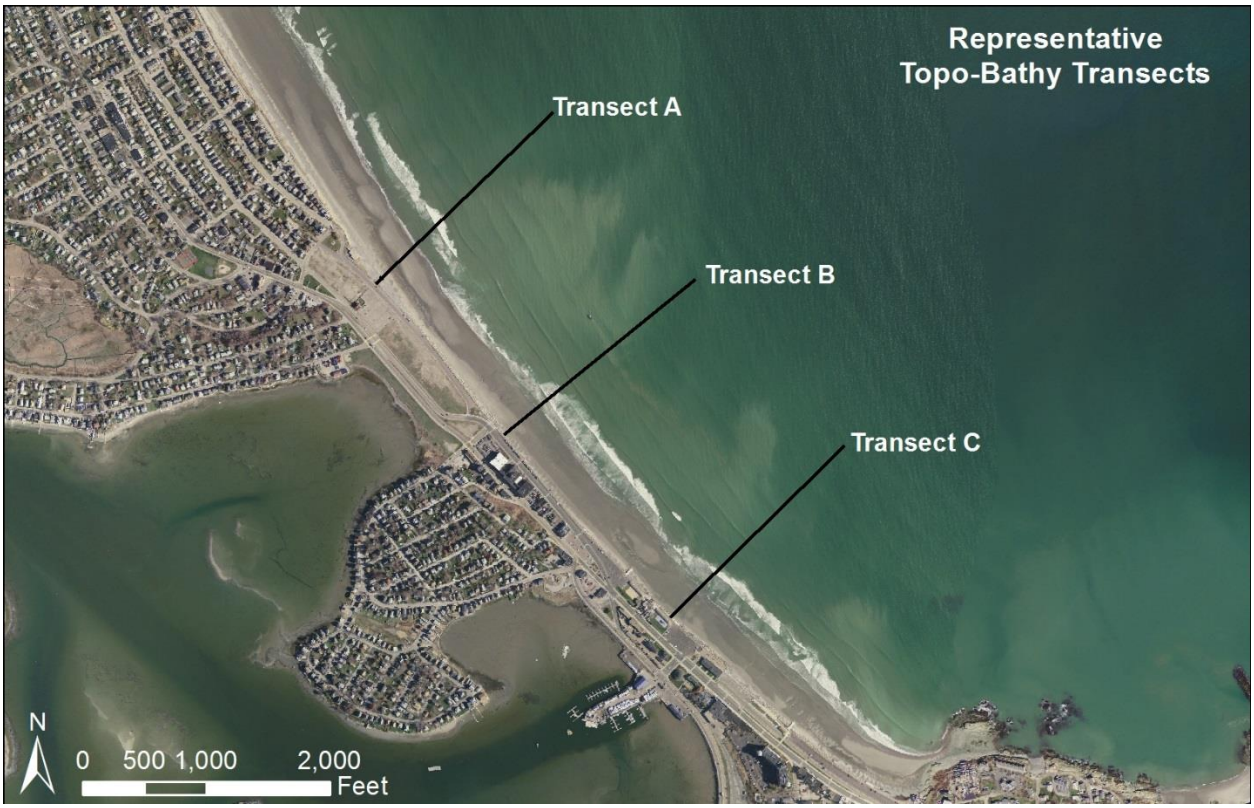


Figure 6-7. Locations of representative topographic and bathymetric transects along Nantasket Beach

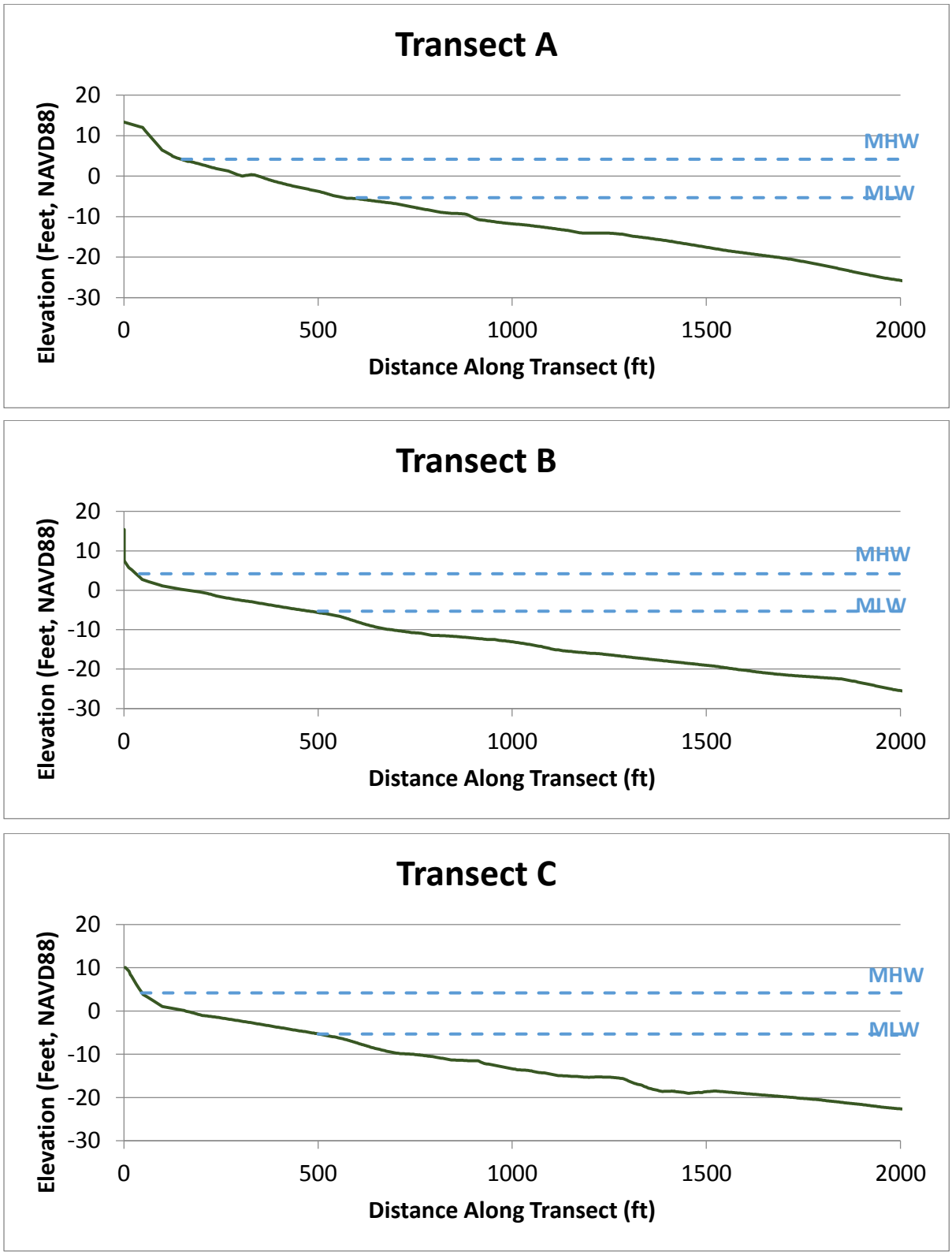


Figure 6-8. Representative topographic and bathymetric transects along Nantasket Beach.

6.1.4 Shoreline Change

Information on historical shoreline change in the vicinity of Nantasket Beach was obtained from the Massachusetts Shoreline Change Project (MSCP). The MSCP contains relative positions of shorelines between 1860 and 2009 for all seaward facing coastal areas within the Commonwealth of Massachusetts. The MSCP includes shoreline positions at Nantasket Beach for the following years: 1847, 1895, 1938, 1978, 1994, 2000, 2001, and 2008. Original sources for the historical shorelines were NOAA/NOS topographic maps, hydrographic maps, Federal Emergency Management Agency (FEMA) topographic maps, orthophotos, and aerial photographs.

Figure 6-9 shows the historical shorelines for Nantasket Beach. Nine shoreline positions from 1847 to 2008 are shown along with the transect locations where shoreline change statistics were calculated. The recent rates of shoreline change between 1978 and 2008 are shown in feet/year (ft/yr) at the end of each transect. The data indicate erosion rates as high as -1.7 ft/yr, and accretion rates as high as +1 ft/yr. The southern end of the beach (south of the Mary Jeanette Murray Bath House) is the only area experiencing accretion, with higher rates of accretion farther south. The average shoreline change rate between 1978 and 2008 for the entire project area is -0.6 ft/yr. The average rate of erosion increases to -1.0 ft/yr if only the area north of the Mary Jeanette Murray Bath House is considered.

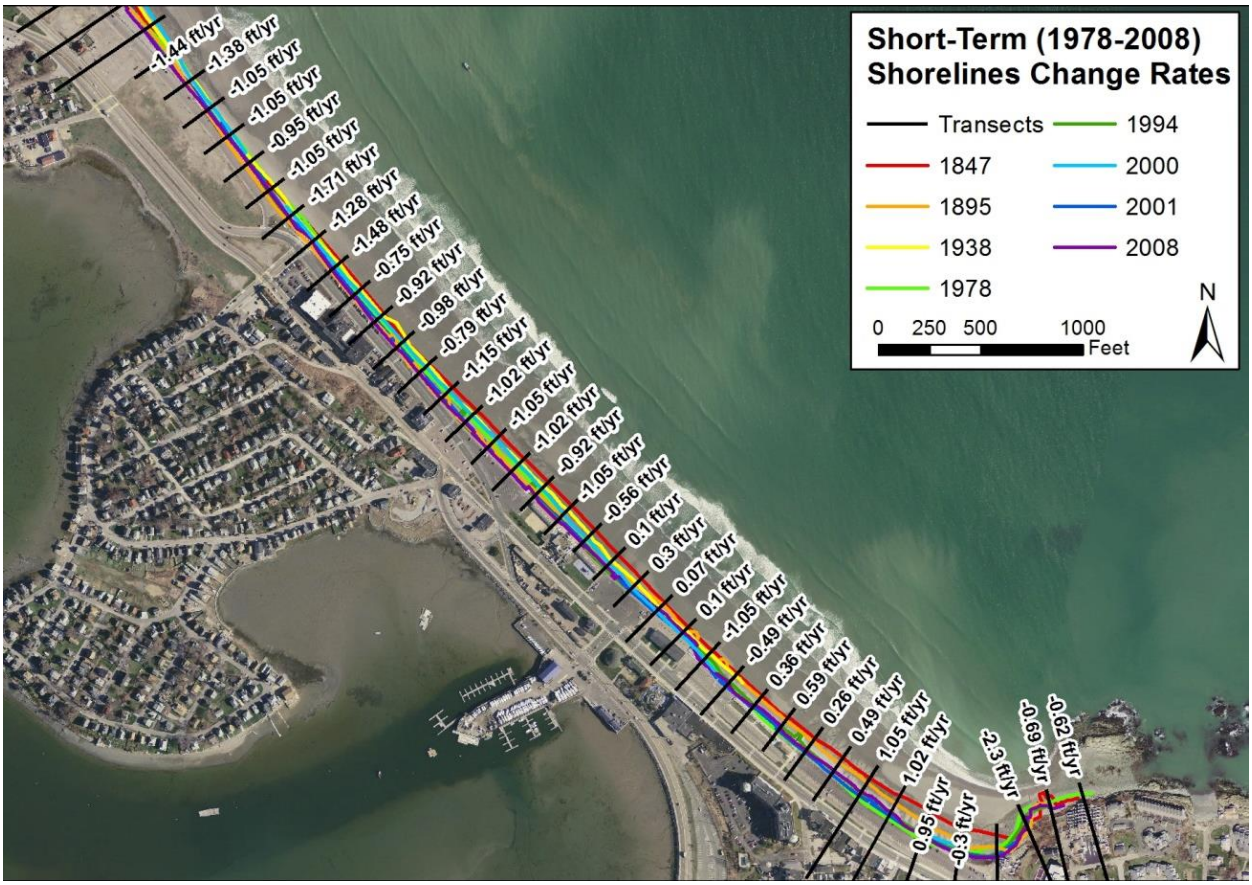


Figure 6-9. Short-term shoreline change rates (1978-2008). Source of data: Massachusetts Shoreline Change Project

6.1.5 Wave Climatology

The impact of waves on nearshore processes, shoreline change, and sediment transport is highly dependent on the offshore wave climate and the transformation of waves propagating to the shoreline. Closer to shore, as waves interact with the coastline, wave-induced currents are a major component of sediment transport and shoreline change. Therefore, a key component of understanding the areas of erosion and accretion along Nantasket Beach is determining the nature of the wave field, both offshore and in the nearshore region.

To quantify the potential impacts of waves on the existing resource areas and the proposed project at Nantasket Beach, site-specific wave conditions were determined using bathymetric and topographic data, wind data, wave data, and a series of numerical and analytical models. A description of the procedures used to compute wave conditions within this portion of Massachusetts Bay is presented in this section. Wave conditions were developed for average annual conditions and for specific storm events. These wave conditions were utilized to assess existing conditions, to aid design scenarios of the nourishment, and to evaluate the potential impacts on the coastline.

6.1.5.1 Wave Data Analysis and Sources

A key component of accurate wave modeling is the analysis and selection of input wave data. The results derived from numerical wave transformation modeling, as well as the subsequent movement of sediment in the coastal zone, are controlled by the selected wave input conditions. This section describes the offshore wave climate at Nantasket Beach and the selection of input wave parameters used for subsequent wave transformation modeling to evaluate site specific wave conditions at the project area.

For this project, the Wave Information Study (WIS) time series of wave and wind data was used to describe the offshore wave climate in the Nantasket Beach region. WIS contains time-series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from the computer hindcast (prediction) model WISWAVE (Resio and Tracy, 1983). Wave measurements collected by NOAA during the 1980s were used to verify the WIS results by comparing the statistics and distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Three WIS stations in the vicinity of the Nantasket Beach region were considered for use in this analysis; Stations 63051, 63052, and 63053 are all located to the northeast, offshore of Nantasket Beach (Figure 6-10).

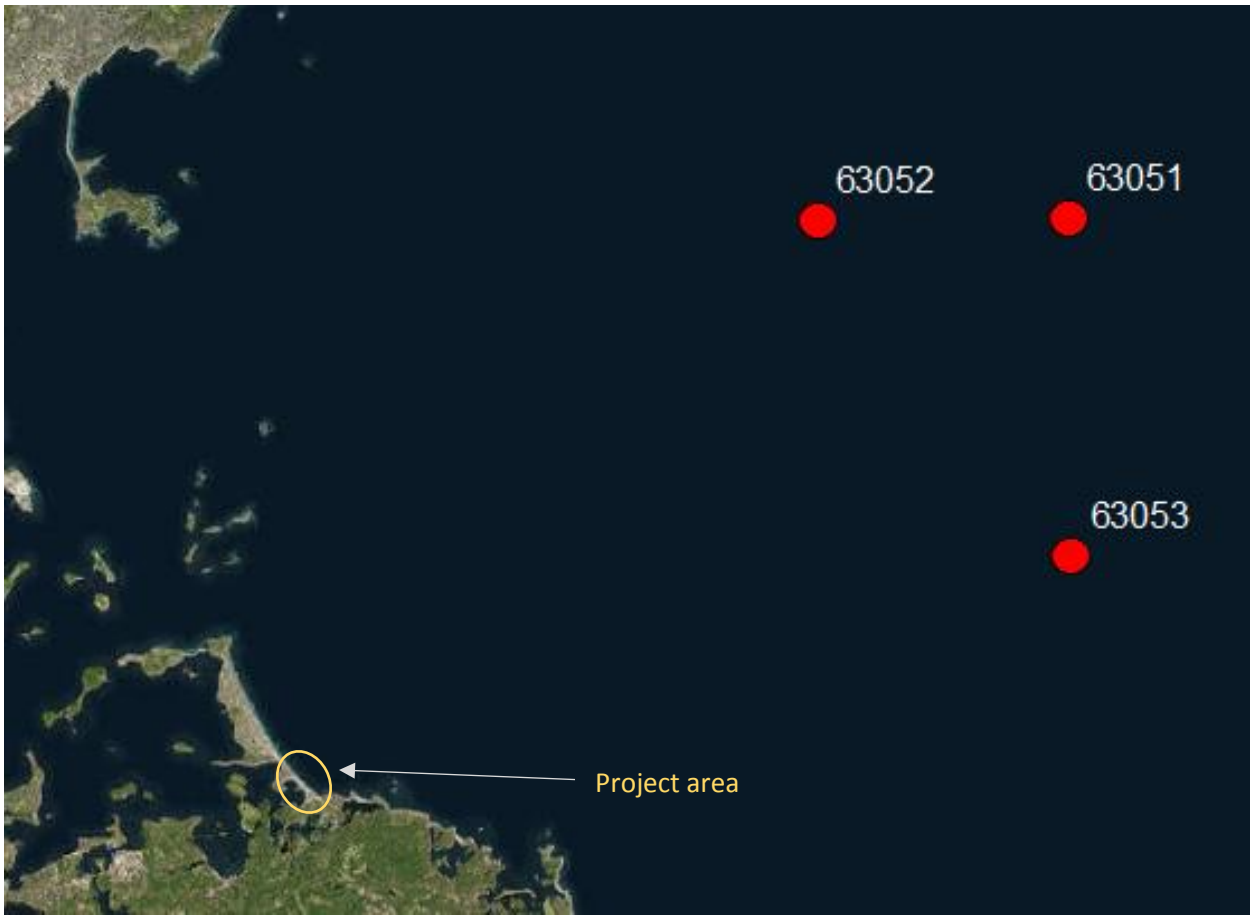


Figure 6-10. Location of WIS Stations 63051, 63052, and 63053

An investigation of the three 20-year (yr) WIS data sets demonstrated little spatial variability in the wave climate among the WIS stations. Figure 6-11 shows the wave roses for these stations, which demonstrate similarity in significant wave height and direction of wave approach among the three stations. Additional investigation demonstrated that mean wave period distribution, percent occurrence directional distribution, and percent wave energy directional distribution all showed similar patterns among the WIS stations. Since each WIS station exhibited similar wave data, Station 63052 (which is located most directly offshore Nantasket Beach) was selected as the offshore wave data source to generate spectral input conditions to the numerical wave transformation model.

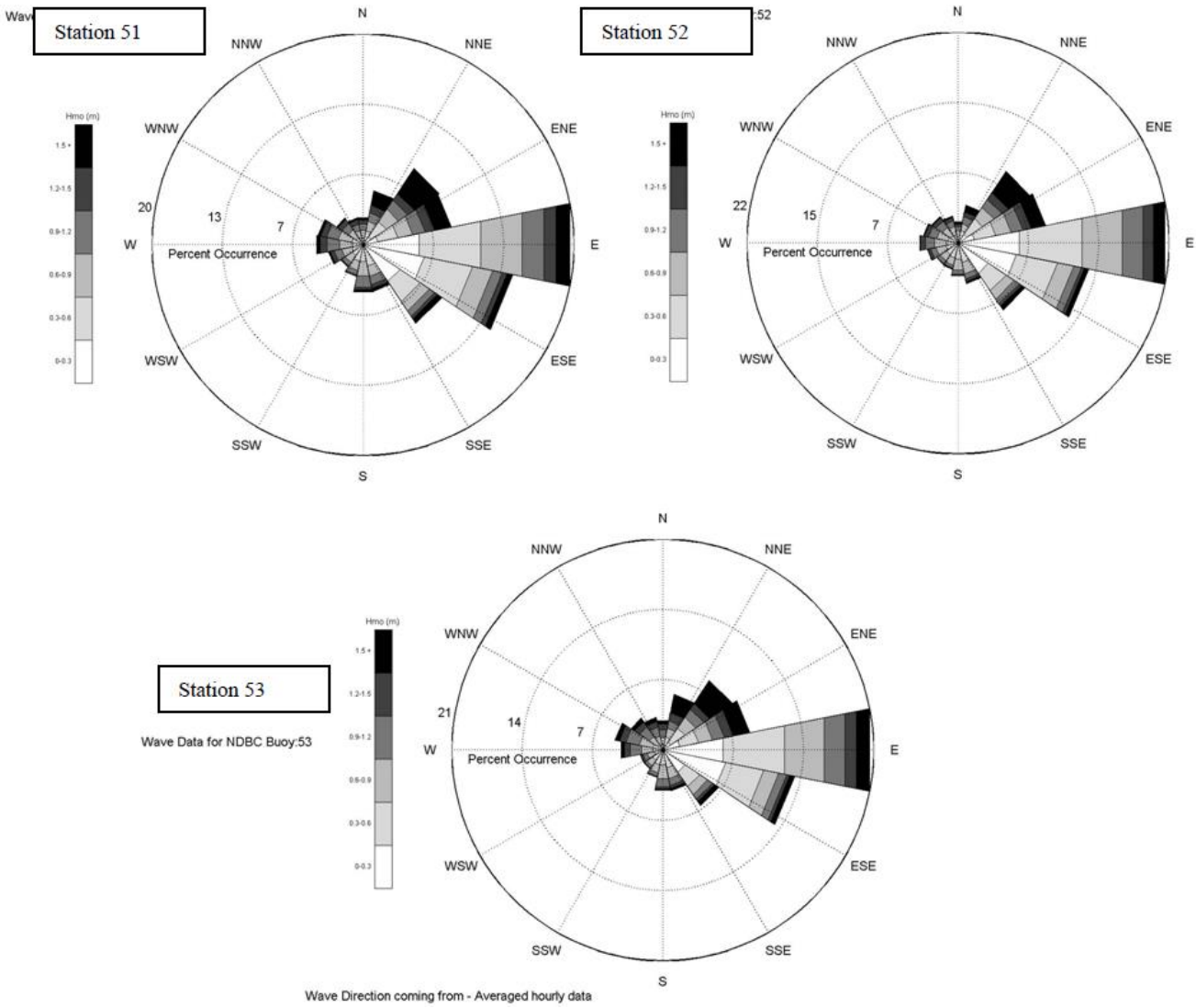


Figure 6-11. Twenty-year, hourly-averaged wave roses for WIS Stations 63051-63053

At the deepwater WIS stations, the most common wave approach direction is from the east; however, the most wave energy is associated with waves coming from the northeast. Figure 6-12 compares the percent occurrence and the percent energy across the directional distribution for WIS Station 63052. The asymmetry between the distributions indicates that although there is a lower percentage of waves arriving from the northeast than the east, the northeast waves are more energetic (which can be explained by the high number of Nor'easter storms that are common to the New England area). Therefore, to properly represent the offshore wave conditions that drive the wave model and help estimate longshore sediment transport at Nantasket Beach, the wave conditions cannot be defined by one single set of wave parameters, or even by a series of specific wave conditions, but rather a compilation of a variety of waves that occur over a longer time frame.

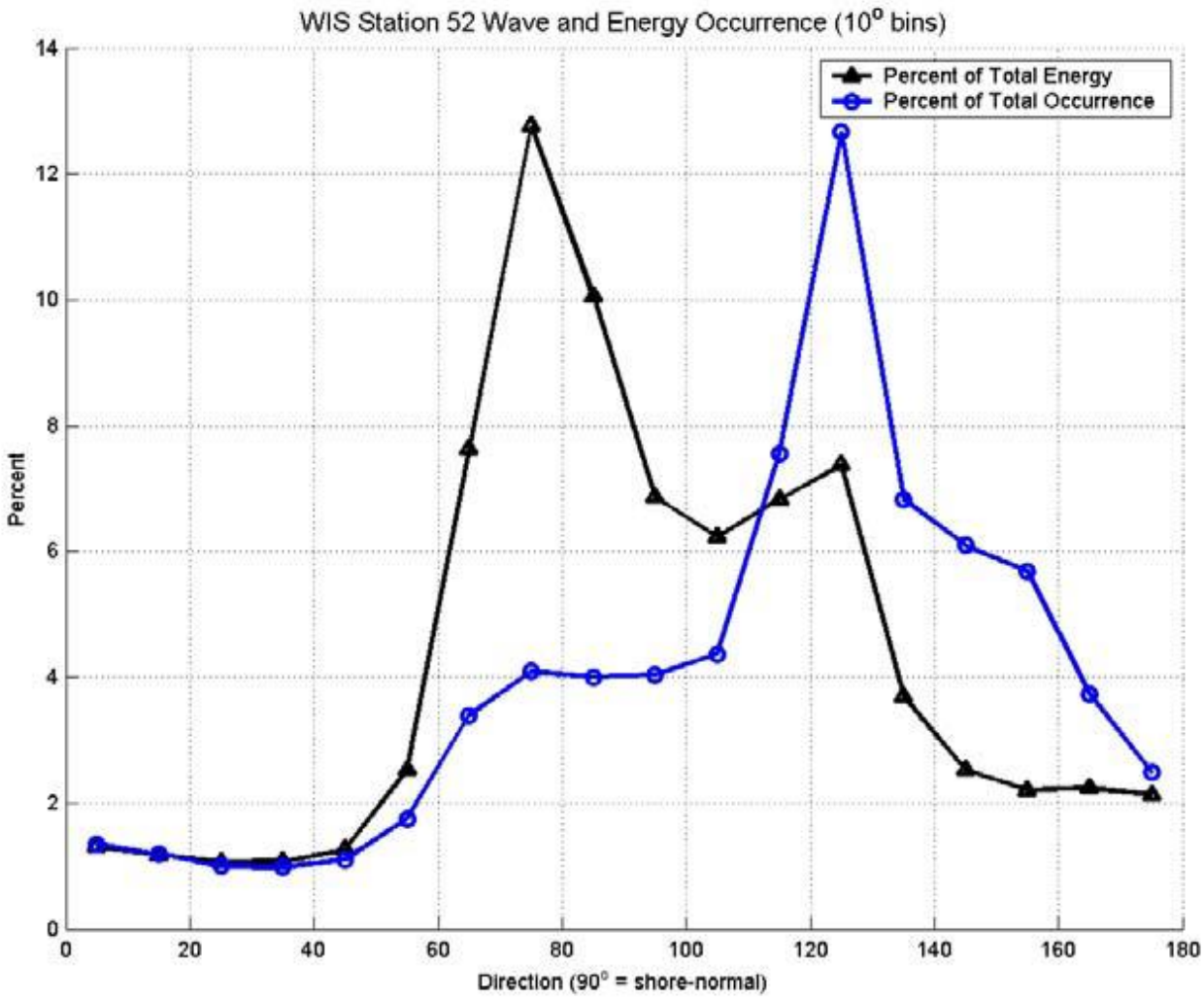


Figure 6-12. Comparison of percent occurrence and the percent energy across the directional distribution for WIS Station 63052

Rather than selecting the most common wave heights and directions, a detailed analysis was conducted to compile and summarize the existing WIS data into detailed input spectra for the wave transformation modeling. Each spectral simulation contains distinct differences in the distribution of wave energy between directional and frequency bands, and consequently produces varying impacts in the transformation and sediment transport patterns.

6.1.5.2 Input Wave Conditions

The numerical wave transformation model used for the Nantasket Beach project (STWAVE), requires input of a directional wave spectrum, which represents the distribution of wave energy in the frequency and direction domains. The two-dimensional wave spectrum is given as the product of the energy and directional spectra. The directional spreading function provides the relative magnitude of directional spreading of wave energy, while the frequency spectrum provides the

absolute value of wave energy density. Input wave conditions were developed for average annual conditions and specific storm events.

Average Annual Waves

Spectral data from WIS Station 63052 were used to derive energy-conserving annual average directional spectrum. Data were segregated by direction of approach, and an energy distribution (as a function of frequency) was generated from all the waves in each directional bin. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000; Woods Hole Group, 2008) and identifies all potential approach directions, including those that may occur only a small percentage of time during a typical year but potentially have significant impacts on the shoreline and sediment transport (e.g., the higher wave energy approaches from the northeast). Table 6-1 presents the cases that were simulated in STWAVE to represent the complete wave climate offshore of Nantasket Beach.

Table 6-1. Input Conditions and Scenarios Used for the Wave Transformation Modeling at Nantasket Beach

Directional Bin (0=N)	**Approach Direction**	**% Occurrence**	**% Wave Energy**	**Significant Wave Height** (ft)	**Peak Period** (sec)	**Peak Direction (0=N)**
329 to 351.5	NNW	2.14	2.11	2.84	3.6	342.2
351.5 to 14	N	2.23	2.44	2.94	3.6	2.7
14 to 36.5	NNE	4.74	7.77	3.31	4.1	27.8
36.5 to 59	NE	9.10	25.88	3.98	5.1	47.8
59 to 81.5	ENE	9.74	14.72	2.92	6.1	70.7
81.5 to 104	E	22.58	14.67	1.97	7.0	92.4
104 to 126.5	ESE	13.57	5.77	1.48	5.6	115.0
126.5 to 149	SE	6.40	3.95	1.76	4.8	133.9
Calm	--	29.49	--	--	--	--

High Energy Events

Since high-energy events have a significant impact on many physical processes (and in most cases significantly contribute to sediment transport), it is crucial to include storm simulations in the wave modeling to determine extreme storm wave characteristics and assess the associated potential impacts on the shoreline along Nantasket Beach. High energy events were evaluated by reviewing existing literature on hurricanes and northeast storms that affected the coast of Massachusetts and by performing an analysis of storm events from the WIS data.

A number of historical storm events in the New England area over the past century have had an impact on Nantasket Beach, including the New England Hurricane of 1938, the Blizzard of ’78, Hurricane Gloria in 1985, Hurricane Bob in 1991, the “Perfect Storm” in October of 1991, the no-named Northeaster storm in December of 1992, the “Storm of the Century” in March of 1993, the Blizzard of ’96, and the April Fools’ Day Blizzard in 1997. Three selected storm events were

simulated in the wave transformation model based on available data and the historical impact on Nantasket Beach.

Wave data from the WIS Station 63052 were used to conduct an analysis of storm events. The wave data were examined and high-energy wave events were characterized based on a set of criteria. A storm event was defined when the significant wave height was greater than 3 meters (m) (9.8 ft) for at least 12 hours. Separate events were defined by requiring a window of 18 hours between wave heights that exceeded the 3-m (9.8 ft) threshold value.

In addition, return-period storm event conditions (10-yr, 50-yr and 100-yr) were developed to provide a complete array of extreme events that could be expected to occur at this location. The return-period storm wave heights were determined using the Generalized Extreme Value (GEV) method. Since the exact wave direction of extreme events is unknown for return-period storms, the most common storm approach and highest energetic direction (northeast 45°) was assumed, based on the average approach direction of all the storms in the WIS hindcast data.

Storm surge values were also included in the wave modeling simulation to represent the increased water level experienced during the passage of a large storm event. Elevated water levels, even with moderate wave heights, can result in significant erosion along the shoreline. For return-period storms, storm surge data were taken from Tidal Flood Profiles of the New England Coastline (USACE, 1988). For the known specific storm events, storm surge elevations were determined from the NOAA Station 8443970 located in Boston Harbor and local observations and historical accounts.

Table 6-2 presents the storm events and their associated wave and storm surge characteristics. Storm spectra were developed for the STWAVE simulations from these storm parameters.

Table 6-2. Extreme storm event characteristics offshore Nantasket Beach used to define input spectra

Storm Event	**Significant Wave Height** (ft)	**Peak Wave Period** (sec)	**Average Wave Direction** (degrees)	**Storm Surge** (ft, above NAVD88)
10-yr	23.0	10.2	45	8.46
50-yr	28.2	11.3	45	9.28
100-yr	30.5	11.8	45	9.69
Perfect Storm (10/31/1991)	18.4	10.0	49	8.76
Nor'easter (12/ 11-14/1992)	24.9	12.5	62	8.60
April Fools' Day Blizzard (4/1/1997)	21.0	11.1	42	6.60

6.1.5.3 Nearshore Wave Transformation Modeling

To assist in refining the beach nourishment design, and to evaluate potential impacts to sediment transport patterns, nearshore wave modeling was required to estimate the refraction, diffraction, shoaling and breaking of waves at Nantasket Beach. Wave refraction and diffraction can result in an uneven distribution of wave energy along the coast and affect the sediment transport along the

shoreline. Wave modeling allows for quantitative predictions of these processes, including information on how waves propagate to the shoreline, as well as the potential locations of areas of increased erosion (the location of "hot spots"). Wave modeling results can also be used to maximize the design life of beach replenishment projects.

The spectral wave model STWAVE version 3.0 (Smith, Sherlock, and Resio, 2001), developed by the USACE Waterways Experiment Station, was employed to evaluate changes in wave propagation across the nearshore region fronting Nantasket Beach. STWAVE is a steady state, spectral wave transformation model, based on a form of the wave action balance equation of Jonsson (1990). The model can simulate wave refraction and shoaling induced by changes in bathymetry and by wave interactions with currents. The model also includes wave breaking, wave growth, and influences of wave white capping on the distribution and dissipation of energy in the wave spectrum. STWAVE simulates the behavior of a random sea surface by describing wave energy density as a function of direction (directional spectrum) and frequency (frequency spectrum). A comprehensive discussion of the theoretical background of STWAVE can be found in Smith, Sherlock, and Resio (2001).

In STWAVE, the reference grid consists of a grid of points with dimensions NI and NJ. At each point within the domain, water depth, as well as ambient current data, can be specified. For the existing project, a nested modeling grid was created using the bathymetric data described in Section 6.1.3. The orientation of the reference grid was selected to parallel the shoreline and extend offshore to water depths deep enough so that waves would not "feel" the bottom at the offshore boundary. The reference grid cell size ranged from 100 m (330 ft) in the offshore grid to 10 m (33 ft) in the nearshore grid, with interpolated depths obtained from the bathymetric or topographic data at each grid intersection point. Figure 6-13 presents the intermediate grid; representations of the offshore and nearshore grids can be found in Appendix B.

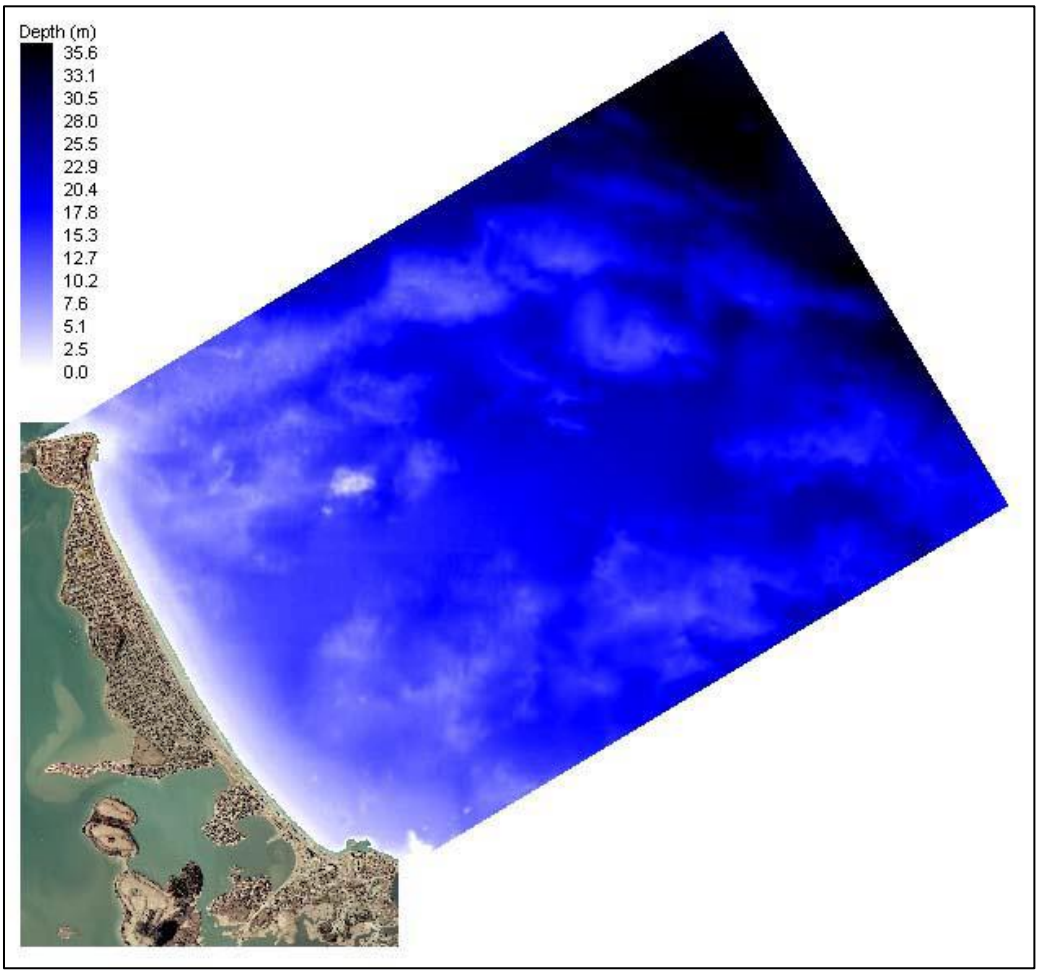


Figure 6-13. Intermediate bathymetric modeling grid. Depths are in meters relative to mean tide level

6.1.5.4 Nearshore Wave Transformation Modeling Results

Model simulations were performed for the average annual wave conditions represented by the directional bin spectra presented in Table 6-1. Wave focusing and divergence occur at several locations throughout the modeling domain, which results in variations in the wave energy propagating toward the coastline of Nantasket Beach for each directional bin. Figure 6-14 illustrates STWAVE results for the intermediate grid modeling domain, for waves approaching from the northeast (36.5 to 59 bin), the most energetic approach direction of the typical condition cases. Therefore, waves approaching from the northeast are an essential component of the wave and sediment transport processes. The color map corresponds to the distribution of significant wave height (m) throughout the modeling domain. Arrows on the figure represent the modeled wave directions as they propagate toward the shoreline.

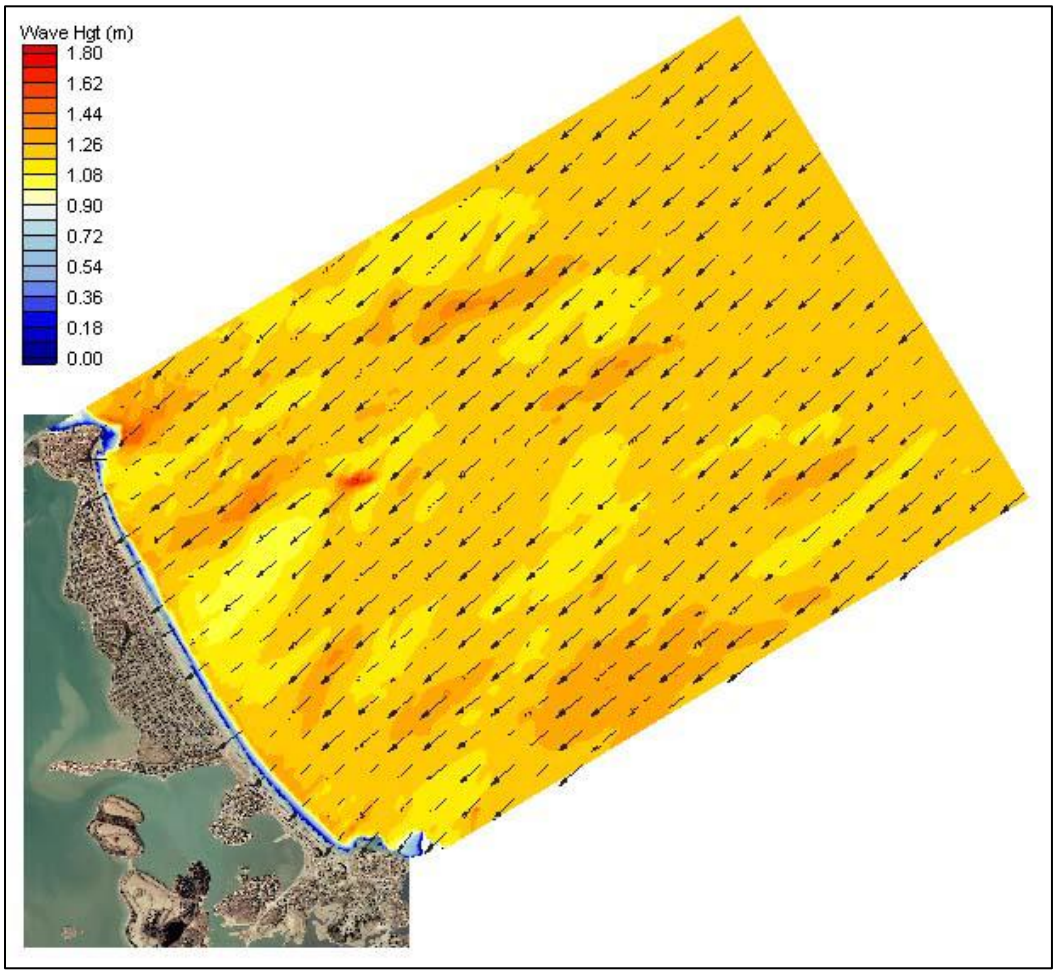


Figure 6-14. Spectral wave modeling results for a northeast approach direction (36.5-59 degree bin)

Figure 6-14 shows how the bathymetric features along the Nantasket shoreline affect wave energy for this specific approach direction. Offshore of the DCR Reservation, the dark orange streaks and dark orange region close to the shoreline indicates that higher wave energy is allowed to penetrate toward the shoreline. Further to the north, along the central portion of the Hull coastline, the wave energy is lower. This example represents one specific approach direction, and all average annual approach directions were considered to represent the overall dynamics along Nantasket Beach. The variability in the wave climate is clearly indicated by the differences in nearshore wave patterns arising from the various input spectra approach directions. Figures for the remaining approach directions for the Nantasket Beach region are presented in Appendix B.

Model simulations were also performed for high energy events represented by the conditions summarized in Table 6-2. The simulation of storm events was important to quantify the short-term impacts that occur during these energetic scenarios, since sediment transport along the coastline can be significant during these episodic events. Figure 6-15 shows the spectral wave model results for the 100-yr return period storm event.

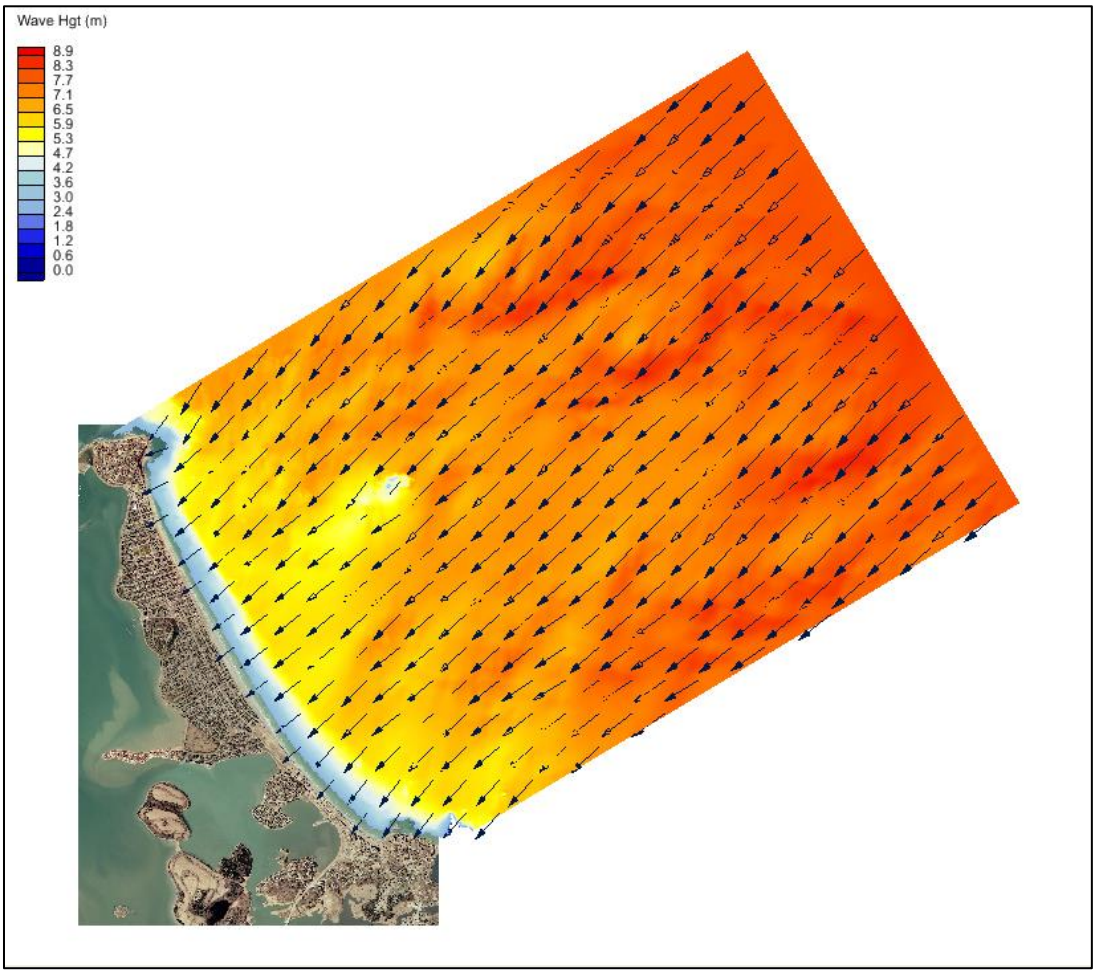


Figure 6-15. Spectral wave modeling results for a 100-yr return period storm in the Nantasket Beach region

Figure 6-15 shows that wave heights are significantly higher than the annual average directional cases, as the offshore wave heights are up to 8.5 m (28 ft) for the 100-yr storm. Overall, the storm simulations show that the region offshore of Nantasket Beach can become a high-energy environment conducive to large wave events (both in wave height and period). These large wave events, although short-lived, can potentially have the most impact on the beach by mobilizing sediment and causing wave-induced damages to the existing coastal infrastructure. Figures for the remaining high energy events for the Nantasket Beach region are presented in Appendix B.

Model results for both average annual conditions as well as high energy events were used to evaluate the existing wave climate and assess existing and post-nourishment sediment transport patterns and rates (see Section 6.1.8). The results were also used to refine the nourishment design and evaluate the lifetime of the project (see Chapter 7).

6.1.6 Tides

The tides at Nantasket Beach are semidiurnal, with two high tides and two low tides of similar heights occurring each day. The spring tidal range is 10.3 ft and the mean tidal range is 9.5 ft. Tidal datums derived from NOAA's Tides and Currents web site for Station 8443970, located in Boston Harbor, are summarized in Table 6-3.

Table 6-3. Tidal Datums for the Nantasket Beach Shoreline

Tidal Datum or Flood Condition	**Elevation** (ft, NAVD88)
Mean Higher High Water (MHHW)	4.77
Mean High Water (MHW)	4.33
NAVD88	0
Mean Tide Level (MTL)	-0.42
NGVD 29	-0.82
Mean Low Water (MLW)	-5.16
Mean Lower Low Water (MLLW)	-5.51

Source of data: NOAA, https://tidesandcurrents.noaa.gov/

6.1.7 Storm Surge

Storm surge is a rising of the water surface due to strong onshore winds and barometric pressure changes during severe storms that "pile-up" water against the shoreline. Tidal elevation changes are predominantly due to the gravitational pull of the sun and moon on the earth's oceans. Coincident storm surge plus high tide levels can result in severe coastal flooding. Combined storm surge plus high tide levels in Massachusetts Bay have been determined for extreme events corresponding to a given return period, such as a 1-, 10-, and 100-yr storms. Nantasket Beach is currently susceptible to storm damage and significantly influenced by heightened water elevations. Table 6-4 presents the mean high, astronomic high, and storm surge elevations for the Nantasket shoreline as reported by the FEMA Flood Insurance Study (FIS) for Plymouth County, MA (2016).

Table 6-4. Mean High, Astronomic High and Storm Surge Flood Elevations for the Nantasket Shoreline

Tidal Condition	**Elevation** (ft, NAVD88)
Mean High Water	4.3
Mean Higher High Water	4.8
Tidal Flood 10-yr return	8.4
Tidal Flood 50-yr return	9.3
Tidal Flood 100-yr return	9.7

Source: FEMA, 2016

6.1.8 Sediment Transport

Sediment transport modeling was conducted for the coastal region along Nantasket Beach to develop estimates of alongshore sediment flux integrated across the surf zone, and subsequently develop estimates of the regional sediment transport.

6.1.8.1 Analysis Approach

Sediment movement in the coastal zone, as well as the effects of coastal structures on shoreline processes, was estimated using a process-based sediment transport model. Process-based models directly address the fundamental physics of waves and sediment transport and are able to account for a time-variable (in direction and height) wave field.

The sediment transport model consists of a hydrodynamic component to determine the wave-induced currents, and a sediment transport component to quantify the amount of sediment moved by those wave-induced currents. The hydrodynamic component is based on the steady-state, depth-averaged mass and momentum equations for a fluid of constant density. These equations are standard in many surf zone applications (e.g., Mei, 1983) and provide a state-of-the-art representation of the alongshore current. The sediment transport component is based on a recent peer-reviewed and published formulation by Haas and Hanes (2004), which has been shown to be consistent with recent complex formulae for wave-driven sediment transport and with the Coastal Engineering Research Center (CERC) formula (USACE, 2002b) for the total (laterally-integrated) alongshore sediment flux. Detailed descriptions of the model theory and the various model component formulations are presented in Appendix B.

The grid for the sediment transport model was the same high-resolution nested grid used for the STWAVE wave transformation model (as described in Section 6.1.5), with 10 m (33 ft) cells spanning 1,920 m (6,300 ft) in the cross-shore direction and 6,170 m (20,243 ft) in the alongshore direction. The results from the STWAVE simulations for the average annual and high-energy events summarized in Tables 6-1 and 6-2 were applied as input into the sediment transport model.

6.1.8.2 Average Annual Sediment Transport Results

Wave results from each of the average annual directional spectra bin simulations were used to develop a complete summary of sediment transport for various wave conditions. Simulations of sediment transport were conducted using a multi-grain size representation (d_{50}=0.25 mm and 28 mm) and the results were assessed to define the average annual sediment transport regime throughout the Nantasket region. Detailed results of these directional analyses are presented in Appendix B and summarized below.

For a northerly wave approach (351.5 to 14 degree) scenario, the sediment transport is in a southeasterly direction along nearly the entire stretch of Nantasket Beach, with rates of transport increasing toward the southeast (ranging between 38,000 and 76,000 cy/yr, with a maximum of 92,000 cy/yr). In general, this northerly approach contains lower wave energy and has a small percentage of occurrence, and therefore produces smaller rates of sediment transport when compared to other approach directions.

For a northeasterly wave approach (36.5 to 59 degree) scenario, the sediment transport is also primarily in a southeast direction. Transport rates are much larger (ranging up to 400,000 cy/yr) for the northeasterly approach than the northerly waves, because the northeast wave directional bin contains the most wave energy. Net transport along the DCR Reservation is to the southeast, although there are areas where the transport is directed to the northwest. These changes in direction of transport indicate areas where there is either a divergence (erosion) or convergence (accretion) of sediments. These abrupt changes in the directionality of sediment transport along the DCR Reservation are an indication that the shoreline in this area is dynamic (under the northeasterly wave approach scenario).

For an easterly wave approach (81.5 to 104 degree) scenario, which is the predominant wave direction for Nantasket Beach, the sediment transport is primarily in a northwest direction. Transport rates range generally between 20,000 and 60,000 cy/yr, with a maximum of approximately 180,000 cy/yr.

To accurately represent sediment transport over an average year, the various wave scenarios were combined to represent an average year of wave climate. Using the percent occurrence of wave approach (Table 6-1), the average annual approach directions were normalized and combined to determine the net longshore transport rate. Figure 6-16 presents the average yearly sediment flux determined using the mixed grain size approach. The vertical axis represents distance alongshore. The DCR portion of Nantasket Beach is located toward the bottom of the figure, in the yellow shaded area on the right panel. Figure 6-16 includes the local water depth from the regional wave transformation model in the left panel, and the associated average annual sediment flux in the right panel. The sediment flux represents the rate of sediment moving along the coast, where negative values indicate movement toward the north/northwest (from bottom to top of the figure), and positive values indicate movement toward the south/southeast (from top to bottom of the figure). This rate is presented in units of 100,000 m^3/yr and can be used to quantify the annual sediment transport in reaches along Nantasket Beach. The solid black line shown in the sediment flux panel is a fit of the flux results, indicating the general movement of sand along the coastline.

The sediment flux indicates that, along the southern portion of Nantasket Beach (0.5 to 2.5 km alongshore [0.3 to 1.6 miles]), the average annual longshore transport is directed to the northwest (negative flux value) at an average rate of approximately 4,060 cy/yr, with maximum rates ranging from 10,000 cy/yr to 50,000 cy/yr. The center portion of Nantasket Beach (3.0 to 4.5 km [1.9 to 2.8 miles]alongshore) experiences sediment transport to the southwest at an average annual rate of approximately 3,800 cy/yr, while the northernmost section of Nantasket Beach (4.5 to 5.5 km alongshore [2.8 to 3.4 miles]) indicates transport to the northwest at a minor rate. As such, net sediment transport along the Nantasket shoreline is relatively small and is directed primarily towards the north/northwest. These relatively small transport rates, and reversals in transport direction along the shoreline, support the historically relatively stable nature of the Nantasket Beach shoreline. For example, the northward sediment transport ranges from 10,000 to 50,000 cy/yr in the DCR portion of Nantasket Beach (as shown in the dashed line) reflect a relatively small flux of sediment, indicating that on an annual basis, not much sand is moved to either the north or the south during average conditions.

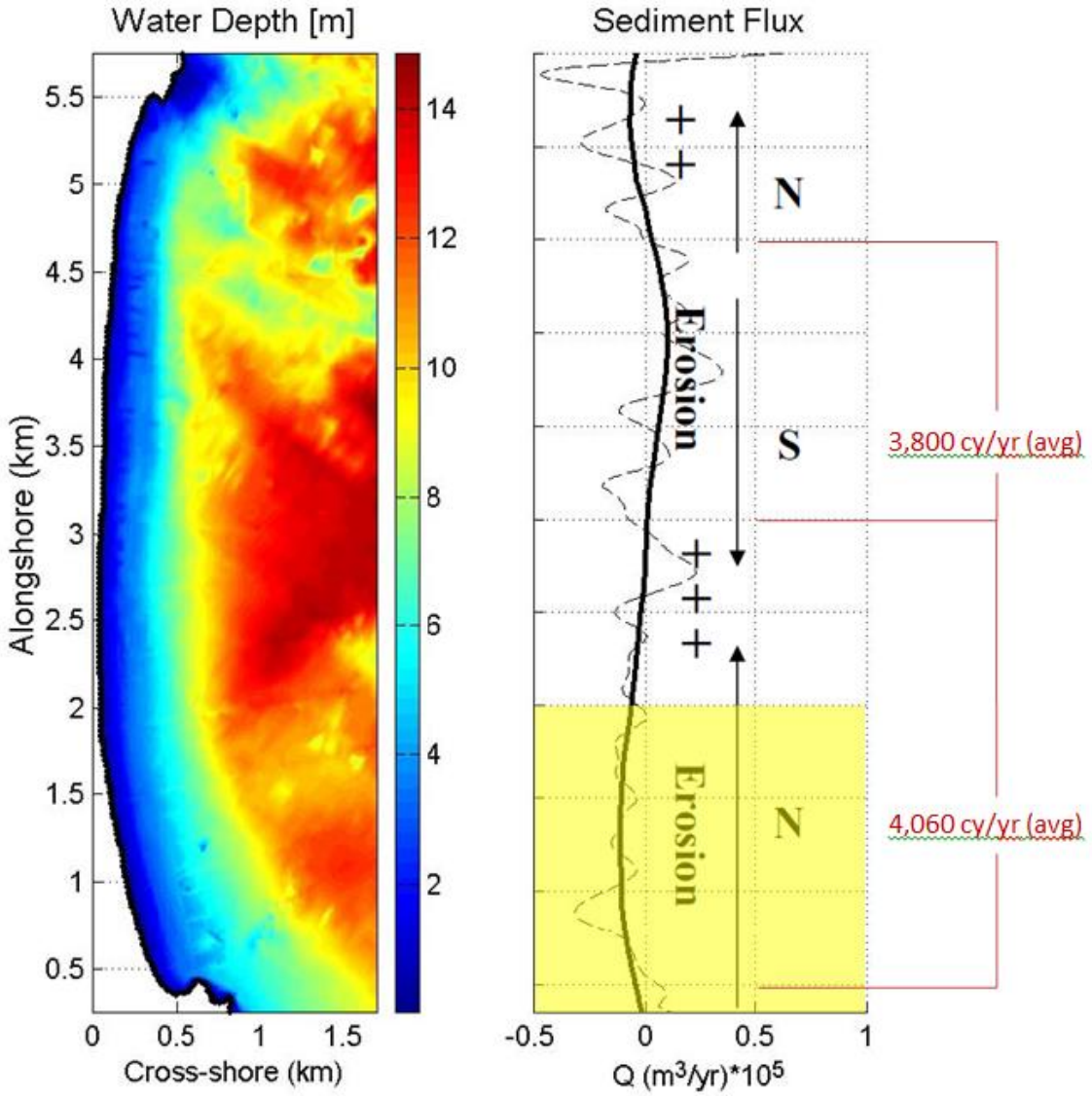


Figure 6-16. Sediment flux results for an average year at Nantasket Beach (DCR portion highlighted in yellow)

The movement of sediment is further illustrated by the arrows expressing direction of sediment transport, as well as the subsequent convergence and divergence of the flux (creating areas of accretion and erosion, respectively). As shown, the sediment in the DCR portion of Nantasket Beach is transported to the north, and since there is no major source of sediment to the beach (due to the Atlantic Hill headland), an area of erosion is created. North of the DCR portion of the beach, there is an area of accretion (identified by '+++' on Figure 6-16) caused by a convergence of southward and northward moving sediment. The model also indicates a region of erosion towards the northern end of the beach where there is a divergence of wave energy and sediment transport.

In general, the larger-sized cobble material is not mobilized during a majority of the average annual wave conditions. The more commonly occurring, but less energetic, wave approach directions

arriving from the east and east-southeast are not capable of mobilizing the cobble material. During these conditions, only the sand portion of the beach is mobilized and transported to the north-northwest.

The sediment transport results were also compared to the historical shoreline change rates to determine the relative performance of the model. Figure 6-17 overlays the model sediment flux results against the historic rates of shoreline change. The red line indicates the sediment flux results, while the black line shows the historic rate of shoreline change. Negative values of sediment flux (red line) indicate movement of sand to the north, while positive values of sediment flux indicate movement of sand to the south. Negative values of shoreline change indicate erosion, while positive values indicate accretion. The modeled areas of erosion and accretion shown in Figure 6-16 (caused by the convergence and divergence of the flux) match the observed shoreline change well. For example, sand moving from the southeast to the northwest in the DCR portion of Nantasket Beach would result in a loss of sediment in this region, and is consistent with the observed shoreline change data for the same area.

Storm Sediment Transport

To identify the amount of material that may be temporarily moved during a significant storm event, the sediment transport model was also used to evaluate sand movement for significant storm events. For example, during a 10-yr storm event, sediment transport rates average 60,000 cy/yr to the southeast, with maximum flux rates exceeding 200,000 cy/yr. This is significantly larger than the average annual conditions. Similarly, for the 50-yr case, sediment transport flux rates average approximately 800,000 cy/yr, with maximums of over 2,000,000 cy/yr. Although these storms don't last an entire year, and therefore move only a fraction of that amount, these high-energy storm events result in a significant amount of sediment movement at Nantasket Beach and play an important role in the overall consideration of alternatives for erosion mitigation. For example, a 1-day 50-yr storm event could transport as much or more material as an entire average year (approximately 2,000 cy). A more detailed description of the sediment transport modeling is provided in Appendix B.

The cobble component of the beach sediments is only mobilized during these more energetic wave conditions (e.g., northeast to north-northeast). During typical storm events that arrive from the northeast, both cobbles and sand are mobilized and transported to the southeast. Therefore, in the alongshore direction at Nantasket Beach, cobbles are more consistently transported to the southeast, while the net movement of sand is more consistently to the northwest. This dissemination of the natural sediment distribution at Nantasket Beach is consistent with the observations of sediment types at the beach, where more of the cobble-based material is generally located in the southeast portion of Nantasket Beach, while the northwest portion of Nantasket Beach generally contains more sand (USACE, 2006).

6.1.9 Water Quality

Water quality data are not available for Nantasket Beach. However, the combination of open ocean conditions outside of Boston Harbor, the absence of any point source discharges, and almost no non-point source runoff create conditions for consistently high water quality for bathing and recreation year-round. Such water quality conditions are rare in urban settings such as Nantasket Beach.

Figure 6-17. Sediment transport flux from modeling results *(red line)* compared to historic rates of shoreline change (ft/yr; *black line*), with sediment transport direction noted *(brown arrows)*

6.2 Environmental Resources

The proposed project would be constructed in several jurisdictional resources protected under state and local wetland jurisdictions. These resources include Coastal Beach, Barrier Beach, Coastal Dune, Land Under the Ocean, Land Containing Shellfish, Land Subject to Coastal Storm Flowage, and Estimated Habitats of Rare Wildlife. These resources are currently sediment starved and experiencing substantial erosion. Through this project they would be nourished and enhanced. This section identifies and describes the existing environmental resource areas within the project area. Chapter 8 provides additional details, including an assessment of project impacts on these resources.

6.2.1 Coastal Beach

The Coastal Beach includes those unconsolidated sediments subject to wave, tidal, and coastal storm action that form the gently sloping shores of the project area, including nearshore tidal flats. The Coastal Beach extends from the mean low water line (MLW) landward to the dune line. Along much of Nantasket Beach, the Coastal Beach is backed by a vertical concrete seawall or a stone revetment rather than a dune. Only in the far northern extent of the project area is the Coastal Beach backed by a Coastal Dune (Figure 6-18). Protectable interests include: storm damage protection, flood control, and the protection of marine fisheries and wildlife habitat.

Benthic communities in the vicinity of the project area are typical intertidal sandy shore assemblages. These assemblages tend to have few species and few individuals and are represented by organisms adapted for life in shifting sand habitats. Some representative organisms in the Nantasket Beach study area identified by Pratt (1996) include haustorid amphipods *(Amphiporeia virginana, Haustorius canadensis,* and *Parahaustorius longimerus),* and some species of polychaetes such as *Paraonis fulgens* and *Nephtys picta* (Appendix E).

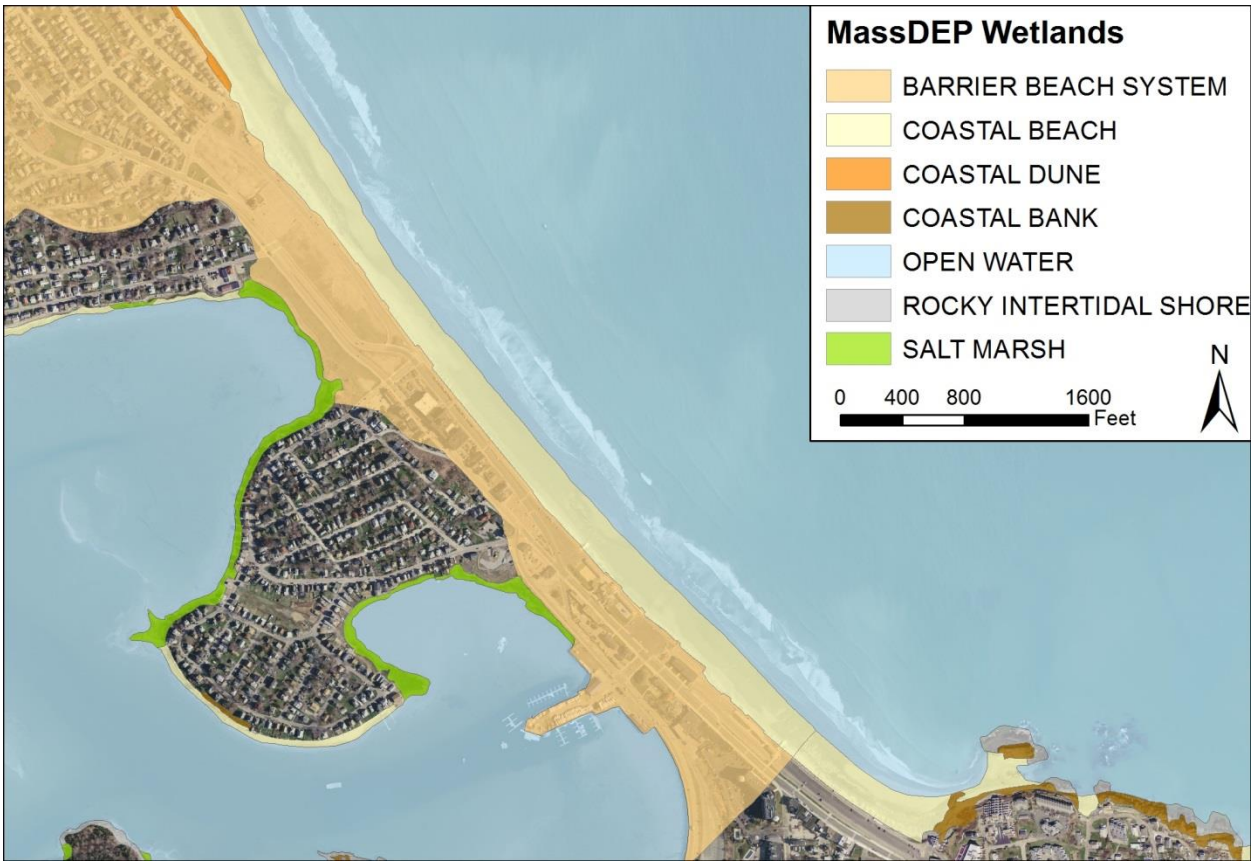


Figure 6-18. MassDEP wetlands in Nantasket Beach project area. Source: MassGIS, 2018

6.2.2 Coastal Dune

Coastal Dune resources are present in the northern section of the project area near the David Cook Comfort Station. They include natural hills, mounds or ridges of sediment landward of the Coastal Beach that have been deposited by wind action, storm overwash, or man-made dune restoration projects. The Coastal Dunes in the project area have crest elevations at approximately 13 ft (NAVD88) and are approximately 20 to 60 ft wide. The Coastal Dunes provide protection for roads and infrastructure behind them. Protectable interests include storm damage protection and flood control.

6.2.3 Barrier Beach

The entire length of the project area at Nantasket Beach is classified as a Barrier Beach, which consists of a narrow low-lying strip of land extending roughly parallel to the trend of the coast and containing Coastal Beach and Coastal Dune resources. The Barrier Beach is separated from the mainland by the Weir River Estuary and Hingham Bay. Protectable interests include: storm damage protection, flood control, as well as protection of marine fisheries, wildlife habitat and land containing shellfish. The entire project site is considered Barrier Beach, starting at the southeastern headland at State Park Road and extending to the northwestern end of the project near the David Cook Comfort Station.

6.2.4 Land under the Ocean (includes Eelgrass and Fisheries)

Land Under the Ocean resource extends from the mean low water (MLW) line seaward to the boundary the Town of Hull's jurisdiction. Nearshore areas of Land Under the Ocean are significant to the protection of the following interests: water circulation, distribution of sediment grain size, water quality, finfish habitat, and important food for wildlife. Essential Fish Habitat (EFH) resources documented by the National Marine Fisheries Service (NMFS) to be in the vicinity of the project site are described in the following section. Eelgrass resources have not been mapped by MassDEP in the vicinity of the project area, nor have any of the investigations performed for this study identified eelgrass offshore of the project area (Appendix I).

6.2.4.1 Essential Fish Habitat (EFH)

Until recently essential fish habitat was designated using a grid comprised of 10x10-minute latitudinal/longitudinal areas "EFH squares" defined by the New England Fisheries Management Council and the National Marine Fisheries Service. The 10x10-minute square encompassing a given project area was used to describe EFH species for purposes of impact assessment.

NMFS is in the process of amending EFH designations to more accurately reflect species and life stages in a specific project area. In the near future, project areas will be specified on an interactive map, and species found within the project area will show up, along with text describing occurrence by life stage, and depth, salinity, and other habitat requirements.

The spatial extent and habitat requirements for EFH species are being updated at this time, so the EFH designations for project areas in the northeast are not available. Therefore, it is not possible to tell at present which species and life stages are likely in the Nantasket Beach project area. However, Table 6-5 provides the set of species listed in a 2013 EFH assessment prepared for the

Hull Coastal Storm Damage Reduction Project (USACE, 2014). This list provides insights on what species are likely in the area.

Table 6-5. Federally-managed Species – Nantasket Beach, Hull (as of 2013)

Species
Atlantic Cod *(Gadus morhua)*
Haddock (*Melanogrammus aeglefinus*)
Pollock (*Pollachius virens*)
Red Hake (*Urophycis chuss*)
Winter Flounder *(Pleuronectes americanus)*
Yellowtail Flounder (*Limanda ferruginea*)
Windowpane Flounder (*Scophthalmus aquosus*)
American Plaice (*Hippoglossoides platessoides*)
Ocean Pout (*Macrozoarces americanus*)
Atlantic Halibut (*Hippoglossus hippoglossus*)
Atlantic Sea Scallop (*Placopecten magellanicus*)
Atlantic Herring (*Clupea harengus*)
Bluefish (*Pomatomus saltatrix*)
Long Fin Squid *(Loligo pealei)*
Short Finned Squid (*Illex illecebrosus*)
Atlantic Butterfish *(Peprilus triacanthus)*
Atlantic Mackerel *(Scomber scombrus)*
Summer Flounder *(Paralicthys dentatus)*
Scup *(Stenotomus chrysops)*
Black Sea Bass *(Centropristus striata)*
Surf Clam *(Spisula solidissima)*
Bluefin Tuna *(Thunnus thynnus)*

Source: USACE, 2014

6.2.4.2 Lobster Habitat

Discussions with the DMF regarding lobster habitat in the project area indicates that while data are not available regarding lobsters, DMF would not be concerned about potential impacts to lobsters since most of the footprint of most of the beach fill would be within the intertidal zone (Kate Frew, DMF, personal communication, March 14, 2018).

6.2.5 Land Containing Shellfish

Land Containing Shellfish includes land under the ocean, tidal flats, rocky intertidal shores, salt marshes, and land under salt ponds when any such lands contains shellfish, including Blue Mussel, American Oyster, European Oyster, Quahog, Ocean Quahog, Razor Clam, Surf Clam, Sea Scallop,

Bay Scallop or Soft Shell Clam. This resource area is significant for the protection of marine fisheries.

Areas throughout Massachusetts waters suitable for shellfish have been delineated by DMF. These areas have been identified through input from the local Shellfish Constable, commercial fisherman, and information contained in maps and studies of shellfish in Massachusetts. These suitability areas represent habitats suitable for the ten species of shellfish listed above. As shown in Figure 6-19, areas just offshore the project area contains habitat suitable for Blue Mussel and Surf Clam.

Figure 6-19. Shellfish suitability in Nantasket Beach project area. Source of data: MassGIS, 2018

A shellfish survey conducted by Battelle in December 2006, indicates that there are low densities of Surf Clam in the vicinity of the project area. The survey was performed over the course of 5 days using hydraulic tows. A total of 53 tows, each approximately 100 m (330 ft) long, were conducted. A commercial hydraulic dredge, which measured 30 inches in width and 15 inches in height was used to collect surf clams. The dredge was equipped with a 2¾-inch mesh catch net. Due to the size of the catch net, clams less than 3 inches in size could have been potentially lost while retrieving the dredge. For surf clams, individuals were counted and measured. Very low counts of other species were collected, including sand crab (*Cancer irroratus*), moon snail (*Polinices duplicatus*), razor clam (*Ensis directus*), window pane flounder (*Scophthalmus aquosus*), blue mussel (*Mytilus edulis*), and lady crab (*Ovalipes ocellatus*). The results of the surf clam survey, displayed in number of clams collected per square foot, are displayed in Figure 6-20.

Higher densities of surf clams were found in shallower areas, with the highest densities (0.5 to 0.7 clams per square foot) observed along the northwestern extent of the project area in the vicinity of tows 1-C, 7-B, 7-D, 1-G, 1-I, and 7-H. Battelle's final report, *Surf Clam Survey in Support of Feasibility Study: Hydraulic Clam Dredging, Nantasket Beach, Hull, MA* is included in Appendix F.

Preliminary discussions with DMF on March 5, 2018 regarding the 2006 shellfish survey suggest that the densities found would be considered too low for the area to be deemed significant shellfish habitat. A similar finding was made recently by DMF for the Scussett Beach offshore borrow site project, in an area where surveys showed similar shellfish densities.

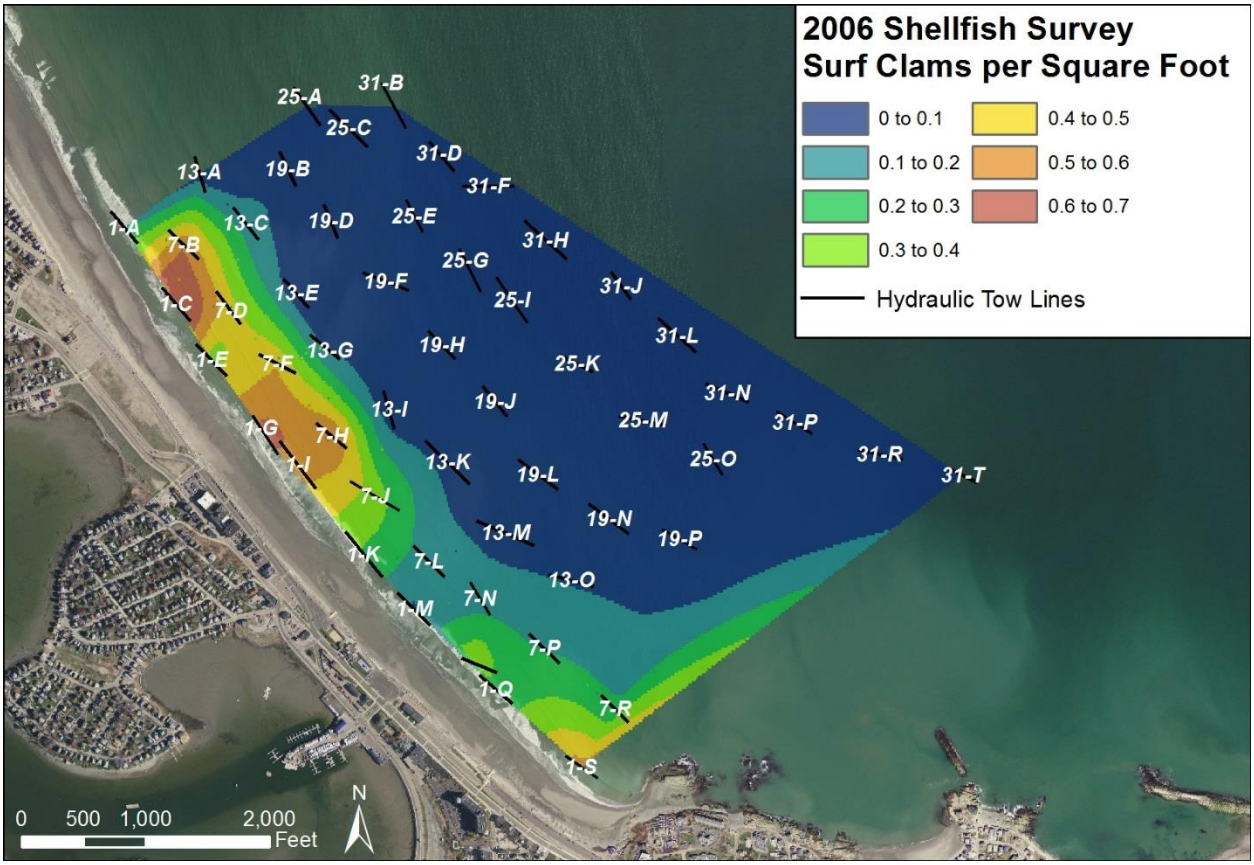


Figure 6-20. 2006 Shellfish survey in Nantasket Beach project area. Source of data: Battelle, 2007

6.2.6 Land Subject to Coastal Storm Flowage

Land Subject to Coastal Storm Flowage is land subject to any inundation caused by coastal storms up to and including that caused by the 100-yr storm, surge of record, or storm of record, whichever is greater, and includes both V zones (velocity zones or areas of wave action), and A zones (the extent of the quantifiable 100-yr coastal floodplain). As seen in FEMA's Flood Insurance Rate Maps (FIRMs) in Figure 6-21, the entire project area is within the 100-yr flood plain, and therefore the entire area is classified as Land Subject to Coastal Storm Flowage.

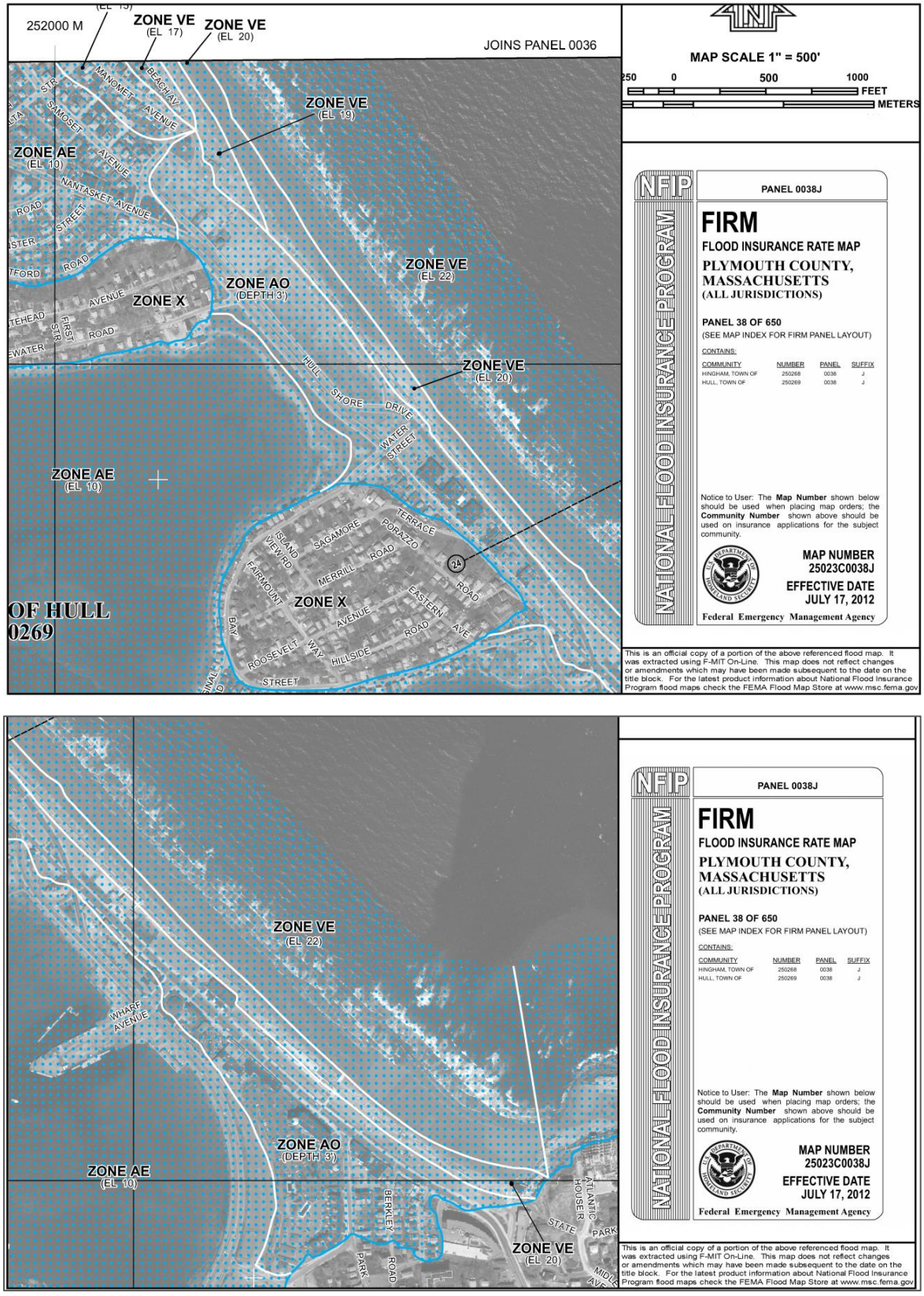


Figure 6-21. FEMA flood zones at Nantasket Beach: northern *(top)* and southern *(bottom)* parts, as of July 2012

6.2.7 Estimated Habitats of Rare Wildlife

According to the Massachusetts Natural Heritage & Endangered Species Program (NHESP), Division of Fisheries & Wildlife, the northern end of the proposed project is located in habitat for the rare species of shorebird, Piping Plover (*Charadrius melodus*) (Figure 6-22). This species is protected under the Massachusetts Endangered Species Act (MESA) and its implementing regulations (321 CMR 10.00), as well as the Wetlands Protection Act (WPA) and its implementing regulations (310 CMR 10.00).

The Piping Plover nests during the summer months along the Atlantic Coast from Massachusetts north to Newfoundland, and south to Virginia and North Carolina. In the winter they migrate farther south, from South Carolina to Florida, the Gulf of Mexico and Caribbean. The Piping Plover nesting habitat includes sandy coastal beaches with flat slopes and no vegetation. They prefer dry, light-colored sand found along the outer coastal shores. The typical nesting area for these birds lies between the high tide line and the foot of the coastal dunes. The critical breeding times in Massachusetts are from late March or April to late July and early September, when the Piping Plover begins to migrate southward.

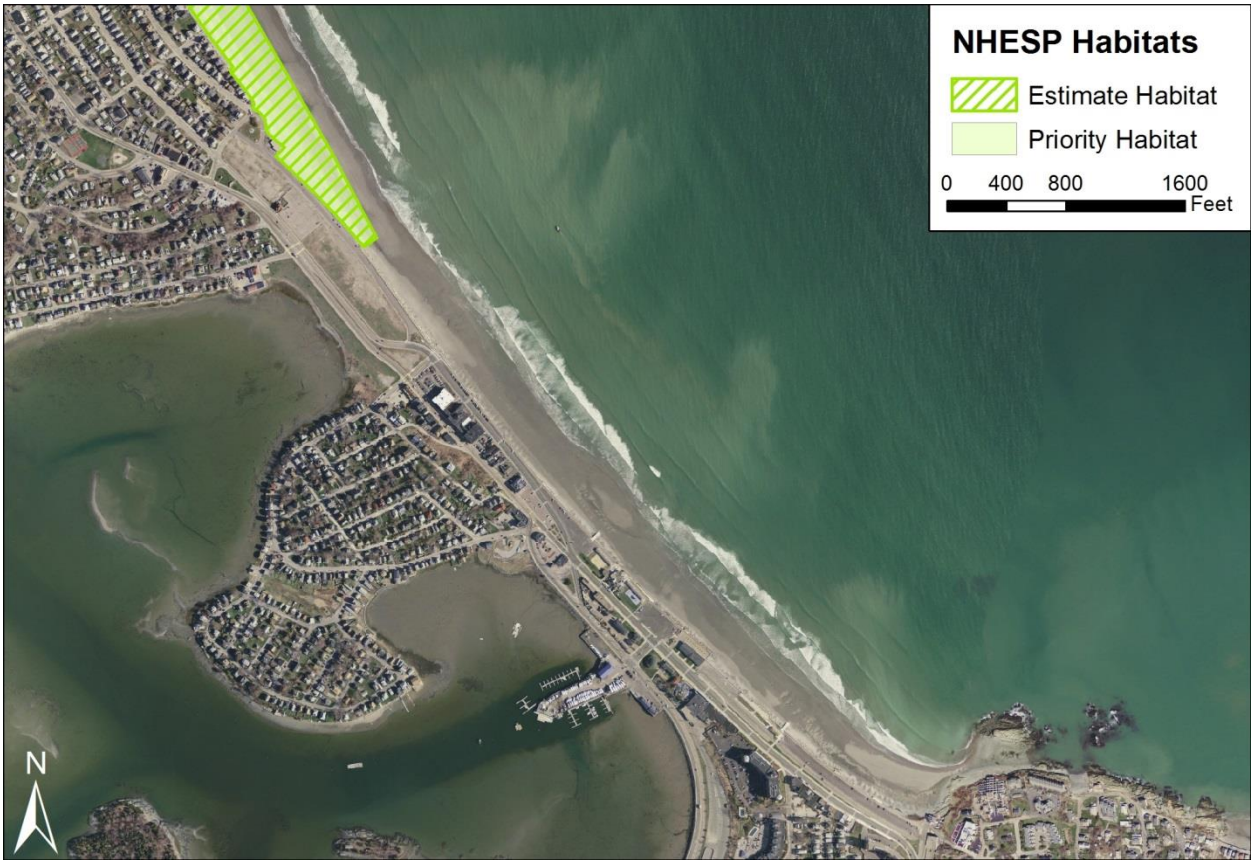


Figure 6-22. NHESP priority habitats and estimated habitat for Nantasket Beach. Source: MassGIS, 2018

Since Piping Plovers were first observed on the adjacent town-owned portion of the beach in 2014, the Town of Hull has contracted with Mass Audubon's Coastal Waterbird Program (CWP) to provide oversight and guidance for their protection. The CWP of Mass Audubon is recognized by federal, state and municipal agencies as one of the most effective programs working to protect coastal birds and barrier beaches in the Northeast. The CWP monitoring begins no later than April 1 each year, and records rare bird species abundance, distribution, reproductive success, causes of nest and/or chick loss, causes of disturbance, and responses to habitat management. In addition, surveillance surveys for new species and new colony sites are ongoing in conjunction with all coastal breeding bird monitoring efforts. The data collected on coastal breeding birds are recorded on CWP field data sheets and entered into the PIPLOIDES database maintained by Mass Audubon and accessed by NHESP. The CWP also works in cooperation with Town of Hull Conservation staff to provide physical protection to Piping Plovers through protective fencing, signage, on-the-beach engagement with public and diversion of adverse activities, and nest/chick guarding during raking and other vehicle used for beach maintenance and emergency activities.

In 2017, four pairs of Piping Plovers were observed on the Town-owned beach north of the project area. All four nests occurred north of Revere Street (more than 1,200 ft north of the northern terminus of the proposed project). Collectively, these four pairs hatched 16 chicks, and fledged eight. Two additional pairs and a lone male defended territories but did not nest. The Audubon (2017) monitoring report is provided in Appendix G.

6.3 Historic and Archaeological Resources

The historic and archaeological resources of the project area were recently summarized in the Environmental Assessment for Phase 1 of the project as follows (USACE, 2014; p. EA-12 to EA-13):

> "Hull, Massachusetts was originally called Nantascot by the Wampanoag Indians. The town dates from 1644 when the town was named for a seaport town in Yorkshire, England. It is now known as Nantasket, but its official name is Hull (Bergan, 1972).
>
> Originally a fishing and agricultural town, the Town of Hull entered its golden age in the late 19th Century and the era of the big hotel. From the early 1880's to the First World War, several palatial inns and resorts transformed the town into a popular summer resort on the Eastern seaboard. Names such as the Rockland House, Atlantic House, Nantasket House, Ville Napoli, Pacific House and Pemberton Hotel dominated the scene. During World War I, however, the growth of the automobile had a destructive effect on the hotels, steamboats, and trolleys that serviced the area. Most of the inns and hotels from this era are now gone.
>
> At about the same time as the rise of the hotel industry, the rise of cottages, primarily as vacation homes, became dominant in the town (Sweetser, 1888). These homes ranging from bungalow-sized to mansion are the late 19th-early 20th Century historic homes that occur near the project. Many examples of the Queen Anne, Victorian Gothic, neo-Tudor and Bungalow styles were built on hillsides in town. Typically, ocean front lots contained larger homes than those further inland. Many buildings of this period (1870-1915) remain in altered condition. Areas which have seen the least alteration of domestic architecture from this period include Hull Village, Allerton Hill

> and to a degree Atlantic Hill (MHC, 1979). At about the same time in 1905, Paragon Park was constructed in the southern portion of town. All vestiges of this popular amusement park are also gone with the exception of the carousel that is preserved on Nantasket Avenue.
>
> The DCR, formerly known as the Metropolitan Parks Commission, took over control of some recreational areas in town, including Nantasket Beach in 1899 (Bergan, 1972), and has controlled the popular beach resort since that time. DCR bathing pavilions located on Nantasket Avenue were built in a variation of the Spanish Mission style circa 1905-1915.
>
> During the Modern period of 1915-1940, bungalow style homes were dominant while the widespread demolition and alteration of existing commercial structures after World War II became apparent as other resort areas rose in popularity. The rise of strip development along Nantasket Avenue had also become prevalent during this period (MHC, 1979)."

There are several properties listed on the National Register of Historic Places within the Town of Hull; they include the Point Allerton Life Saving Station, Telegraph Hill Historic and Archaeological District and the Hull Village Historic District. Properties eligible for inclusion on the National Register include the Metropolitan Park System of Greater Boston. The Park System includes the Nantasket Beach Reservation that is part of the Park System. There are several buildings within the Reservation that are eligible for listing on the National Register of Historic Structures as contributing structure within a potential Nantasket Beach Reservation Historic District such as the Clocktower building, Police Station Building, and Dormitory Building.

6.4 Socio-economic Resources

The Nantasket Beach Reservation is a popular destination for beachgoers, walkers, joggers, and others taking in the sights and sounds of the adjacent Atlantic Ocean.

The Reservation is on a long and narrow strip of land (500 ft wide in some locations) that separates Hull Bay and the Atlantic Ocean. The Reservation is bounded by Phipps Street to the north, Hull Shore Drive and Nantasket Avenue (Route 228) to the west, the end of State Park Road to the south, and the Atlantic Ocean to the East. The Reservation encompasses approximately 28 acres and 6,800 ft of beachfront, as stated previously. At low tide, the beach becomes a wide, expansive area that can accommodate hundreds of beachgoers. At high tide, much of the beach is presently overtaken by the ocean and beachgoers retreat to the promenade, upland of the seawall.

6.4.1 Public Access to Waterfront

The existing infrastructure of the Nantasket Beach Reservation includes the beach, seawall, sidewalks/promenade, various buildings, parking lots, and roadways. Contributing to the beach's appeal is its high level of pedestrian and vehicular accessibility from adjacent, largely residential areas, and its proximity to the Boston metropolitan area. Visitors traveling by car to the Reservation will likely park in one of DCR's off-street parking lots or in parking spaces along the DCR-owned roadways. There are over 1,000 parking spaces on the Reservation, with the highest concentration at the southern end of the Reservation. There are a total of six parking lots – five are

situated adjacent to the beachfront and the sixth is an overflow lot located to the west along George Washington Boulevard. The on-street parking spaces are predominately located on the northern half of the Reservation.

Pedestrian access to the beachfront is encouraged with 29 crosswalks fairly evenly distributed along Nantasket Avenue and Hull Shore Drive at intersection and mid-block locations. There is a beachfront promenade along the entire length of the Reservation, providing beach users physical and visual access to the 6,800-ft long beachfront as well as passive and active recreation opportunities. The beachfront promenade is located between the parking areas adjacent to the beach and the seawall and connects to various seating and shade areas. Accessibility to the beach from the promenade is provided via intermittent entry points in the seawall. Access to the beach from these points is provided by either concrete or granite stairs or Americans with Disabilities Act (ADA) compliant ramps (see Figures 5-7 and 5-8 in Chapter 5).

6.4.2 Buildings

The DCR Reservation includes a multitude of buildings, some of which are for public use while others are for DCR operations. These buildings consist of the following:

- Bath houses:
  - Mary Jeanette Murray Bath House
  - David A. Cook Comfort Station
  - Comfort Station (205 Nantasket Avenue)
  - Tivoli Bath House
- Landside Operations and Maintenance Buildings
  - Island District Buildings
  - Former Metropolitan District Commission (MDC) Police Station
  - Garage Building
  - Wood Store Room
  - Upper Maintenance Garage and Artist Studios
  - Lower Maintenance Garage (with attached Carpenter Shop)
  - Lifeguard Cottage (also known as Guard House)
  - Greenhouse
- Other Buildings
  - Bernie King Pavilion
  - Carousel and Clocktower Building

Other buildings and land also fronting the ocean are a mixture of retail businesses, residential units, and a hotel on a nearby town-owned parcel on Hull Shore Drive and along Nantasket Avenue. The Hull Redevelopment Authority (HRA) owns a large vacant tract of land that it plans to have developed by a developer.

6.4.3 Recreation

Visitors come to Nantasket Beach year-round for recreation (beach walking, watching the ocean, and sunbathing and swimming in the summer). An informal visitor survey was conducted by DCR

in 2006 to gain a better understanding of visitors' use and impressions of the Reservation. The responses provided valuable background information for development of the Master Plan (DCR, 2016; see Section 8.6, Cumulative Impacts). Specifically, a total of 101 individual surveys were conducted on Monday, July 24; Sunday, July 30; and Wednesday, August 16, 2006. Although a few of the comments regarding facilities are now out of date, the majority of the responses are still relevant. The responses are summarized below:

- **Visitors:** Almost 90% of the visitors surveyed were from outside of the Town of Hull. It is assumed that many Hull residents use the Town portion of the beach, rather than the DCR portion of the beach. Respondents came from areas west and south of Hull, from up to 40 miles away. 91% of the respondents came to the beach by car. This is consistent with the finding that most of the people on the DCR beach are not from Hull (transit connections to the beach were very limited – the Greenbush Commuter Rail Line did not reopen until 2007). Approximately 7% of respondents walked (Hull residents) and 2% drove a motorcycle. Young crowds (13-25 years of age) tended to congregate at the southern end of the beach near the Tivoli Bath House, whereas families (adults with children under 18 years of age) tended to congregate at the northern end of the beach near the Cook Bath House. Approximately 25% of the respondents came with children under 18 years old.

- **Beach Experience:** On hot days, many beachgoers go into the water. A total of 72% of the respondents reported swimming; 28% said they had not been in the water, but many of these respondents said they would be going in shortly.

- **Attraction to Local Restaurants and Shops:** 67% of the respondents said they had been, or planned to go, to a restaurant, shop, museum or other business in town while at the beach. Approximately 30% of the respondents who gave improvement ideas for the Reservation wanted more food-related facilities (more beach vendors, more convenient food).

- **Beach Nourishment:** 66% of the respondents said they would support beach nourishment with sand of another color. 74% of the respondents said they would like a wider beach at high tide.

6.4.4 Economics

Based on US Census (2018), the Town of Hull has a median annual household income of $78,114 (2012-2016). The population was reported with 10,293 (2010); the town, outside of the Reservation, is densely developed. The primary employers include the government, trade, and service industries (Commonwealth of Massachusetts, 2012). Public services offered by the Town of Hull include a fire department, law enforcement, public schools, water and sewer services, recreation, and libraries. The form of government for the Town of Hull is by a Board of Selectmen, a Town Manager, and open town meetings.

The backshore of Nantasket Beach is occupied by commercial and residential properties. The beach itself is used by residents and visitors for various recreational activities.

In recent years there have been several community development plan and master plan efforts by the Town and by the DCR. DCR completed the Nantasket Beach Reservation Master Plan in 2016 (see summary in Section 8.6; the complete Master Plan is provided in Appendix H).

7. Analysis of Alternatives

This Expanded NPC has identified and evaluated alternatives for beach nourishment at Nantasket Beach. Alternatives for sources of beach compatible sand have also been evaluated. The specific goal of the alternatives assessment was to identify and evaluate a number of practicable and feasible alternatives that would reduce vulnerability to flooding and storm damage in the vicinity of Nantasket Beach, while minimizing short and long-term adverse effects. This chapter describes the engineering alternatives that were identified for the beach nourishment and the analysis process that was used for evaluation. A total of four alternatives were developed and evaluated, consisting of a No-action alternative and three different nourishment designs. Alternative beach fill sources were also evaluated, including upland, offshore, and beneficial reuse of dredged material.

7.1 Beach Nourishment Alternatives

7.1.1 Nourishment Alternative A: No-Action

At this time, No-Action constitutes a seawall with toe protection in place in the mid- and southern sections of the seawall, a revetment in place in the northern section of the seawall, and a combination of riprap revetment and natural dunes in the northern 1,400 ft of the Reservation. This alternative does not provide Nantasket Beach with additional sediment for beach nourishment, additional protection for the existing seawall nor revetment, protection of nearby coastal infrastructure, or improvements to the recreational uses of the site.

7.1.2 Nourishment Alternative B: Nourishment of up to 226,000 cy

The beach nourishment design for this alternative is similar to the USACE design evaluated as part of the Coastal Storm Damage Reduction Project (USACE, 2002a). This alternative includes the placement of 226,000 cy of beach-compatible sediment on Nantasket Beach. The nourishment footprint would cover 31.2 acres and would extend over the full 6,800 linear ft of the project site (Figure 7-1). Alternative B involves a beach nourishment design with an average berm width of 50 ft at an elevation of 11.2 ft (NAVD88). The nourishment profile then slopes at a 1V:15H grade to meet the natural elevation of the existing beach.

The resources impacted by Alternative B include:

- No direct impact to Land Under the Ocean; the nourishment footprint is entirely above the mean low water (MLW) line (-5.16 ft, NAVD88).
- No impact to Coastal Dune; the nourishment footprint is entirely below the coastal dunes in the northern portion of the property.
- Direct impacts to 29.7 acres of Coastal Beach, including 26.7 acres of intertidal coastal beach (between mean high water [MHW] and MLW).

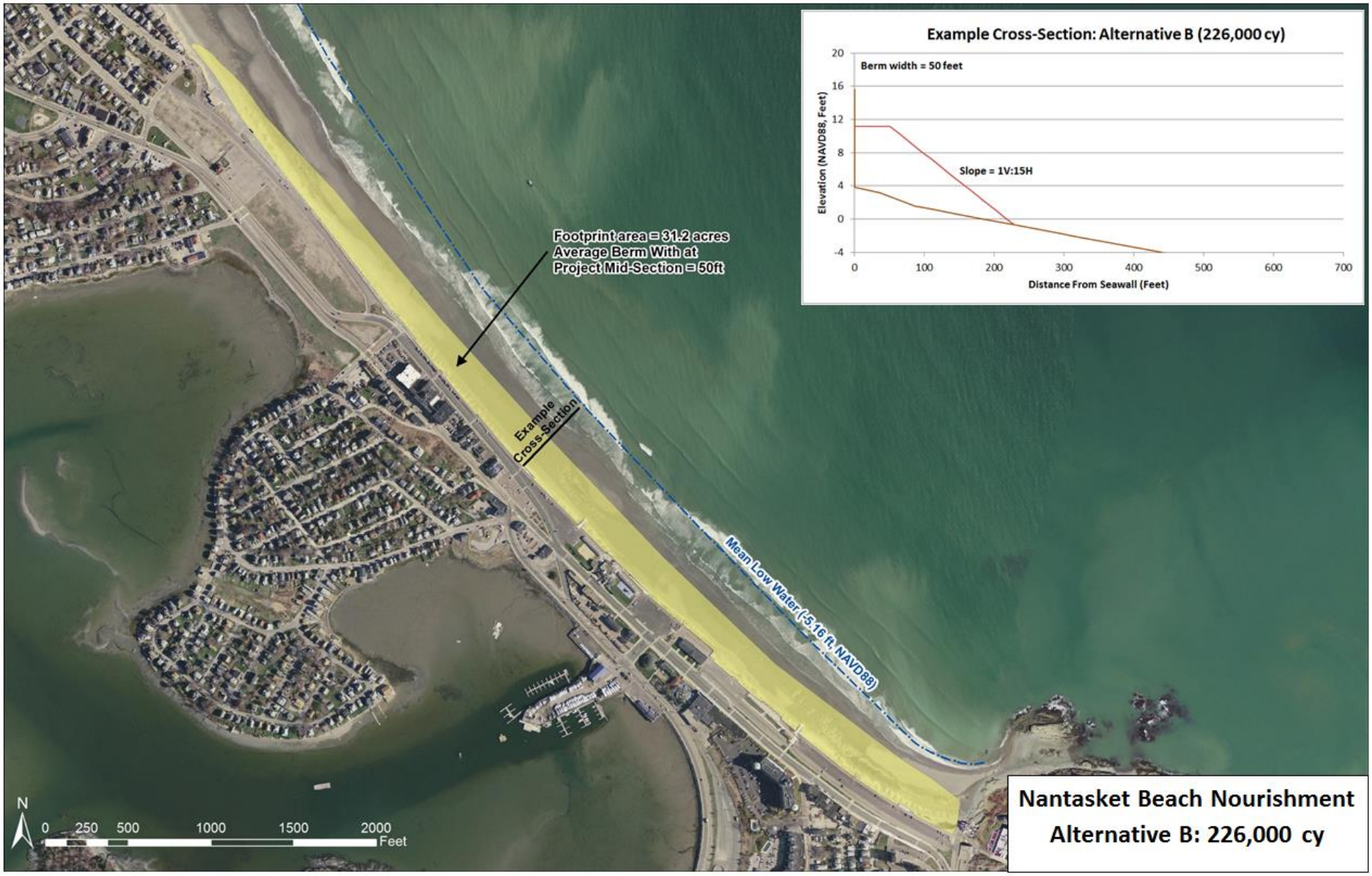


Figure 7-1. Footprint of nourishment Alternative B (226,000 cy)

7.1.3 Nourishment Alternative C: Nourishment of up to 378,000 cy

The beach nourishment design for this alternative is similar to the design selected by the USACE in 2014 as part of the revised Coastal Storm Damage Reduction Project to protect the mid-section of the seawall (USACE, 2014; Appendix C).

Alternative C includes the placement of 378,000 cy of beach-compatible sediment on Nantasket Beach. The nourishment footprint covers 54.6 acres and extends over the full 6,800 linear ft of the project site (Figure 7-2). Alternative C involves a beach nourishment design with an average berm width of 25 ft at an elevation of 11.2 ft (NAVD88). The nourishment profile then slopes at a 1V:25H grade to meet the natural elevation of the existing beach.

The resource areas impacted by Alternative C include:

- Direct impacts to 1.3 acres of Land Under the Ocean; below MLW (-5.16 ft, NAVD88).
- No impact to Coastal Dune; the nourishment footprint is entirely below the coastal dunes in the northern portion of the property.
- Direct impacts to 51.8 acres of Coastal Beach, including 48.8 acres of intertidal coastal beach (between MHW and MLW).

7.1.4 Nourishment Alternative D: Nourishment of up to 700,000 cy

The beach nourishment design for this alternative was identified by Woods Hole Group and Louis Berger (2010) as the preferred design to assure long-term protection of the upland resources and a recreational beach.

Alternative D includes the placement of 700,000 cy of beach-compatible sediment on Nantasket Beach. The nourishment footprint covers 75.3 acres and extends over the full 6,800 linear ft of the project site (Figure 7-3). Alternative D involves a beach nourishment design with an average berm width of 150 ft at an elevation of 11.2 ft (NAVD88). The nourishment profile then slopes at a 1V:25H grade to meet the natural elevation of the existing beach.

The resource areas impacted by Alternative D include:

- Direct impacts to 7.4 acres of Land Under the Ocean; below MLW (-5.16 ft, NAVD88).
- No impact to Coastal Dune; the nourishment footprint is entirely below the coastal dunes in the northern portion of the property.
- Direct impacts to 66.4 acres of Coastal Beach, including 48.8 acres of intertidal coastal beach (between MHW and MLW).

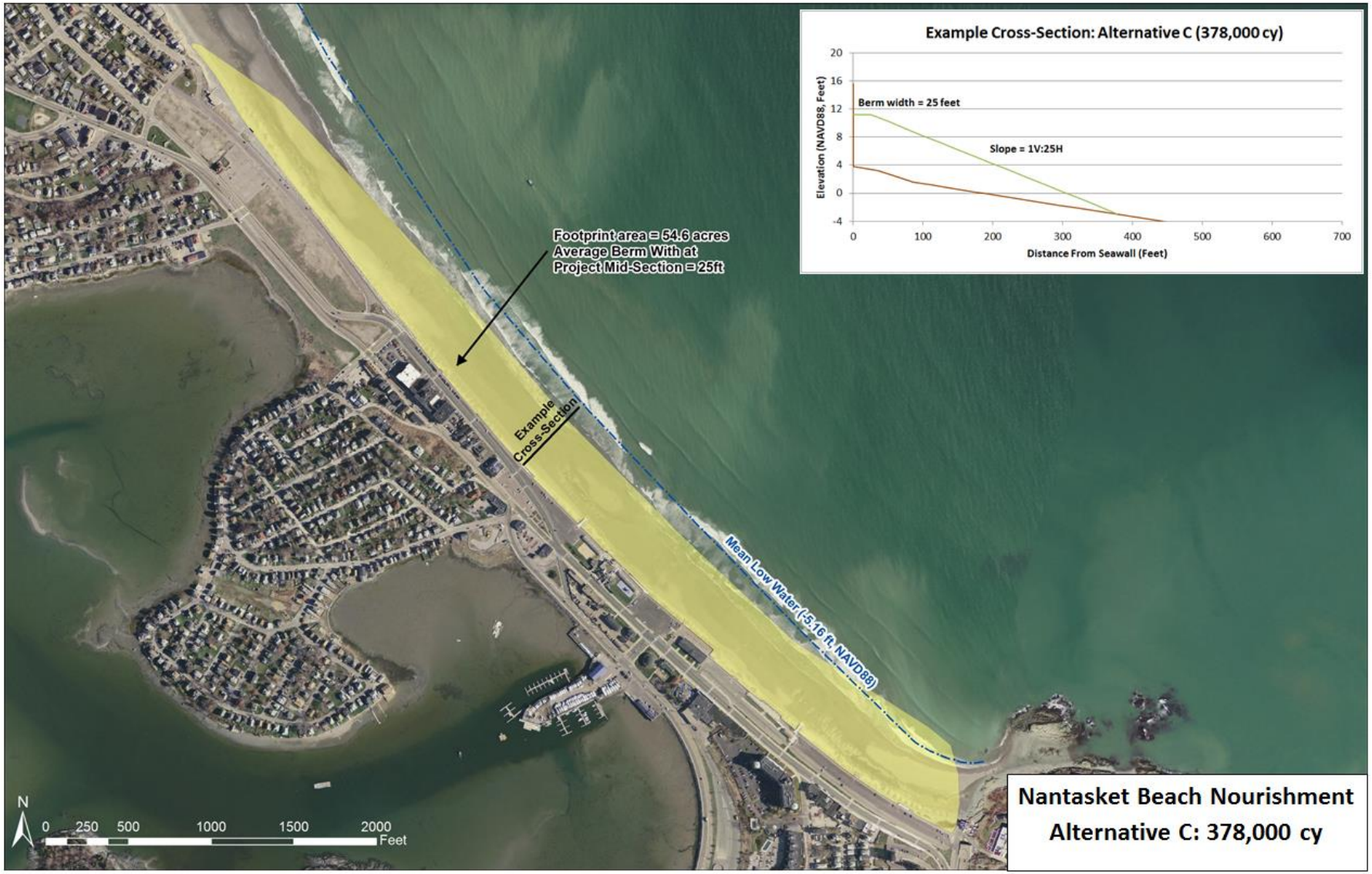


Figure 7-2. Footprint of nourishment Alternative C (378,000 cy)

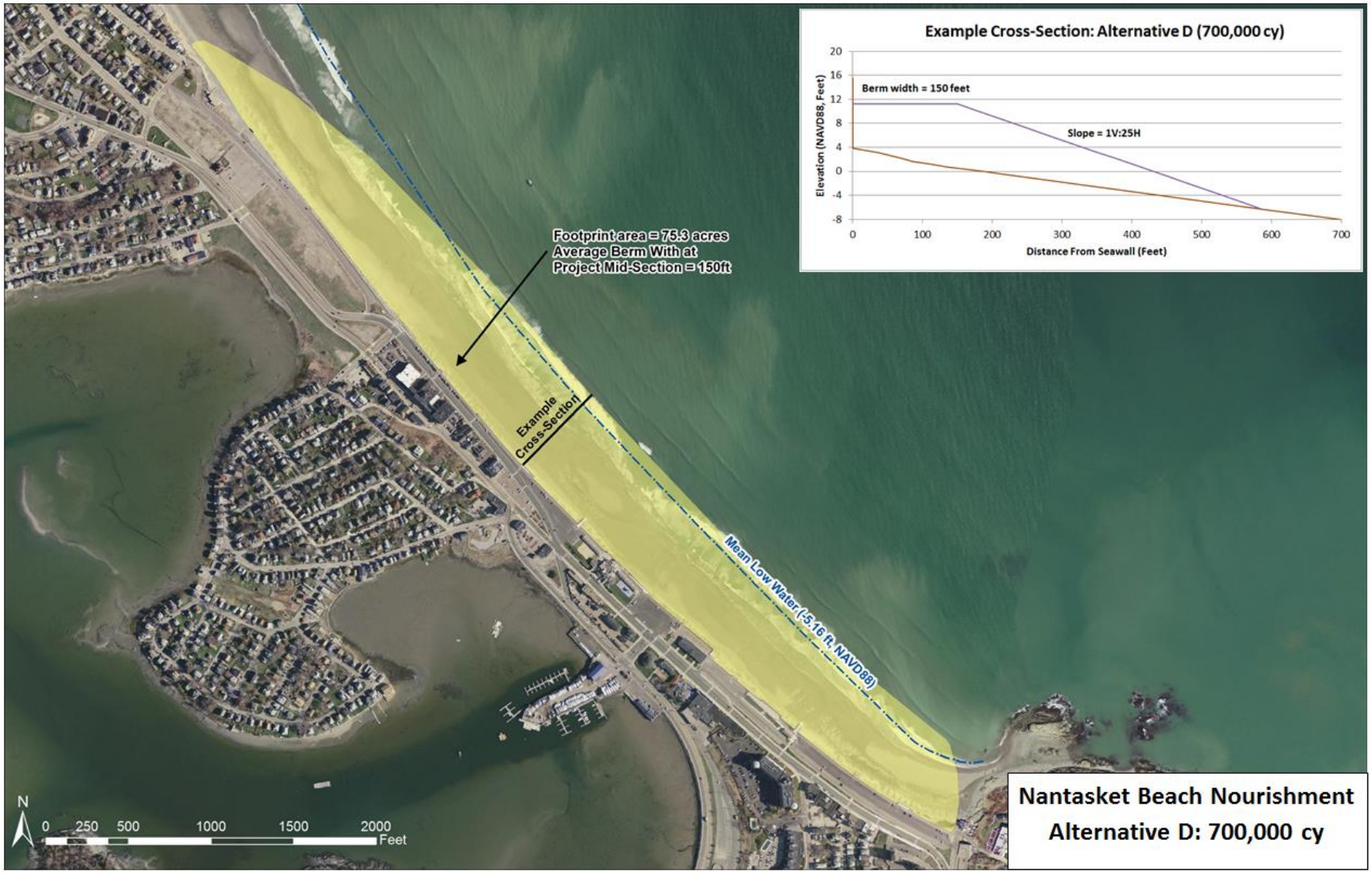


Figure 7-3. Footprint of nourishment Alternative D (700,000 cy)

7.2 Assessment of Beach Nourishment Alternatives

Assessment of the four alternatives followed a tiered approach. Each alternative was evaluated against the following criteria:

- Storm protection benefits
- Service life
- Impacts to wetland resources
- Socio-economic impacts

7.2.1 Storm Protection Benefits

Cross-shore sediment transport from the nourishment footprints and the ability of the project to continue providing storm damage protection from wave overtopping and flooding were evaluated using the XBeach numerical model. XBeach is an open-source numerical model developed to simulate wave, hydrodynamic, and morphodynamic processes. The model has been developed with support of various agencies including the USACE, Rijkswaterstaat and the EU, together with a consortium of UNESCO's Institute for Water Education, Deltares (formerly WL Delft Hydraulics), Delft University of Technology, and the University of Miami.

XBeach includes the hydrodynamic processes of short wave transformation (refraction, shoaling and breaking), long wave (infragravity wave) transformation (generation, propagation and dissipation), wave-induced setup and unsteady currents, as well as overwash and inundation. The morphodynamic processes include bedload and suspended sediment transport, dune face avalanching, bed update, and breaching. Effects of vegetation and hard structures can also be simulated. The model has been validated with a series of analytical, laboratory, and field test cases using a standard set of parameter settings. XBeach has options for defining the model domain in one or two dimensions, depending on the circumstances. For evaluating cross-shore impacts to average wave conditions and storm events, the 1-D model is considered sufficient and requires less computation time. Further details of the XBeach model and its theory can be found in the XBeach Technical Reference (Deltares, 2015).

The storm damage performance using the XBeach model was evaluated along a representative cross-shore transect located in the middle of the DCR Reservation. Elevations along the transect were specified at a uniform 2-m (7 ft) resolution out to a depth of approximately 40 ft NAVD88. All points landward of and including the seawall were defined as non-erodible, preventing erosion landward of the seawall, but allowing model interaction with the seawall. A sediment grain size with a D_{50} of 0.44 mm and a D_{90} of 11.0 mm was specified in the model simulations.

The model was used to simulate cross-shore transport for each of the nourishment alternatives (Alternatives B, C, and D) under average annual and storm conditions (Table 7-1). For the storm scenarios, synthetic surge hydrographs were developed for input into XBeach using the peak water levels for each storm event listed in Table 6-4. Each storm event was created from 48 hours of normal tidal data, with water levels ramping up and down to/from the storm surge value for each storm over a 24-hour period. The return-period storm wave heights and associated periods were determined using the Generalized Extreme Value (GEV) method. This method provides reliable

estimates of extremes without assuming the distribution type is known (Resio, 1989). The GEV method uses asymptotic methods to fit sampled maxima to the tail of a parent distribution, whose characteristics are estimated from the original sample. Storm wave heights and periods were the same as used for the nearshore wave transformation modeling (Table 6-2).

For normal conditions, a synthetic tidal signal developed from the Boston NOAA tide gauge was utilized at the boundary for seven days to allow the profile to equilibrate. For normal conditions, a significant wave height of 1.97 ft, with a period of 7.0 seconds was utilized as the offshore boundary condition for the entire 7-day run, as this was identified as the most prevalent wave height through the wave analysis.

Table 7-1. Boundary Conditions for XBeach Simulations

Storm Event	**Significant Wave Height** ft)	**Peak Wave Period** (sec)	**Storm Surge** (ft, NAVD88)
Normal Conditions	1.97	7.0	Normal Tidal Conditions
10-yr	22.97	10.2	8.46
50-yr	28.22	11.3	9.28
100-yr*	30.51	11.8	9.58

*only modeled for Alternative D.

Two options are possible in XBeach for the specification of wave conditions: (1) wave spectra, and (2) non-spectra, such as stationary wave conditions or time series. For the Nantasket Beach model simulations, the wave spectra boundary condition option was applied and a JONSWAP parametric spectrum was used. The spectrum shape is defined through the specification of wave height, wave period, wave angle, and other parameters, which XBeach then uses to generate a random wave time series. A conservative shore normal direction was specified for all waves. For the storm scenarios, wave heights and periods were ramped up from typical wave conditions to the storm wave conditions over a 24-hour period corresponding to the storm surge. Model simulations were performed using the XBeach model with the defined cross-shore profiles for each storm scenario. The storm model simulations were simulated for 48 hours to capture the gradual growth and peak of the event, while the normal scenario cases were simulated for 7 days to allow the profile to equilibrate.

The model output consists of wave height, water surface elevation, and velocity along the profile for each time step, along with changes in the bottom profile showing areas of erosion and deposition. The final profile was extracted from the model simulations for comparisons with the initial profile to determine performance of the nourishment and potential impacts due to cross-shore spreading.

Results from the storm condition simulations for Alternatives B, C, and D are shown in Figure 7-4. The 10- and 50-yr return period storm simulations were evaluated for all three alternatives, while the 100-yr storm event was only evaluated for Alternative D. Under the 10-yr and 50-yr storm scenarios for Alternative B, and the 50-yr storm scenario for Alternative C, the simulations resulted in erosion of the entire width of the design berm at elevation 11.2 ft NAVD88 and above back to the seawall. All three storm scenarios resulted in milder slopes of the beach for all of the

nourishment alternatives. This resulted in a more significant loss of volume in Alternative B than in Alternatives C and D, due primarily to the steeper design slope with Alternative B.

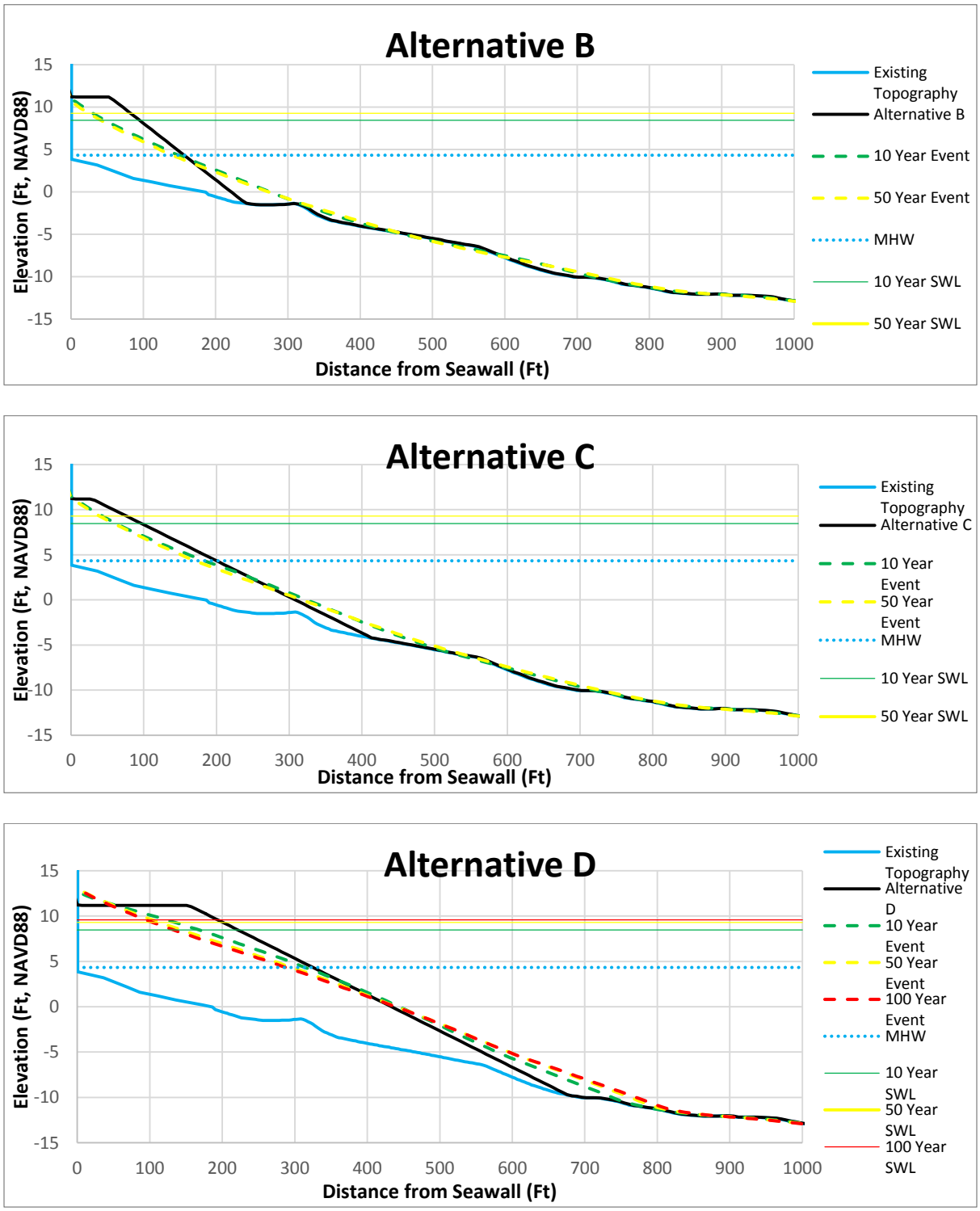


Figure 7-4. Modeled storm erosion profiles for Alternatives B, C, and D

For Alternative B, the 10- and 50-yr storms resulted in erosion of the design berm back to the seawall, with a lowering of the beach elevation immediately in front of the wall by 4 to 10 inches. For Alternative C, the 50-yr storm also eroded the design berm back to the seawall and the beach elevation in front of the seawall is lowered by approximately 6 inches. Alternative D was the only beach nourishment design that maintained a portion of the design berm after the 10-, 50-, and 100-yr storm events. With the 10-yr storm event, approximately 50 ft of the design berm was left; with the 50-yr storm event, 48 ft of the berm was left; and with the 100-yr storm event, 45 ft of the design berm remained after the storm. All three storm scenarios with Alternative D resulted in accretion of 1 ft or more immediately in front of the seawall. Based on modeling conducted during the 2010 Woods Hole Group and Louis Berger study, a critical berm width of 15 ft berm at elevation 11.2 ft NAVD88 and above was determined for the beach nourishment designs. At berm widths less than 15 ft, the modeling showed potential storm damage and flooding from wave overtopping during a 10-yr storm. Based on this threshold, and the cross-shore storm modeling conducted for the three beach nourishment designs, Alternative D provides the best storm damage benefits.

7.2.2 Service Life

Another important criterion in the evaluation of nourishment alternatives is the performance or service life of each alternative. For the long-term solution at Nantasket Beach, this consists of the following consideration:

- How long does the beach last before the recreational value returns to the current condition of no high tide beach, and how long does the beach continue to provide storm damage protection and flood control?

Since the material diffuses (spreads) over time, it is possible to evaluate the longevity of the nourishment by looking at the volume of material left in the project area over time. In this way, alternatives can be compared to one another based on their ability to maintain a beach. The service life of the beach nourishment is based upon the volume of the initial beach nourishment left within the boundary of the initial fill. The volume would decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment may have been transported offshore or along the beach. Therefore, although the sediment no longer falls within the initial nourishment template, it has not disappeared from the system as a whole. The lifetime is calculated using wave and sediment transport model results for average annual conditions. These annual wave conditions include typical storm events that occur over the course of an average year, but do not include larger storm events that may move a significant volume of material during a single event. Since the infrequent, larger storms are unpredictable, they are not directly included in the analysis. Therefore, the performance evaluation provides a reasonable estimate of the lifetime of the beach for each alternative given typical conditions that can be expected. If an infrequent, larger storm does occur during the project lifetime, the expected longevity would be reduced.

Figure 7-5 presents the performance of the nourishment Alternatives B, C, and D. The performance is expressed in terms of volume of material remaining in the initial template region, as a function of time. All of the results include a background erosion rate of 1.0 ft/yr. In addition to the dispersion that occurs, the analysis also considers an additional 1.0 ft/yr erosion, based on

the highest average rate of erosion from CZM shoreline change data (Section 6.1.4). The volume of material remaining is presented along the left (Y) axis, while the time (in years) is presented along the bottom (X) axis. For example, after 10 years, approximately 180,000 cy of fill is remaining in the initial footprint with Alternative D, only 40,000 cy is remaining with Alternative C, and none of the fill is remaining in the initial footprint after 10 years with Alternative B. As expected, performance is increased for the larger nourishment design. A general rule of thumb is that renourishment is warranted when 30% of the fill volume is remaining in the initial footprint. Based on the spreading analysis (Figure 7-5), this would occur at only 4 to 5 years for Alternative B and 8 to 10 years for Alternative D.

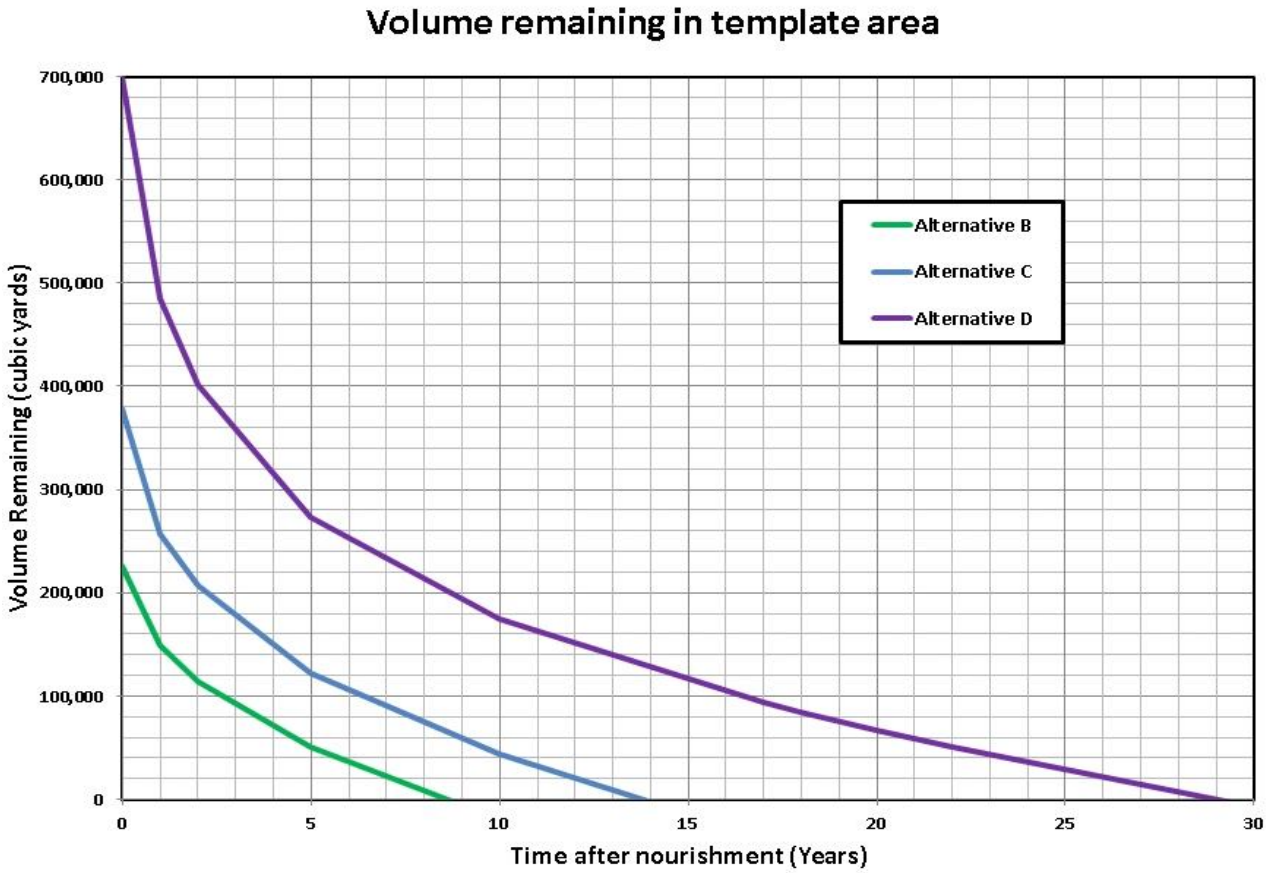


Figure 7-5. Service life analysis showing volume of nourishment remaining in the original fill template over time for Alternatives B, C, and D

The critical berm width of 15 ft determined during the 2010 Woods Hole Group and Louis Berger study can also be used as a measure of service life. In this case the service life ends when the berm width reaches 15 ft, at which point the nourishment is no longer capable of providing added protection for the seawall and nearby infrastructure from storm damages and flooding during a 10-yr storm event. Figure 7-6 shows the change in berm width over time for each of the three beach nourishment alternatives. Using the 15 ft criteria, Alternatives B and C are shown to have a service life of less than 5 years, while Alternative D has a much longer service life of 20 years.

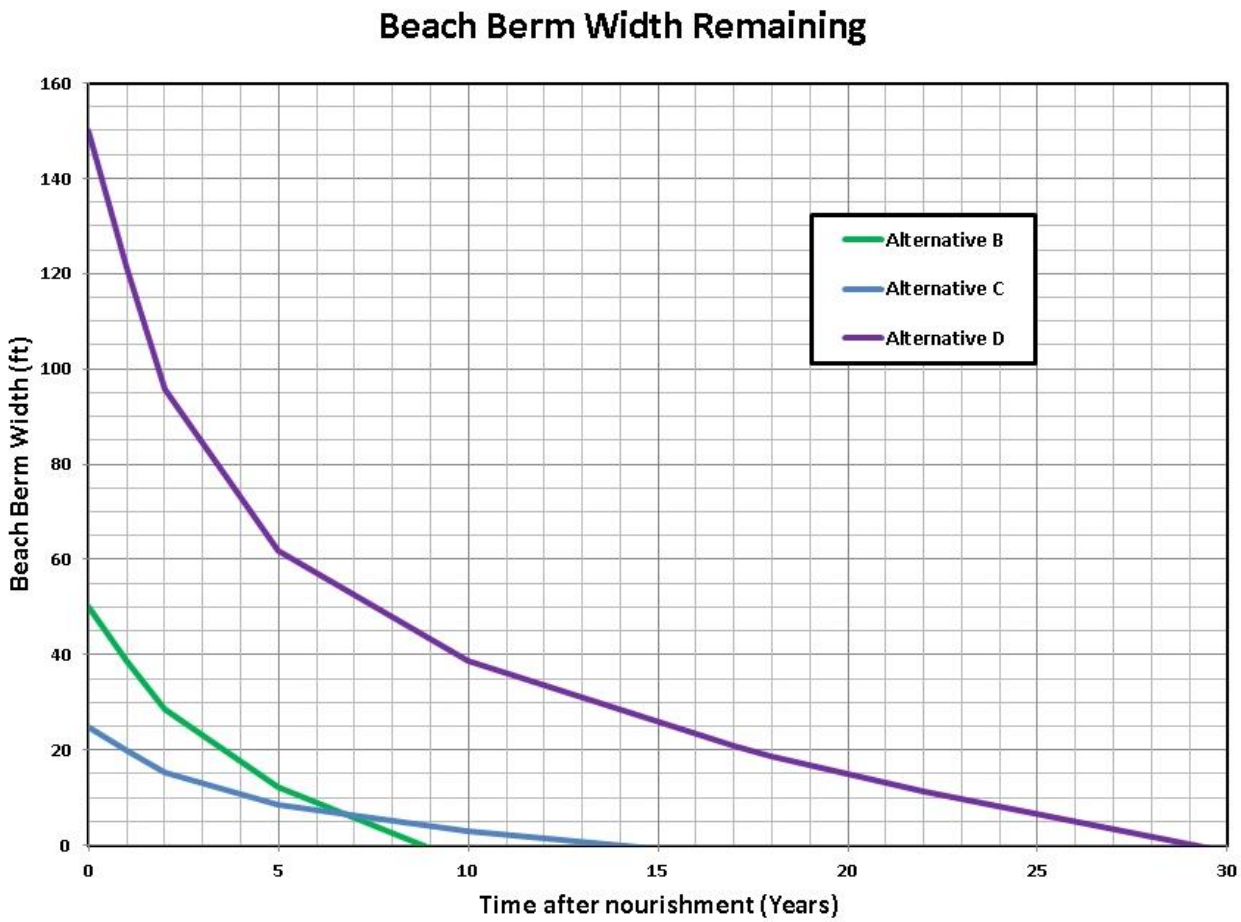


Figure 7-6. Service life analysis showing beach berm width remaining over time for Alternatives B, C, and D

Table 7-2 provides a summary of the service life analyses using the nourishment volume and critical berm width criteria. Based on these metrics it is clear that Alternative D provides the longest service life and is the preferred alternative for long-term protection of the Reservation.

Table 7-2. Service Life Metrics for Beach Nourishment Alternatives at Nantasket Beach

Nourishment Alternative	Volume Based Service Life	Critical Berm Width Service Life
A	0 years	0 years
B	4-5 years	4.5 years
C	5-6 years	2 years
D	8-10 years	20 years

7.2.3 Impacts to Wetland Resources

Initial construction of the beach nourishment would have direct impacts to the coastal resources in the area where the sand is placed. Table 7-3 summarizes the wetland resource areas directly impacted by the various nourishment alternatives. Because the size of the nourishment footprint

increases from Alternative B to D, the areas of impact for each resource area also increase. Alternative B impacts the smallest area of coastal beach and intertidal, and does not extend below MLW, and therefore does not directly impact land under the ocean. On the other hand, Alternative D impacts the largest area of coastal beach, intertidal, and land under the ocean.

Table 7-3. Direct Impacts to Resource Areas from the Beach Nourishment Alternatives

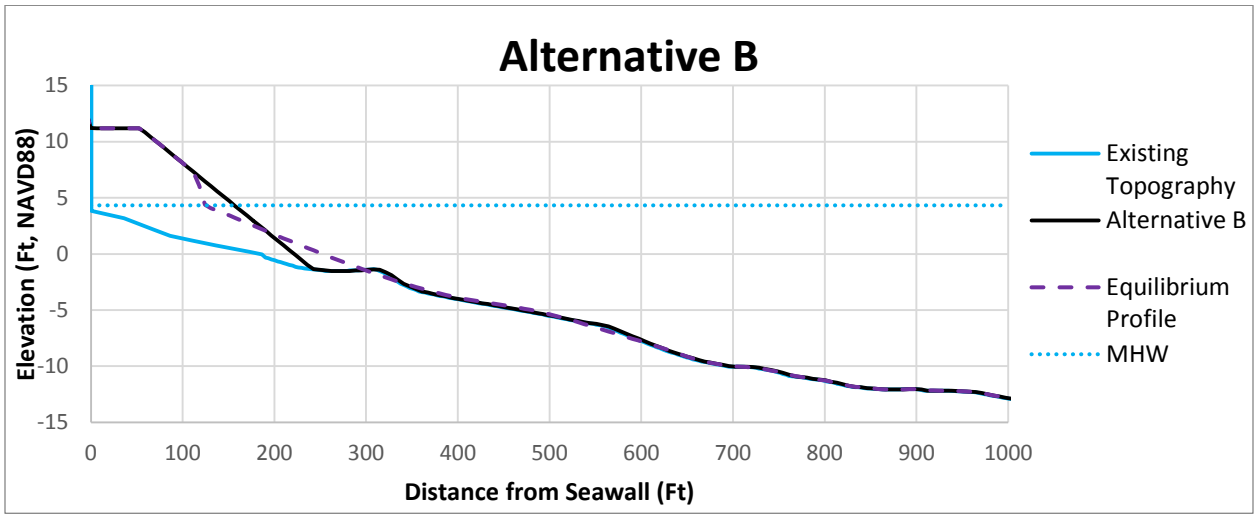
Nourishment Alternative	**Area of Coastal Beach Impacted** (acres)	**Area of Intertidal Impacted** (acres)	**Area of Priority Habitat Impacted** (acres)	**Area of Land Under the Ocean Impacted** (acres)
A	Not applicable			
B	29.7	26.7	3.3	0
C	51.8	48.8	4.3	1.3
D	66.4	48.8	4.9	7.4

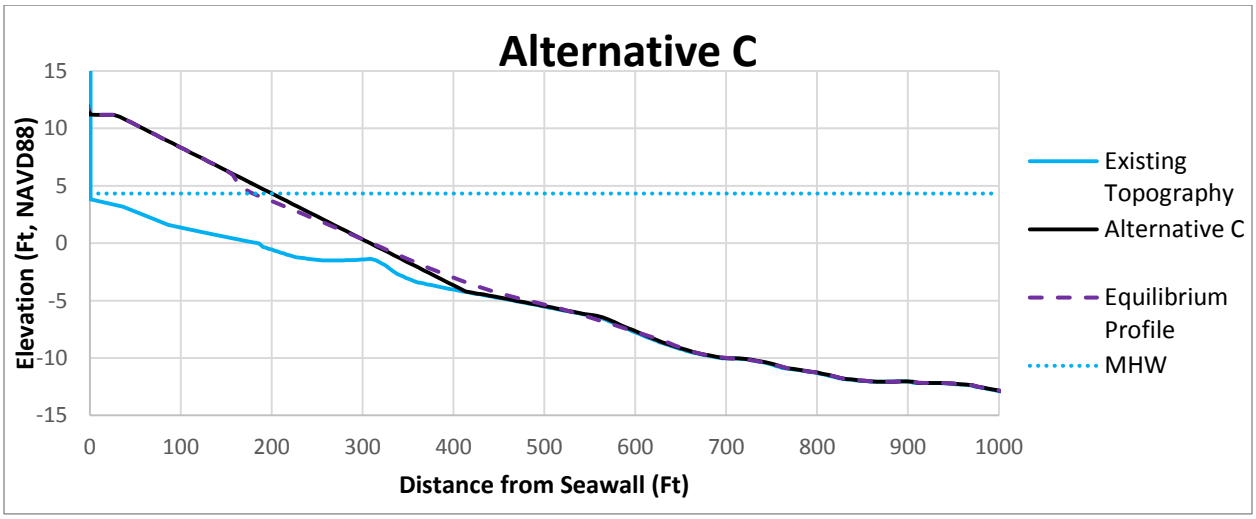
Impacts to coastal beach and land under the ocean resources for all alternatives would be temporary, only during placement of the nourishment sand. Due to the absence of eelgrass, rocky substrate, and significant shellfish resources, there would be no impacts to these resources. Any disturbed subtidal areas are expected to be recolonized by benthic organisms within one year of the nourishment, as is typical of nearshore sandy habitat recruitment (Burlas et al., 2001).

Impacts to benthic habitat in the nearshore region associated with equilibrium and storm-induced spreading of the nourishment alternatives were evaluated using the XBeach cross-shore model. Simulations were run for each alternative given the average annual conditions and storm events shown in Table 7-1.

Results from the average annual simulations for Alternatives B, C, and D are shown in Figure 7-7. The figures represent the approximate profile to which the nourishment template would equilibrate over time. Alternative B shows scarping of the design profile at approximately 110 to 200 ft from the seawall, near the high tide line. Similar results are seen for Alternatives C and D near the high tide line, although the milder slopes (1V:25H) result in much less erosion. All three alternatives show spreading in the seaward direction at the toe of the nourishment under equilibrium conditions (Figure 7-7), as well as for the storm simulations (Figure 7-4).

Table 7-4 summarizes the extent of spreading beyond the toe of the nourishment for each alternative. The cross-shore modeling shows the greatest spreading with Alternative B, with movement 55 ft beyond the toe of the fill under average annual conditions, and up to 480 ft with the 50-yr storm simulation. The greater extent of spreading is due to the steeper design of the offshore slope (1V:15H) with Alternative B. Results for Alternative D, which has a much milder slope (1V:25H), show spreading beyond the toe of the fill of 5 ft under average annual conditions and up to 160 ft with the 100-yr storm simulation. Because Alternative D starts with a footprint that is much larger than for the other two alternatives, the total extent of land under the ocean impacted, both immediately after initial placement and after equilibrium spreading, is greater than Alternatives B or C. The impacts are expected to be equally minimal between the three nourishment alternatives, because of the absence of sensitive offshore resources (i.e., eelgrass, hard bottom, shellfish),





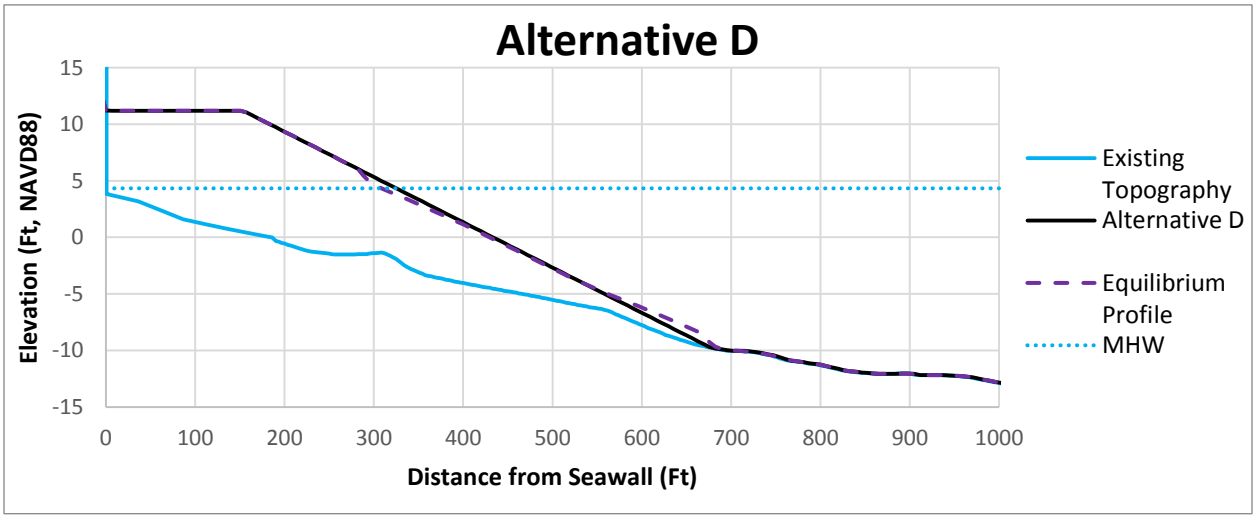


Figure 7-7. Modeled equilibrium profiles for Alternatives B, C, and D

Table 7-4. Distance of Cross-shore Spreading for Alternatives B, C, and D

	Alternative B		Alternative C		Alternative D	
	Distance from Seawall (ft)	**Distance from Nourishment Toe** (ft)	**Distance from Seawall** (ft)	**Distance from Nourishment Toe** (ft)	**Distance from Seawall** (ft)	**Distance from Nourish-ment Toe** (ft)
Normal Conditions	290	55	465	60	680	5
10-yr Storm	710	475	710	305	735	60
50-yr Storm	715	480	715	310	790	115
100-yr Storm	Not modeled	Not modeled	Not modeled	Not modeled	835	160

Impacts to priority habitat for the endangered Piping Plover (also federally threatened) located at the northern end of the project are expected to be beneficial for all three nourishment alternatives. However, due to the significant increase in area available for nesting and foraging associated with the 700,000 cy scenario, Alternative D provides the greatest benefit.

7.2.4 Socio-economic Impacts

While all three beach nourishment alternatives would provide socio-economic benefits by reducing the risk of storm damage and flooding, and creating a wider beach for recreational purposes, Alternative D provides the greatest benefit.

7.3 Sand Source Alternatives

A key component of Phase 2 of the Nantasket Storm Damage Reduction Project is identification of a suitable sand source(s) that meets the engineering design criteria, is affordable, and is acceptable from an environmental standpoint. DCR has worked over the years to evaluate a range of potential sand sources, including upland and offshore sources, as well as opportunities for beneficial reuse of sand dredged from navigation projects.

7.3.1 Upland Sand Sources

As part of the 2010 Woods Hole Group and Louis Berger study for DCR, an evaluation of upland sand sources for building the 700,000 cy nourishment project at Nantasket Beach was performed. The evaluation looked at a range of vendors, including quantities placed annually, grain size characteristics, trucking distance, trips per day, unit cost, and nourishment performance given a multi-year construction schedule. Table 7-5 summarizes the parameters assessed as part of the study. For large nourishment projects like Nantasket Beach, the use of upland sand sources generally requires the nourishment to take place over multiple years since the trucking operations are constrained by travel routes, traffic and community concerns. Table 7-6 shows four different delivery rate scenarios that were used to evaluate nourishment performance given the multi-year construction schedules required for constructing the 700,000 cy project.

Table 7-5. Nantasket Beach Upland Source Parameters (based on 2008 costs)

Vendor	Source Location	Material Quantity (cy/year)	Material Grain Size (D_{50} mm)	Delivery Method	Delivery Distance (miles)	Rate of Delivery (cy/ workday)+	Unit Cost ($/cy)
Kingstown Corporation	Plymouth, MA	100,000	0.38	26 cy Dump Trailer	30	2,000 – 3,000	$16.50
P.A. Landers, Inc.	Plymouth, MA	100,000	0.3 – 0.6	26 cy Dump Trailer	30	3,000	TBD*
Cape Cod Aggregates	Bourne and Sandwich, MA	100,000	0.41 – 0.53	26 cy Dump Trailer	47 – 52	800 – 1,100	$22.50
G. Lopes Construction	Taunton, MA	100,000	0.3 – 0.45	28 cy Dump Trailer	46	2,100 – 2,600	$19.25
Plympton Sand and Gravel	Plympton, MA	60,000	0.65	26 cy Dump Trailer	35	2,000 – 3,000	$23.75
A.A. Will Materials Corporation	Sandwich, MA	100,000	0.36	26 cy Dump Trailer	50	~300	$28.50
A.D. Makepeace	Wareham and Carver, MA	100,000	0.61	26 cy Dump Trailer	45	2,100	$20.00

* PA Landers did not provide a cost/cubic yard of material.
\+ Assumes an 8 hour workday

Source: Woods Hole Group and Louis Berger, 2010 (provided as Appendix B)

Table 7-6. Nantasket Beach Upland Nourishment Scenarios Used for Performance Evaluations

Scenario	Total Volume per Season (cy)	Individual Load Volume (cy)	Loads per Day	Truck Passage Frequency (minutes)	Project Time (Seasons)
1	25,000	12 cy	16	14	28
2	50,000	26 cy	16	15	14
3	75,000	26 cy	30	8	9.3
4	100,000	26 cy	60	4	7

Source: Woods Hole Group and Louis Berger, 2010 (provided as Appendix B)

The feasibility and performance (service life) of each of the four upland-based scenarios shown in Table 7-6 was evaluated using results from the wave transformation modeling described in Section 6.1.5, grain size data, and information on the nourishment design. The performance of the project was quantified by looking at the percent of nourishment remaining over time, and comparisons were made with a single initial nourishment of 700,000 cy. While the results of the technical assessment showed that an upland-based sediment source is technically feasible at Nantasket Beach, limitations to using a multi-year nourishment approach were identified. The Woods Hole Group and Louis Berger (2010) analyses indicated that until enough sediment (approximately 30%) is supplied to the beach, the Reservation and nearby commercial and residential properties would remain vulnerable. It would take approximately 5 to 6 years of construction with upland sand before threats to these properties would be reduced.

7.3.2 Offshore Borrow Sites

Offshore borrow sites as a sand and gravel source for nourishing Nantasket Beach were also evaluated in the Woods Hole Group and Louis Berger (2010) study (Appendix B). Based on experience at other nearby projects where proponents were unsuccessful at securing permits for offshore sand mining, the use of an offshore borrow site was ruled out for Nantasket Beach.

7.3.3 Beneficial Reuse of Sand Dredged from Navigation Projects

The Piscataqua River dredging project became recently available as a source for nourishing Nantasket Beach (USACE and NHPDA, 2014). The USACE is permitted to dispose the dredged material in the open ocean offshore of the mouth of the Portsmouth Harbor. A total of approximately 728,000 cy of material will be dredged at the site, and is available for beneficial use. Availability for Nantasket Beach requires permits in place before the USACE would be able to consider Nantasket Beach as a site for receiving the material for nourishment.

If permits cannot be secured in time, other sources for beach nourishment would be sought. Similarly, other sources might be sought to (a) expand the beach fill volume up to 700,000 cy, and (b) potentially renourish the beach in the future (assuming adequate funding was available). The approach for placing material from other sources would be similar to the approach used for placing Piscataqua River material (see description of construction approach in Section 5.5). All future sources of material would need to undergo a suitability assessment, just like was done for the Piscataqua River material (see Appendix D, and summary in Section 8.1.2). General guidelines for this assessment are provided below.

- **Grain size:** Sediment to be considered for nourishment should not be finer-grained than the sediment along the beach and intertidal zone of Nantasket Beach. The targeted grain size distribution would be as follows:
    - *Silt/clay:* The Piscataqua River source contains approximately 10% fines, which is the upper limit of what would be acceptable in future nourishment sources.
    - *Gravel:* The gravel content of Nantasket Beach was measured with 13% in cores along the beach and intertidal zone and 22% in large test pits dug by backhoe. The mean gravel content in the Piscataqua River sediments was 21% (weighted mean). The

gravel content of potential sediment sources for future nourishment should not exceed 22%.

- *Sand:* Sand shall be the dominant grain size. The sand content along Nantasket Beach is approximately 85–90%. Most of the sand is fine sand. The mean sand content in the Piscataqua River sediments is approximately 70%, and also mostly fine sand although slightly coarser than the sand at Nantasket Beach. The sand content of acceptable sediment for future nourishment shall typically meet or exceed 70% and consist predominantly of fine and medium sand, with smaller concentrations of coarse sand.

Figure 7-8 presents an envelope of grain sizes (falling between the dashed lines) that would be considered acceptable for nourishment of Nantasket Beach. However, each potential source would need to be evaluated prior to utilization within the approved beach nourishment template. This evaluation would integrate findings from monitoring the performance of placed sediment on Nantasket Beach, which may result in slight adjustments of the grain size distribution above, as appropriate and in consultation with CZM.

- **Color:** The color of sediment to be used for future nourishment shall generally be compatible with the color of Nantasket Beach sediment (see Section 8.1.2). However, it is possible that the source sediment is slightly more brown or yellowish than the sand along Nantasket Beach as a result of natural iron oxide staining. Often, the color lightens over time as iron is reduced with exposure to the ocean water and the atmosphere.

- **Chemical characteristics:** Any sediment placed in the future at Nantasket Beach must not present a risk to human health or the aquatic ecosystem. An approach similar to the approach used for the Piscataqua River (see Appendix D) would be used to evaluate the chemical suitability of sediment to be placed on Nantasket Beach from future sources. The approach would be based on an understanding of potential contaminant sources at the source location. This evaluation approach would likely use similar thresholds, guideline values, and human risk screening levels that were developed for the Piscataqua River.

7.4 Preferred Alternative

The preferred beach nourishment design chosen for Nantasket Beach is Alternative D. This alternative is superior to the other designs in terms of storm damage protection and service life. Impacts to wetland resource areas with Alternative D are not significantly different than the other designs. For priority habitat impacts, Alternative D actually provides a greater increase in habitat area than Alternatives B and C. Benefits to socio-economic resources are also greatest with Alternative D.

Alternative D also provides the greatest amount of flexibility for nourishing Nantasket Beach in the immediate future with Piscataqua River material, as well as thereafter with material from other sources (since the Piscataqua River source provides only a portion of the 700,000 cy beach fill volume). Considering that other nourishment sources may become available on short notice, Alternative D allows DCR to be able to accept the material (after an appropriate suitability analysis).

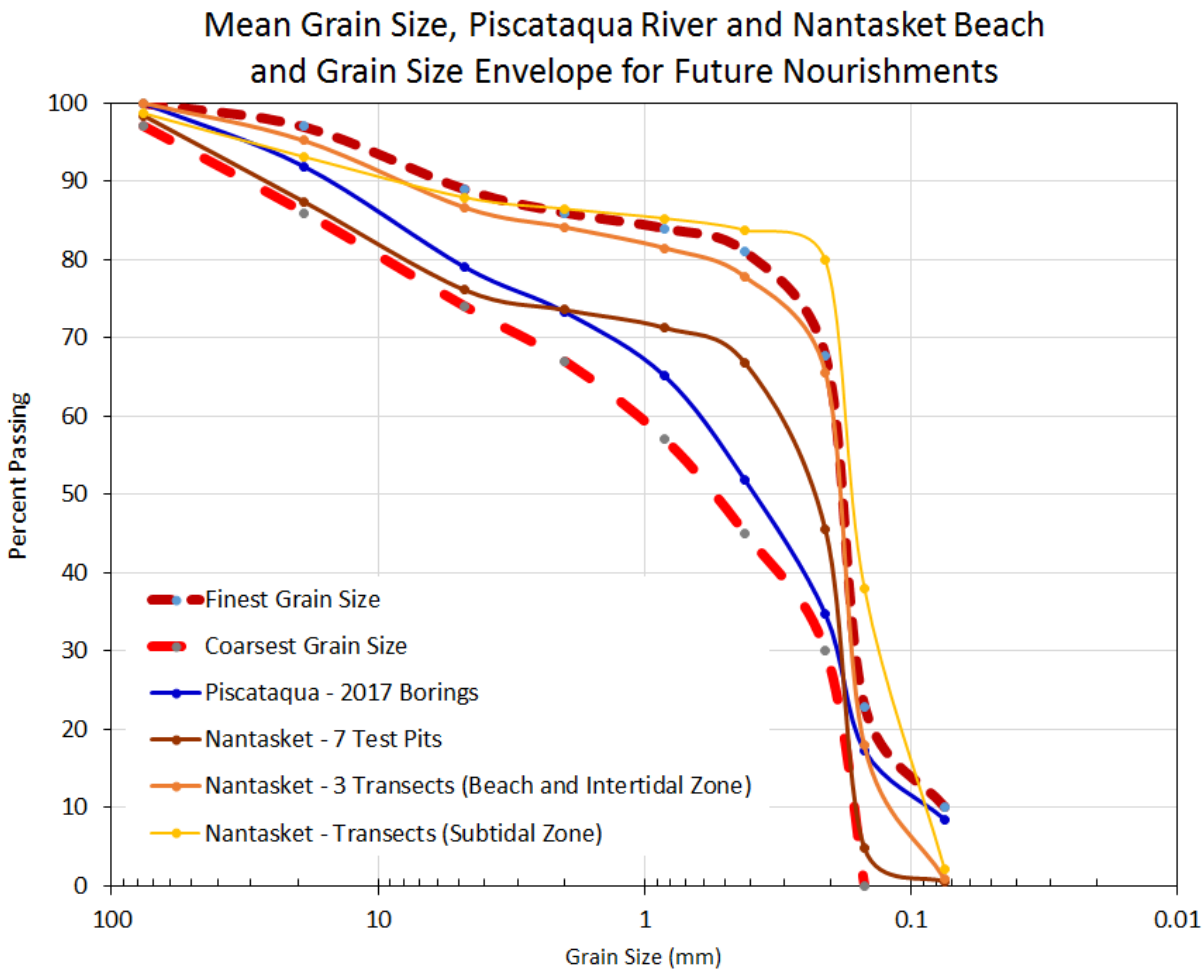


Figure 7-8. Grain size envelope for future nourishments. See Section 8.1.2 and Appendix D for more detailed descriptions of sediment types at Nantasket Beach and the Piscataqua River site.

In terms of a sand source for nourishing Nantasket Beach, beneficial reuse of sand dredged from the Piscataqua River is the preferred alternative. While other sources of sand many be needed in the future, the USACE project at the Piscataqua River offers a unique and near-term opportunity to use sand compatible with Nantasket Beach for restoration of the critically eroded beaches.

8. Assessment of Impacts of Preferred Alternative

This chapter addresses environmental impacts associated with the Preferred Alternative. Addressed are both the potential adverse impacts and benefits to the environmental from placement of Piscataqua River sediments in the nourishment design template Alternative D. Although environmental impacts are unavoidable, the project is focused on minimizing potential adverse impacts, while achieving project objectives.

This section is organized into six subsections that discuss the impacts of the Preferred Alternative associated with:

- Physical impacts
- Ecological impacts
- Impacts to historic and archaeological resources
- Socio-economic impacts
- Construction impacts
- Cumulative impacts

8.1 Physical Impacts

8.1.1 Shoreline Change

Rates of shoreline change at Nantasket Beach after placement of the nourishment are expected to be consistent with the historical shoreline change data developed by CZM (Section 6.1.4). It is likely that rates of erosion would increase slightly over the short-term rates presented by CZM, since the shore protection structures at Nantasket Beach have limited the landward retreat of the beach over the past 10 to 20 years as the MHW line has approached the seawall and revetment. Additionally, initial spreading of the fill until the equilibrium profile is reached would result in a higher rate of erosion than the natural background rate. Despite these factors, the proposed nourishment design would push the MHW line seaward by more than 300 ft. Small changes in the rate of shoreline change are not expected to have an adverse impact on the performance of the project.

8.1.2 Sediments

Sediments from the Piscataqua River site are compatible with the sediment at Nantasket Beach. The predominant material type in the Piscataqua River site is sand (approximately 70%), with lower concentrations of gravel (20%) and silt/clay (10%). At Nantasket Beach, the predominant material type in the beach and intertidal zone is also sand (approximately 85%), with lower concentrations of gravel (13%) and silt/clay (1%). More specifically, the sediments from the Piscataqua River site and at Nantasket Beach compare as follows (Figure 8-1); see Appendix D for the suitability assessment report:

- **Sand:** The Piscataqua River sediments are more poorly-sorted than those at Nantasket Beach; however, the predominant material at both sites is fine sand, particularly in the particle size fraction of 0.15 to 0.25 mm. Total concentrations of this fine sand fraction

are not as high at the Piscataqua River site as at Nantasket Beach; instead, the medium and coarse sand fractions are higher at the Piscataqua River site. As such, the sand fraction would be slightly coarser from the Piscataqua River source than at Nantasket Beach.

- **Silt/clay:** The Piscataqua River sediments contain approximately 10% silt/clay; Nantasket Beach sediments contain less than 3%. If Piscataqua River sediments were placed at Nantasket Beach, much of the silt and clay in the dredged material would eventually be re-suspended by waves and transported offshore such that the remaining material would trend toward the existing particle-size distribution over time. Overall, the difference in silt/clay content is small. Silt/clay that is resuspended and transported offshore would be accounted for in the placement design by appropriate overfill to reach the target nourishment volumes.

- **Gravel*:*** The mean fine and coarse gravel content observed in the Nantasket Beach sediments was 22% in the test pit samples, 13% in the beach and intertidal zone, and 11% in the subtidal zone. These concentrations are comparable to the mean gravel concentration of 16% measured in the Piscataqua River sediments.

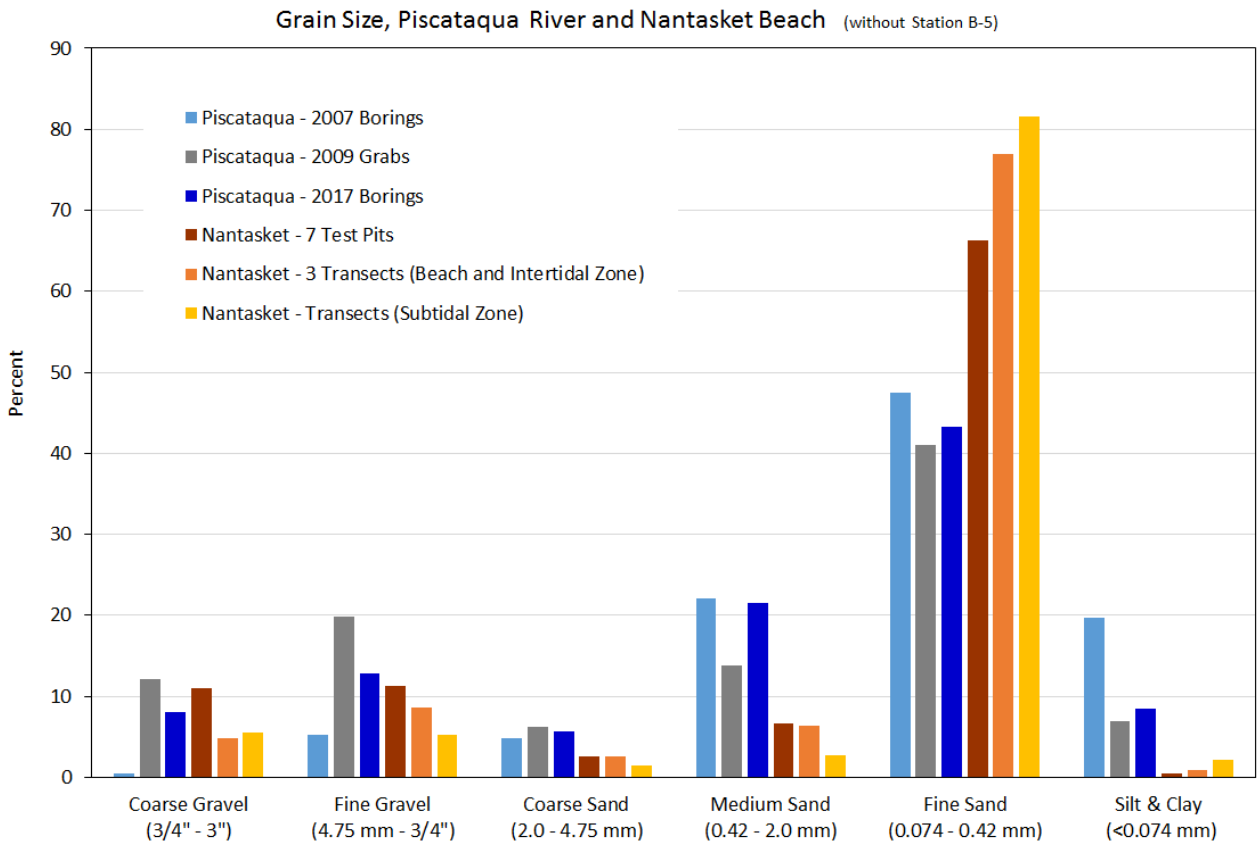


Figure 8-1. Mean grain size distribution by major size fractions for sediment samples from the Piscataqua River and Nantasket Beach. Source: Louis Berger, 2018

- **Cobble:** Cobbles accumulate along the seawall at Nantasket Beach, although the test pit samples did not contain high concentrations of cobble. The concentration of cobble in the Piscataqua River sediments is not known. Bottom photographs from 2009 show that some cobble and rocks can be expected, although the comparatively uniform grain size distribution observed in many of the borings from the planned dredging area suggests that the cobble content in the Piscataqua sediments is small to minimal.

- **Color:** Dry Piscataqua River sediments are predominantly yellowish brown; wet sediment are predominantly light olive brown (Figure 8-2). Dry Nantasket Beach sediments are predominantly gray; wet sediments are predominantly dark gray. Overall, the sediments from the Piscataqua River site are more yellowish than the Nantasket River sediments. Over time, Piscataqua River sediment placed at Nantasket Beach would be bleached, changing the color to more closely resemble native conditions.

- **Chemical Characteristics*:*** Chemical analyses were conducted on sediment samples collected from the upper 5-ft depth interval of 12 of the 17 stations cored at the Piscataqua River site during November 2017. In addition, seven deeper core segments (up to 20 ft deep) were analyzed at selected stations. A total of 19 samples were submitted for laboratory analyses. Detailed chemical results are provided in Appendix D. Described below are measured concentrations as they relate to human and ecological health:

    - *Human Health Risk:* All detected chemical concentrations in Piscataqua River sediment samples were lower than health risk-based screening levels protective of individuals that contact the sediment while recreating at a beach. Also, all detected chemical concentrations in the sediment samples were lower than MassDEP reportable concentrations (referred to as Category RCS-1 and RCS-2) for soil. The more stringent Category RCS-1 values apply to locations with the highest potential for exposure, and are defined as "at or within 500 ft of a residential dwelling, a residentially-zoned property, school, playground, recreational area or park." In summary, the risk screening evaluation, as conducted, indicates that dredged sediments used for nourishment of Nantasket Beach would not affect the health of recreationists that contact them.

    - *Ecological Health:* As stated, all measured concentrations were below the background concentration in natural, undisturbed soils (MassDEP, 2002). None of the concentrations of any compound exceeded the NOAA "Effects Range Median" (ERM) guideline values; the ERM value is indicative of concentrations above which adverse biological effects frequently occur. Some samples slightly exceeded the NOAA "Effects Range Low" (ERL) guideline value for arsenic (12 samples); the ERL value is indicative of concentrations below which adverse biological effects rarely occur. The measured arsenic concentrations most likely reflect natural background conditions; all measured arsenic concentrations were below the background concentration in natural, undisturbed soils listed in MassDEP (2002) as 20 mg/kg.

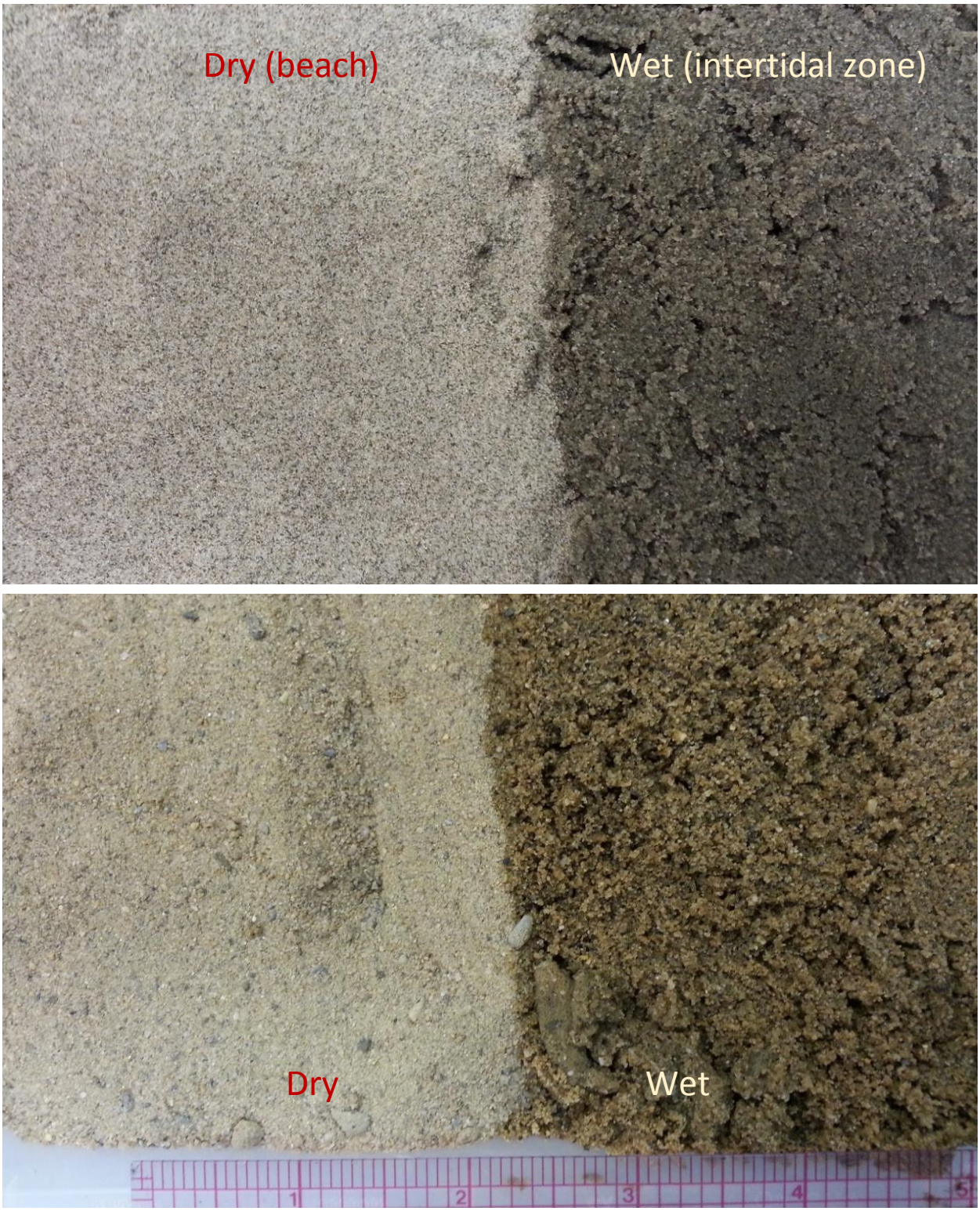


Figure 8-2. Comparison of the color of sediments from Nantasket Beach *(top)* and the Piscataqua River site *(bottom)* under dry and wet conditions. Source: Louis Berger, 2018

One sample had exceedances for mercury, total PCBs, and the pesticide DDE. In addition, a dioxins/furans concentration in one sample exceeded the interim sediment quality guideline (ISQG) developed by the Canadian Council of Ministers of the Environment (CCME); ERMs and ERLs are not available for these compounds. Considering that sampling was conducted in the upper 5 ft of the sediment body to be dredged where contaminants of man-made origin tend to accumulate, and considering mixing of the sediment during dredging, the average metal and organic compound concentrations of the entire sediment body to be dredged are expected to be below the ERL, except for arsenic. In summary, the risk screening evaluation, as conducted, indicates that Piscataqua River sediments used for beach nourishment at Nantasket Beach would not affect the health of biota that contact them.

8.1.3 Water Quality

Water quality impacts would be limited to short-term increases in turbidity during construction when sediments would be dewatered on the beach, and post-construction when large storms would continue to resuspend residual fines in the sediment. During construction, the source of turbidity would be localized and comparatively small compared to the size of the open ocean. During post-construction, elevated turbidity may occur along a broader front, but would not be expected to be considerably more turbid than what can be expected as a result of resuspension at this location during large storms.

Water quality impacts from the chemical composition of the Piscataqua River sediment would not be not expected, based on the analytical results of the Piscataqua River sediments and considering the open-ocean conditions with rapid dilution.

8.1.4 Sediment Transport

The proposed Nantasket Beach nourishment project would have no impact on the directions sediment transport at the site. The net direction of transport under average annual conditions would still be to the north as shown in Figure 6-16. The new source of sand placed on the beach would serve as a source of sediment for eroded beaches to the north. This would have a beneficial impact on the storm damage protection and flood control functions of barrier beach to the north. Similarly, the project would not impact the direction of net southerly transport during storms. It is likely that the southerly moving sediment would be trapped or impounded by the headland to the south of the Reservation beach. Overall, the project would supply a new source of sand for a critically eroded beach.

8.2 Ecological Impacts

8.2.1 Resource Areas

In general, ecological impacts from the construction of nourishment Alternative D would be temporary and of minor significance, with any adverse impacts limited to the period of construction. There would be temporary impacts to 66.4 acres of coastal beach and 7.4 acres of land under the ocean. The impacts to coastal beach would result in restoration of a protective

beach resource at Nantasket, one that would serve to protect the seawall and nearby upland infrastructure from storm damages and flooding. The total area of coastal beach (between the seawall and MLW) within the Reservation will increase from approximately 78.6 acres to 85.5 acres. However, the area of coastal beach above MHW will be increased substantially. The project would result in a seaward shift of land under the ocean resources.

8.2.2 Benthic Habitat

Limited benthic resource have been mapped in the project area. Resources include epifauna and infaunal invertebrates, but no submerged aquatic vegetation is present. The proposed beach nourishment would bury these benthic communities, but the disturbed areas are expected to be recolonized by benthic organisms within one year of the nourishment, as is typical of nearshore sandy habitat recruitment (Burlas et al., 2001). Because the nearshore area at Nantasket Beach is located within an area impacted by high energy storms, the sediments are mobile and the associated benthic communities have adapted to this dynamic environment. Many of the benthic species closer to the toe of the nourishment are expected to survive the initial placement. By restricting construction to primarily the winter months, the work would coincide with biological dormancy, which would eliminate/minimize substantial impacts to the benthic environment.

Discussions with the DMF regarding shellfish in the project area indicates that there are no significant shellfish resources in the nearshore area of Nantasket Beach. Therefore, no mitigation or special conditions are planned for the protection of shellfish resources.

8.2.3 Fisheries

Most of the species listed in Table 6-5 either reside entirely in deeper waters, or utilize inshore shallow habitats only during the spring, summer and early fall months. Therefore, since the construction of the proposed project would be constrained primarily to the winter months, and would affect only a small nearshore area, potential adverse impacts to EFH species are not expected to be significant. (See additional discussion on EFH in USACE, 2014, Section 7.3 in Appendix C.)

In addition, rocky habitat would not be impacted by the project, as the substrate in the project area consists of sand (Figure 6-1). Rocky habitat is found at a distance of more than 2,000 ft from the seawall.

8.2.4 Rare Species

The northern end of the Reservation beach is mapped habitat for the Piping Plover. To minimize any impacts to the birds, the project has been designed with a construction window that ends prior to the nesting season for threatened and endangered shore birds (by the end of March).

The beach nourishment has also been designed to enhance habitat for federal and state-listed shorebirds. The nearshore slope of the nourishment is very gradual at 1V:25H, and therefore the birds would be able to move freely from the waterline to more protected areas along the back shore. Additionally, there are no plans for beach grass planting or sand fencing. As such, the project is not expected to have any adverse impacts to rare or endangered species of shorebirds.

Once the project is in place, the habitat area for rare species would be increased. The DCR is committed to establishing and following a management plan for Piping Plover that would ensure compliance with both the Massachusetts Endangered Species Act (MESA) and the federal Endangered Species Act (ESA) (see Section 10.2.3). Protection efforts would consist of fencing, predator control, monitoring, outreach, and enforcement.

8.3 Impacts to Historic and Archaeological Resources

In the Environmental Assessment for the Phase 1 of the Coastal Storm Damage Reduction Project, the USACE (2014) stated the following in the section on Environmental Effects (p. EA-19 to EA-20):

> "An examination of the site files at the [Massachusetts Historical Commission] MHC indicated that no prehistoric archaeological sites are located within the proposed project area. Two sites, 19-PL-265 and 266, were located north of the project area in the Allerton section of town. Both sites have been destroyed by urban development in the area. No historic archaeological (HA) sites are located within the project area. [A site,] HA-1, is located well south of the study area in the Straits Pond area and consists of a protohistoric cemetery whose exact location is unknown. This site is also referenced as the Atlantic Hill Site or 19-PL-268. HA-2 is located to the northwest of the study location within the Telegraph Hill section and the Telegraph Hill Archaeological District.
>
> This project was previously coordinated with the Massachusetts State Historic Preservation Officer (SHPO), the Massachusetts Board of Underwater Archaeological Resources (BUAR), and the Wampanoag Tribe of Gay Head (Aquinnah) by letter dated March 25, 1996. At that time, the preferred alternative consisted of the placement of sand fill with periodic beach nourishment along the Nantasket Beach Reservation. We found that this alternative would have no effect upon significant historic properties due to the extensive erosion and development at this location. Repairs or rehabilitation of the existing seawall as well as construction of a revetment at this location, if selected for implementation, would also have no impact upon cultural resources as any sites that may have been present were likely previously disturbed or destroyed during construction of the original wall. The MA SHPO concurred with these determinations via letter dated April 24, 1996."

The project area considered for consultation in 1996 and again in 2014 has remained the same, with the exception of a slight widening of the nourishment footprint seaward under the preferred alternative. Due to the disturbed nature of the present seawall and extensive erosion at this location, impacts to cultural resources are not expected and findings in USACE (2002a; 2014) on archaeological resources remain applicable. Construction of a beach fill at Nantasket Beach would not impact upon the National Register eligibility of the DCR Nantasket Beach Reservation as a component of the Metropolitan Park System of Greater Boston. To confirm the findings from previous consultations, coordination with the Massachusetts Historical Commission was initiated by Project Notification Form (PNF) emailed on March 13, 2018; coordination with the Massachusetts Board of Underwater Archaeological Resources (BUAR) was also initiated by letter emailed on March 13, 2018. DCR anticipates concurrence by MHC and BUER with the earlier determinations.

8.4 Socio-economic Impacts

8.4.1 Upland Damages to Buildings and other Structures

The proposed action would prevent upland damages to buildings and other structures from overtopping. Under the No-Action alternative, upland damage costs were estimated as $20 million (2010 dollars) over a 50-yr life cycle. These costs were obtained from the USACE and included in Woods Hole Group and Louis Berger (2010). By comparison, upland damages with a 700,000 cy beach nourishment in place (Alternative D) over a 50-yr life cycle were estimated to be $2.5 million, assuming intermittent renourishment. These costs do not yet include additional costs from long- and short-term loss of revenue by businesses, which would be proportionately under the No-Action Alternative.

8.4.2 Beach Usage and Economic Impacts

As shown in Figures 5-2 to 5-4, there is no high tide beach along the southern and mid-sections of the seawall, and the high tide beach is narrow in the northern section of the Reservation. Many beachgoers currently leave the Reservation rather than wait for the tide to recede. Other beachgoers wait out the high tide on top of the large armor rocks. If high tide occurs during the middle of the day, some potential beachgoers rather stay home or go elsewhere because they know that there is mostly no high tide beach at Nantasket Beach.

Nantasket Beach is a unique resource as it features consistently clean waters, parking, and opportunities for residents of the surrounding communities to enjoy the ocean, particularly on hot summer days. A high tide beach created through nourishment would result in more beach visitors in the summer as well as in the offseason. Visitors that come to Nantasket Beach would stay longer on average. More visitors, and more time spent by visitors on average, would translate into more economic opportunities for businesses on the Reservation and in the Town of Hull. This effect would likely further be multiplied following the implementation of the Nantasket Beach Reservation Master Plan (DCR, 2016); see discussion in Section 8.6 (Cumulative Impacts).

In the Environmental Assessment for Phase 1, USACE (2014) estimated annual recreational benefits of $1.2 million, both for their beach fill alternatives of 246,000 cy and up to 378,000 cy in the mid-section of the seawall. In the initial Feasibility Report and EA for the Coastal Storm Damage Reduction Project, the USACE (2002a) estimated annual recreational benefits of $2.2 million for beach fill of 226,000 cy to 424,000 cy along the entire 6,800-ft shoreline.

8.4.3 Human Health

Executive Order (EO) 13045, Protection of Children from Environmental Health Risks and Safety Risks, requires federal agency to identify and assess environmental health risks and safety risks that may disproportionately affect children from its actions. If dredging occurs in 2019/20 or thereafter, the project may include federal funding. Environmental health risks and safety risks include risks to health or to safety that are attributable to products or substances that the child is likely to come in contact with or ingest (such as the air we breathe, the food we eat, the water we drink or use for recreation, the soil we live on, and the products we use or are exposed to).

As stated in Section 8.1.2, the risk screening evaluation, as conducted, indicates that Piscataqua River sediments used for beach nourishment at Nantasket Beach would not affect the health of recreationists that contact them, including children. The proposed project therefore would comply with EO 13045.

8.4.4 Environmental Justice

EO 12898 on Environmental Justice requires the environmental analysis of proposed federal actions address any disproportionately high and adverse health or environmental effects on minority and low-income communities. If dredging occurs in 2019/20 or thereafter, the project may include federal funding.

This proposed project would not have disproportionately high and adverse effects on any low-, or minority income communities, in compliance with EO 12898. Access to the enhanced beach would continue to be available unrestricted to all community groups.

8.5 Construction Impacts

Potential impact from construction includes the following:

- **Dewatering of Sediment:** The sediment slurry pumped onto beach will be dewatered in settling basins prior to spreading on the beach. Fine-grained sediment particles suspended in the overflow may result in localized turbidity.

- **Noise:** During offloading, the barge-mounted pump would be located approximately 2,600 ft from shore, which would not cause noise impacts to shore communities. Beach nourishment would occur along the coast and in the intertidal zone along Nantasket Beach. Noise along the Reservation would be generated by a bulldozer(s) spreading the sand that is pumped onto the beach, as well as any auxiliary pumps that may be used during construction and dewatering. Nighttime noise levels would be unaffected since operation of construction equipment would be confined to daylight hours. Neighbors and Reservation visitors would hear the operating construction equipment, but noise levels would be similar in nature to noise generated by local construction projects. Overall, noise impacts would be temporary and not expected to be significant.

- **Air Quality:** Emissions from construction equipment would be minor compared to background conditions at the Reservation, originating from two busy roads (Nantasket Avenue, and George Washington Boulevard). Sediment that would be placed onto the beach are expected to be free of odors considering their coarse grain size and with minimal organic content. Odors were not observed during field investigations at the Piscataqua Rivers source in November 2017 (Appendix D).

- **Access Limitations to the Beach for Beachgoers:** As stated in Section 5.5, nourishment would likely start in the southernmost corner of Nantasket Beach, and gradually progress to the north. The length of the construction zone on the beach at any given time would be approximately 1,000 ft. This zone would gradually move to the north, as additional

pipeline is added to advance the beach nourishment to the north. Where necessary, sediment deposited from the discharge pipe would be regraded using land-based excavators and/or bulldozers to ensure the nourishment matches the design specifications and nourishment template. Most of the beach would remain accessible to beachgoers during the construction period.

8.6 Cumulative Impacts

Cumulative effects are defined as the effects on the environment, which are caused by the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. As summarized in USACE (2014), past and current activities in the Nantasket Beach project area include recreational use of the beach for swimming, walking, fishing, and other coastal recreational activities. Reasonably foreseeable future actions include the continuation of current recreational uses. Past activities within the project area also include the construction of storm damage reduction structures (toe protection, revetment) along the entire seawall, which includes the currently implemented Phase 1 in the mid-section of the seawall. These activities coupled with the proposed project would not change public access to the project area; instead, they would instead improve future use of the project area. Past construction actions in the project area have not significantly altered environmental resources in the project's ecosystem and, as discussed in this Expanded NPC, the proposed project is anticipated to have only minimal impacts on these resources.

A substantial beneficial cumulative effect would result from the implementation of DCR's Master Plan for the Nantasket Beach Reservation (DCR, 2016; provided in Appendix H). The plan was initiated in 2005, interrupted by the economic downturn during the financial crisis in 2008, and completed in 2016. The plan includes beach nourishment as an item recommended for implementation.

The overarching goal for the Nantasket Beach Master Plan is to provide an enhanced natural and recreational experience at Nantasket Beach, with:

- Attractive amenities to support a wide range of activities
- Safe and convenient access for pedestrians, cyclists, transit and ferry passengers, and automobile users
- Connections to adjacent bicycle paths and parking areas, as well as commercial and entertainment opportunities
- Increased amenities for high-tide and shoulder-season visitors.

The Plan was designed to provide visitors with a "great day" at the Reservation from arrival to departure, while aiding the DCR in operating and maintaining the Reservation. The recommendations were developed to achieve that vision, and to respond to DCR's needs and concerns, as well as the concerns that were expressed by the community and the Citizens Advisory Committee throughout the Master Plan process. Key recommendations included:

- Nantasket Green - a major new park at the foot of Wharf Avenue, providing a welcoming entrance to visitors and an important gathering spot (Figure 8-3)
- A continuous boardwalk with shade shelters and spaces for vendors, extending the length of the Reservation (Figure 8-4)
- A bicycle lane (adjacent to the boardwalk in most locations) extending the length of the Reservation and connecting to existing and proposed (by the Town of Hull) bicycle routes; along with new bicycle racks and opportunities for bicycle rental
- Relocation of both the David A. Cook and Tivoli Bath Houses to more protected locations
- Expanded playgrounds at both the David A. Cook and Mary Jeanette Murray Bath Houses
- Improved plazas adjacent to the Bernie King Pavilion and Tivoli Bath House
- New landscaping throughout the Reservation
- A reconfigured Nantasket Avenue/Hull Shore Drive intersection to improve traffic flow and allow for an expanded and reorganized DCR operations and maintenance facility
- Repairs to existing buildings
- Potential reuse options for the Dormitory Building, Clocktower Building and Police Station
- Improved parking operations and continued monitoring of parking demand and capacity.

Figure 8-3. Conceptual drawing of Nantasket Green proposed in DCR's Master Plan. Source: DCR, 2016

Figure 8-4. Conceptual drawing of promenade proposed in DCR's Master Plan. Source: DCR, 2016

The Master Plan would be implemented in stages lasting in total more than a decade. Costs are projected to be approximately $47 million for full implementation (in 2016 dollars). Beach nourishment would incur added costs.

Any stage of the implemented Master Plan would bring additional visitors to the Reservation. A nourished beach would have an important multiplier effect, as visitors would have a much enhanced, multifaceted experience at Nantasket Beach. As a result, this effect would have economic benefits for businesses on the Reservation and in the Town of Hull that would like also extend further into the shoulder seasons (spring, fall). In addition to recreational and economic benefits, Phase 2 of the Coastal Storm Damage Reduction Project (beach nourishment) would protect the upland investments through reduced overtopping during major storms.

9. Regulatory Standards and Requirements

9.1 Required Permits

9.1.1 Local Wetland Jurisdiction

Consistency with applicable standards of the Wetlands Protection Act (WPA), as administered by the Town Of Hull's Conservation Commission.

The proposed Phase 2 Beach Nourishment project contributes to the interests of the WPA as follows:

- No impact on public or private water supply, or groundwater
- Provides storm damage prevention and flood control (by reducing overtopping)
- Does not increase erosion; instead beach nourishment reduces current and future scouring and erosion at the base of the seawall
- Imported material has been tested and would not adversely impact the beach or water
- No adverse effects on marine fisheries or wildlife habitat; with minor short-term and no long-term impacts to shellfish and benthic organisms
- Best available measures used to minimize impacts.

Proposed beach nourishment would aid in protecting the existing seawall and revetment as best feasible measure to protect properties landward that would be impacted by seawall failure.

9.1.2 State Wetlands Jurisdiction

Consistency with 314 CMR 9.00: 401 Water Quality Certification Regulations

The proposed Phase 2 Beach Nourishment project is exempt from Section 401 Water Quality Certification as identified in *314 Code of Massachusetts Regulations: Division of Water Pollution Control, Section 9.03: Activities Not Requiring an Application*. Item #2 identifies the following activates not requiring an application:

- Beach Nourishment. Beach nourishment activities with a Final Order of Conditions issued under M.G.L. c. 131, § 40.

Under M.G.L. c. 131, § 40, a project involving fill/dredging of a wetland/river/ocean is to file a written notice of intention to the Conservation Commission. As this project will be filing a Notice of Intent (NOI) with the Town of Hull's Conservation Commission, the project meets this exemption from Section 401 Water Quality Certification regulations.

9.1.3 State Waterways Program

Consistency with Chapter 91 the Massachusetts Public Waterfront Act, and 301 CMR 9.00: Massachusetts Waterways Regulation

The project overall serves the interests of Chapter 91 by aiding in the stabilizing of a coastal seawall structure that is vulnerable to further deterioration and potential collapse from re-occurring

storms and wave action. The proposed Phase 2 beach nourishment would aid in flood protection and storm damage reduction benefits by protecting the recently installed revetment. The project would not interfere with public rights to fish, swim or navigate, nor would it affect waterfront property owner's ability to approach the land from the water. The Preferred Alternative project includes placing up to 700,000 cy of material at the base of the seawall, seaward for approximately 500 to 600 ft, and improves public beach use.

9.1.4 State Coastal Zone Management - Federal Consistency Review

Consistency with Coastal Zone Management Policies

The project requires a Section 404 Individual Permit from USACE (as a federal action). If dredging occurs in the fall of 2019, DCR anticipates the award of federal funding through Section 103 Authority. Therefore, the project requires review for consistency with the program policies established under the Coastal Zone Management Act of 1972. The project requires state agency permits and would receive funding from the Commonwealth of Massachusetts, and is subject to review for consistency with state coastal policies.

This Phase 2 of the project is consistent with CZM's Coastal Hazards policy because it would prevent or reduce threats to public safety and property resulting from flooding and storm damage. The project would also support CZM's public access policy by creating additional beach area for public use.

The proposed beach nourishment would further aid in stabilizing an existing coastal seawall/revetment and would not result in significant adverse impacts to natural physical coastal processes. This non-structural alternative would aid in storm damage reduction and flood protection functions (in addition to the Phase 1 project of revetment placement).

Additional information to support CZM's review is provided in other sections of this Expanded NPC narrative, including the sections on consistency with MassDEP Chapter 91 and the Wetlands Protection Act. Also, for a more in-depth analysis of alternatives, and wave transportation and sediment modeling studies, see the attached 2010 Woods Hole Group and Louis Berger study) (Appendix B).

9.1.5 Massachusetts Endangered Species Act

Consistency with the Massachusetts Endangered Species Act (MESA)

The project serves the interests of MESA by not adversely impacting mapped habitat for federal and state listed species. The project construction period would occur in the winter months (October through March) when nesting birds are not present. As the area north of the project area has been designated by Natural Heritage & Endangered Species Program as a priority habitat of rare species (Piping Plover), the creation of a high tide beach in Phase 2 would result in an expansion of this habitat. The DCR has a management plan for the operation of Nantasket Beach and would implement additional measures described in Section 10.2.3 to protect and monitor federal and Massachusetts-listed species.

9.1.6 Federal Wetlands Permit

Consistency with 404 Clean Water Act regulations

Section 404 of the Clean Water Act regulates water quality with regards to dredge or fill materials into Waters of the United States unless a permit is obtained. As the material for the beach nourishment project would be placed within the intertidal zone (below mean high water) a permit from the USACE is required. Discussions with the USACE has identified that that project will require an Individual Section 404 Permit application to be submitted to the USACE. The application will include discussion on project description, purpose & need, alternative analysis, cultural resources, impact analysis, and mitigation. The USACE will review the application to ensure it satisfies Section 404(b)(1) guidelines (compliance with restrictions on discharge of fill material) and is not contrary to the public interest.

As the material for the proposed project is anticipated to come from the USACE sponsored Piscataqua River dredging project, the USACE is familiar with the source material. The USACE is also currently managing the construction of Phase 1 (seawall toe protection) of the overall project.

9.2 Coastal Resilience (Executive Order 569)

Executive Order 569 (Establishing an Integrated Climate Strategy for the Commonwealth) directs each agency to participate in vulnerability assessment and climate adaptation plans. DCR has been monitoring and assessing the vulnerability of the Nantasket Beach seawall for many years and the work undertaken, including alternatives analysis and project design, will inform DCR's overall coastal resiliency planning efforts. Aside from the toe protection currently being installed, the beach nourishment further reduces vulnerability and enhances resilience to flooding and storm damage. The need for coastal resilience measures were demonstrated by the collapse of the seawall in 1992 (northern section), and the emergency measures needed along the southern section when the footing of the seawall was exposed after storms.

10. Proposed Mitigation Measures

The project area contains limited nearshore resources, as discussed in Chapter 5. At the completion of the project, all areas would naturally re-establish and stabilize, and would recolonize with similar species and similar community structure. This chapter describes specific mitigation measures.

10.1 Construction Mitigation

All in-water beach nourishment activities would be constrained to an environmental window between October 1 and March 31. This period represents a typical environmental window for shoreline and nearshore construction in Southern New England. The project is anticipated to take no longer than six months. Dredging at the Piscataqua River site would start on October 15, allowing for approximately two weeks of mobilization at Nantasket Beach prior to the earliest arrival of material.

Sediment dredged from the Piscataqua River would be hydraulically pumped to Nantasket Beach from a pump-out hopper moored offshore. As the slurry is pumped to the shoreline, the sediment would naturally settle on the beach and the water would drain back to the ocean. After placement, the material would be reshaped to final design specification and profiles using heavy equipment and following the permitted design specifications. Construction activities would have short-term impacts on the resource areas within the project region. The impacts would be minimized by appropriate construction techniques, well-defined work limits, and most importantly, the winter construction window. The impacts would be temporary and the project would provide beneficial long-term results.

10.1.1 Sediments and Water Quality

The Piscataqua River sediments proposed for use in the beach nourishment project consist predominantly of sand and gravel with small percentages of fines (10%). During construction of the nourishment there would be increased turbidity in the vicinity of the beach due to suspension of the finer-grained sediments. The impacts would be temporary during construction only, and adverse impacts to water quality are not expected based on the chemical composition of the sediments and the open coast setting of the beach. Adherence to the environmental window (October 1 to March 31) would serve to protect sensitive species during migration, nesting, and breeding.

10.1.2 Benthic Habitat

As described in Section 8.2.2, long-term impacts to benthic organisms are not expected. Similarly, discussions with the DMF regarding shellfish in the project area indicates that there are no significant shellfish resources in the nearshore area of Nantasket Beach. Therefore, no mitigation or special conditions are planned for the protection of shellfish resources or benthic resources.

10.1.3 Finfish

Beach nourishment activities would have little impact on finfish in the project area. Important sport fisheries are typically pelagic, and therefore can avoid areas of construction. Additionally, most of the species listed in Section 6.2.4.1 either reside entirely in deeper waters, or utilize inshore shallow habitats only during the spring, summer and early fall months. Therefore, since construction of the proposed project would be constrained primarily to the winter months, and affect only nearshore areas, adverse impacts to EFH species are not expected. In addition, since the turbidity increases would be localized to the areas of construction along the beach and would be temporary during construction only, there would be no secondary impacts on finfish resources due to turbidity or sedimentation.

10.1.4 Rare Species

The northern end of the Reservation beach is mapped habitat for the Piping Plover. To minimize any impacts to the birds, the project has been designed with a construction window that ends prior to the nesting season for threatened and endangered shore birds (by the end of March). In addition, DCR would provide a monitor on site for the month of March, in case the nesting season starts earlier than usual.

The beach nourishment has also been designed to enhance habitat for federal and state-listed shorebirds. The nearshore slope of the nourishment is very gradual at 1V:25H, and therefore the birds would be able to move freely from the waterline to more protected areas along the back shore. Additionally, there are no plans for beach grass planting or sand fencing.

10.2 Post-Construction Monitoring and Management

The proposed project has been designed to minimize or eliminate adverse impacts to the surrounding resources. However, prudence dictates on-going monitoring to document the long-term effects of the project and to understand the performance of the project and needs for future renourishment.

10.2.1 Nourishment Performance Monitoring

The MassDEP Superseding Order from August 31, 2017 specified under Special Condition 5 that DCR shall monitor implement the beach elevation to document the effects of the STP project (Phase 1) on the beach for a minimum of 5 years. Monitoring is to be done twice a year (spring and fall), and after significant storm events. Transects shall be spaced every 100 ft along the length of the revetment in the mid-section of the beach. Each transect shall extend at least 200 ft from the MHW line or a depth of three feet below MLW, whichever is closer to the shore. This type of beach elevation monitoring has been conducted by DCR since 2006 along the entire 6,800-ft long shorefront of the Reservation. A total of 69 transects are monitored during each survey. Therefore, compliance with Special Condition 5 consists of a continuation of DCR's existing beach elevation monitoring program.

To also assess the performance of the beach nourishment (Phase 2), DCR would expand the monitoring as follows:

- The length of the monitoring transects would be extended out to a distance of 600 to 700 ft from the seawall or revetment. These extended transects would be monitored at 500-ft intervals along the beach (i.e., every 5th transect of the Phase 1 monitoring program, or a total of 14 transects out of the 69 total transects).
- Each survey would compare beach fill volume with the original as-built survey (conducted immediately after completion of the nourishment) to determine the loss of beach fill in most areas but also the build-up of beach fill in some other areas.
- Monitoring would be targeted for the second half of March and the second half of September each year.

The findings of the monitoring program would be used to inform plans for future nourishment.

10.2.2 Beach Management

DCR has a beach management plan in place to accommodate the needs of operating the beach both during the peak season in the summer and during colder seasons with more frequent storms. Beach management is conducted from DCR's facilities at 215 Nantasket Avenue on the Reservation. Overall, this beach management plan is considered well-suited to accommodate the needs of the larger beach area with potentially more visitors in the summer. Prior to implementation of beach nourishment, this plan would be reviewed and updated as appropriate.

10.2.3 Plover Management

Considering that the northern section of the Reservation is already designated by NHESP as a priority habitat of rare species and also estimated habitat of rare wildlife, the creation of a high tide beach would result in an expansion of the habitat to the south along the remainder of the Reservation's shorefront. As part of the beach nourishment construction, a management plan would be developed to address concerns related to the high priority species (Piping Plover, Common Tern, and Least Tern) nesting and foraging habitat. The plan's components would be designed to ensure compliance with both the Massachusetts Endangered Species Act (MESA) and the federal Endangered Species Act (ESA). Protection efforts would consist of fencing, predator control, monitoring, outreach, and enforcement. Both outreach and enforcement would primarily be focused on the extended construction period and the few first years following construction of the beach, as this time period would represent the public adjustment to the overall beach nourishment program. The management plan would be reviewed and updated, as appropriate, depending on how many birds breed on the newly created beach.

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Appendix A

Previous MEPA Certificates and RODs

Included are the following documents:

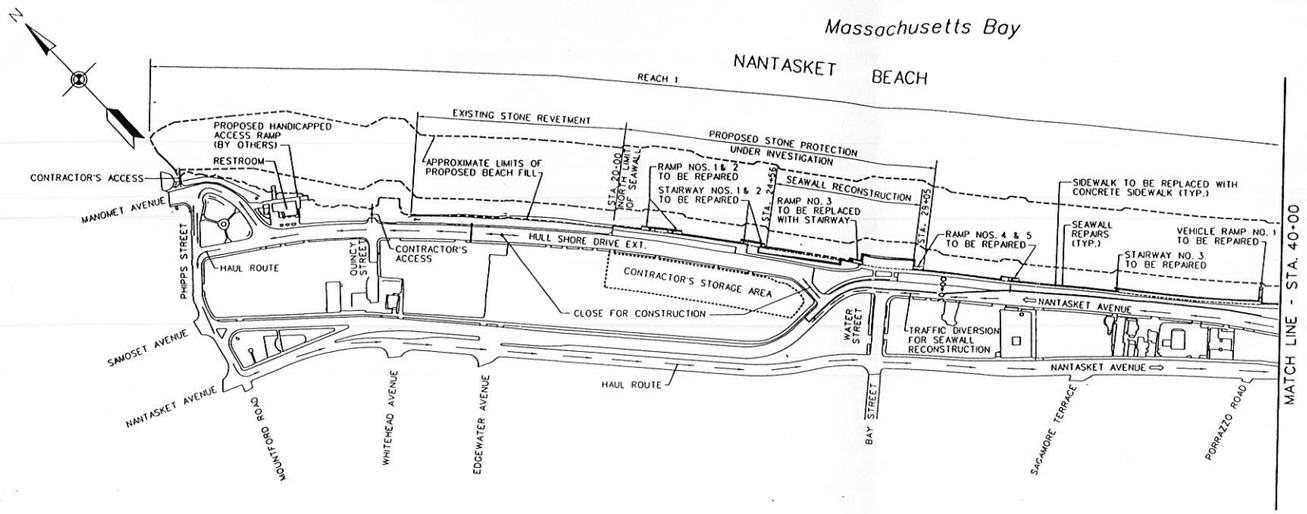
A1. Original project plan that included beach nourishment

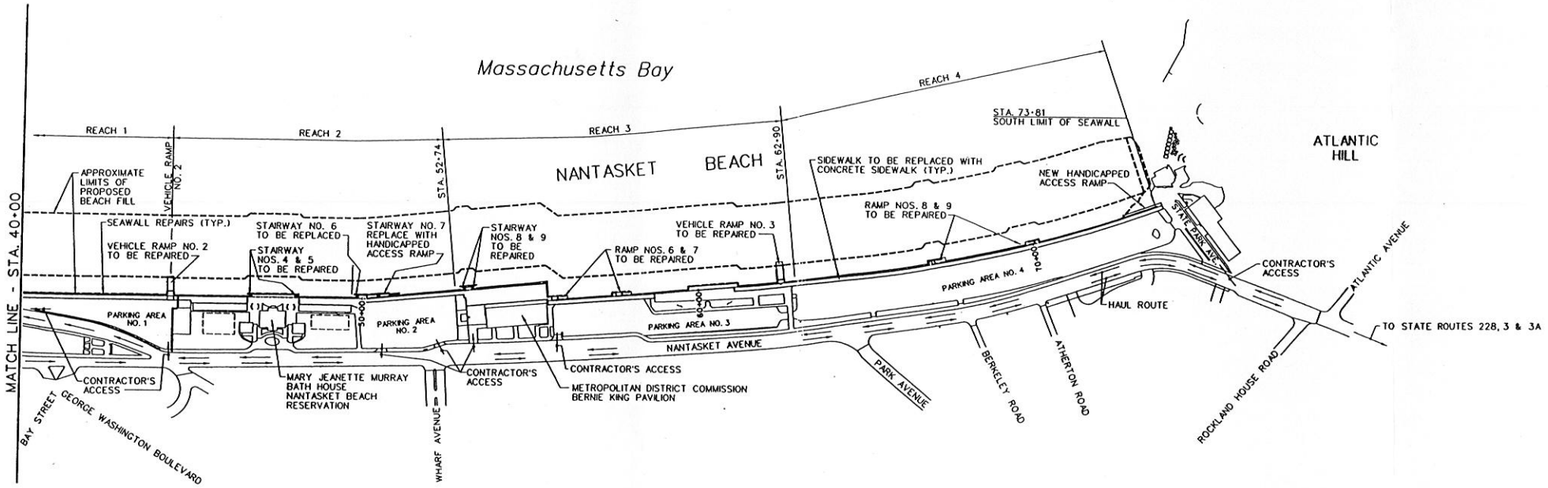
A2. Certificate of the Secretary of Environmental Affairs on the Environmental Notification Form (January 25, 2002)

A3. Certificate of the Secretary of Environmental Affairs on the Notice of Project Change and Request for Phase 1 Waiver (December 15, 2006)

A4. Secretary's Final Record of Decision (January 12, 2007) granting a Phase 1 Waiver

ATTACHMENT A1



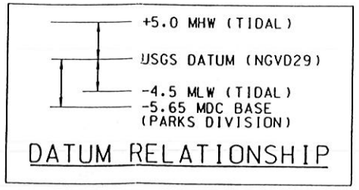


INDEX TO DRAWINGS

DRAWING NO.	REFER NO.	SHEET NO.	TITLE
XXX - X	T-1		COVER SHEET
"	G-1		GENERAL PLAN AND INDEX
"	C-1		PLAN NO. 1
"	C-2		PLAN NO. 2
"	C-3		PLAN NO. 3
"	C-4		PLAN NO. 4
"	C-5		PLAN NO. 5
"	C-6		PLAN NO. 6
"	C-7		PLAN NO. 7
"	C-8		PLAN NO. 8
	C-9		PLAN NO. 9
"	C-10		SECTIONS NO. 1
"	C-11		SECTIONS NO. 2
"	S-1		STAIRWAY PLANS AND ELEVATIONS
"	S-2		RAMP PLANS AND ELEVATIONS
"	S-3		VEHICLE RAMP PLANS, ELEVATIONS, AND SECTIONS
"	S-4		SEAWALL REPAIR SCHEDULES
"	S-5		TYPICAL REPAIR DETAILS AND NOTES
"	S-6		NEW SEAWALL, SIDEWALK, STAIRWAY SECTIONS AND DETAILS
"	S-7		HANDICAP ACCESS RAMP AND NEW STAIRWAY NO. 6

GENERAL PLAN

SCALE: 1" = 200'



DATUM RELATIONSHIP

GENERAL NOTES:

1. ALL ELEVATIONS REFER TO NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29).
2. COORDINATES REFER TO MASSACHUSETTS COORDINATE SYSTEM (NAD83).
3. PHOTOGRAMMETRIC MAPPING AT 1" = 30' SCALE PERFORMED BY EARTHDATA INTERNATIONAL OF MARYLAND. DATE OF AERIAL PHOTOGRAPHY: 1 MAY 2000.
4. EXPLORATION LOGS ARE INCLUDED IN SECTION XXXXX OF THE SPECIFICATIONS.

1" = 200' GRAPHIC SCALE 200' 0 200' 400'

US Army Corps of Engineers New England District

Symbol	Description	Date	Appr.	Symbol	Description	Date	Appr.

Rev.

Date:

Design file no. NEWC401.DGN

Drawing code:

File name:
Plot date:
Plot scale: 1" = 300'

Designed by: Mary A. Donovan
Drawn by: Stephen W. Kelley
Reviewed by:
Submitted by:
Chief, Civil Engrg Sect

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
CONCORD, MASSACHUSETTS

HULL, MASSACHUSETTS

NANTASKET BEACH SEAWALL REHABILITATION
GENERAL PLAN AND INDEX

Reference number:
G-1

Sheet of

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ATTACHMENT A2

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
251 Causeway Street, Suite 900
Boston, MA 02114-2119

JANE SWIFT
GOVERNOR

BOB DURAND
SECRETARY

Tel. (617) 626-1000
Fax (617) 626-1181
http://www.magnet.state.ma.us/envir

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January 25, 2002

CERTIFICATE OF THE SECRETARY OF ENVIRONMENTAL AFFAIRS
ON THE
ENVIRONMENTAL NOTIFICATION FORM

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Metropolitan District Commission (MDC)
DATE NOTICED IN MONITOR	: December 26, 2002

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 61-62H) and Section 11.03 of the MEPA regulations (301 CMR 11.00), I hereby determine that this project **requires** the preparation of an Environmental Impact Report (EIR).

As described in the Environmental Notification Form (ENF), the proposed project involves a phased storm damage protection project. Phase I involves repairs of an existing 5,400 linear foot section of seawall, replacement of a 550 linear foot collapsed section of seawall, and rubble toe protection of 450 linear feet of seawall immediately north of the collapsed section. Phase II involves the placement of approximately 280,000 square feet of sand for beach nourishment and dune creation. The source for the sand is currently under study.

The project is undergoing MEPA review and requires the preparation of an EIR pursuant to Section 11.03 (3)(a)(1)(b) of the MEPA regulations, because the project involves alteration of more than ten acres of wetlands other than Bordering Vegetated Wetlands.

The project will require Water Quality Certification and possibly a Chapter 91 License from the Department of Environmental Protection (DEP), and an Order of Conditions from the Hull Conservation Commission (and hence a Superseding Order from DEP

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if the local Order were appealed). Because the proponent is an agency of the Commonwealth, MEPA jurisdiction extends to all aspects of the project that may cause significant Damage to the Environment.

The proponent has asked for a waiver to allow Phase I of the project to proceed pending completion of the EIR for the project as a whole. However, at the site visit the proponent indicated that it is studying alternatives seawall configurations and alternatives to the seawall itself over portions of the project area. The results of this alternatives analysis, being undertaken in cooperation with the U.S. Army Corps of Engineers, will not be available for several months. The proponent is also studying the most appropriate timing for Phase II relative to Phase I (it may be more beneficial to perform beach nourishment as close to the time period of seawall repair as possible).

Given the outstanding issues, I find that the waiver request does not meet the standards laid out in Section 11.11 of the MEPA regulations, and I am therefore denying the waiver request at this time. However, I will allow the proponent to again request a Phase I waiver, after the results of the Army Corps alternatives analysis have become available. If the proponent wishes to pursue a Phase I waiver at the appropriate future time, it should file a Notice of Project Change to allow for public review of the waiver request.

SCOPE

General

The proponent should prepare the EIR in accordance with Section 11.07 of the MEPA regulations, as modified by this Certificate. The EIR should contain a copy of this Certificate and a copy of each comment received. The proponent should circulate the EIR to those who commented on the ENF, to any state agency from which the proponent will seek permits or approvals, and to the Hull Conservation Commission and Hull Beach Management Committee.

Alternatives

The EIR should fully analyze the proponent's preferred alternative, as well as the no-build alternative to establish baseline conditions. For Phase I, the EIR should evaluate alternative configurations for the seawall access stairs and ramps. The EIR should also evaluate alternatives to replacement-in-kind of the collapsed section of seawall, including

construction of a sloped rock revetment in this area. The EIR should also consider construction of a dune seaward of the failed section of seawall as part of Phase I, in an effort to further enhance storm damage protection.

For Phase II, the EIR should analyze alternative sources for sand, including upland or offshore sources. The EIR should evaluate the environmental impacts in the source area, particularly if the source is offshore. (The proponent may seek to use a borrow pit for sand that is currently also under consideration as a source for sand for beach nourishment in Winthrop. I refer the proponent to the scope issued for the Winthrop project (EOEA #10113) to guide analysis of impacts from the offshore borrow pit alternative.)

Permitting

The EIR should briefly describe each state permit required for the project, and demonstrate that the project design can meet any applicable performance standards. The EIR should also discuss the consistency of the project with any applicable regional or local land use or open space plans.

Wetlands/Drainage/Water Quality

The EIR should identify the wetland resource areas (including any banks, land under the water, bordering land subject to flooding, and isolated land subject to flooding) and buffer zones present on the site on a reasonably scaled plan. The EIR should identify the significance of the resources, including value to public and private water supply, flood control, storm damage prevention, prevention of pollution, riverfront area, and fisheries and wildlife habitat. The EIR should analyze both direct and indirect impacts on wetlands resulting from the project. The EIR should provide information on grain size, projected equilibration of the nourishment, impacts to fisheries, and impacts to downdrift areas. The EIR should quantify the wetland impacts from each alternative. The EIR should demonstrate that proponent has avoided, reduced, or minimized impacts to the maximum feasible extent. The EIR should propose appropriate mitigation for all wetland impacts demonstrated to be unavoidable.

Beach Management and Monitoring

The EIR should include a beach maintenance and management plan, the aim of which should be to minimize impacts on resources from activities such as beach cleaning, maintenance of access

structures, and similar activities. The EIR should also include a monitoring plan to evaluate the continued evolution of the beach nourishment, as well as to aid planning for any additional nourishment that may be needed to minimize impacts from the seawall/revetment structures.

Construction Period

The EIR should analyze impacts from the construction period, including any impacts in sand source areas. The EIR should also evaluate the constructing phasing of the project, and the relative benefits and disadvantages of scheduling Phase II work immediately after Phase I, versus allowing a longer time interval between Phase II and Phase I.

Comments

The EIR should include responses to the substantive comments received. The EIR should include additional technical analysis and/or narrative as appropriate to address the concerns raised.

Mitigation

The EIR should include a summary of all mitigation measures to which the proponent has committed. The EIR should include Proposed Section 61 Findings for use by the state permitting agencies (and the proponent, which will also be responsible for Section 61 Findings).

January 25, 2002
Date

Bob Durand

Comments received:

01/15/02 Division of Marine fisheries
01/15/02 Department of Environmental Protection NERO
01/17/02 Coastal Zone Management

BAD/ASP/asp

ATTACHMENT A3

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114-2524

MITT ROMNEY
GOVERNOR
KERRY HEALEY
LIEUTENANT GOVERNOR
ROBERT W. GOLLEDGE, JR.
SECRETARY

Tel. (617) 626-1000
Fax. (617) 626-1181
http://www.mass.gov/envir

December 15, 2006

CERTIFICATE OF THE SECRETARY OF ENVIRONMENTAL AFFAIRS
ON THE
NOTICE OF PROJECT CHANGE
AND REQUEST FOR PHASE I WAIVER

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Department of Conservation and Recreation (DCR)
DATE NOTICED IN MONITOR	: November 8, 2006

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 6I-62H) and Section II.06 of the MEPA regulations (30I CMR II.00), I hereby determine that this project **continues to require** the preparation of an Environmental Impact Report (EIR).

As described in the Environmental Notification Form (ENF) reviewed in January, 2002, the proposed project involves a phased storm damage protection project along Nantasket Beach. As originally proposed, Phase I involved:1) repairs to an existing 5,400-foot-long section of seawall; 2) replacement of a 550-foot-long section of collapsed seawall; and 3) rubble toe protection of a 450-foot-long section of seawall located immediately to the north of the collapsed section. Phase 2 involved the placement of approximately 280,000 cubic yards (cy) of sand along the 6,800-foot-long beach.

The project is subject to environmental review pursuant to 30I CMR II.03 (3)(a)(I)(b) of the MEPA regulations because it involves alteration of more than ten acres of wetlands other than Bordering Vegetated Wetlands. The project will require a 401 Water Quality Certification and a Chapter 9I License from the Department of Environmental Protection (DEP) and may require Federal Consistency Review by the Office of Coastal Zone Management (CZM). The project also requires a Programmatic General Permit from the U.S. Army Corps of Engineers and an Order of Conditions from the Hull Conservation Commission (and hence a Superceding Order of Conditions from DEP if the local Order is appealed). Because DCR is an agency of the Commonwealth, MEPA jurisdiction extends to all aspects of the project that may cause significant Damage to the Environment.

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In January, 2005 the proponent submitted a Notice of Project Change (NPC) which addressed two separate changes to the project: a Temporary Seawall Fortification (TSF) that was constructed in the summer of 2004 under emergency authorizations from DEP, the MEPA Office and the Hull Conservation Commission for an area of the seawall most prone to failure; and the division of the project into three phases: 1) replacement of the northern section of seawall with an approximately 930-foot-long new stone revetment; 2) repairs to the remainder of the existing seawall; and 3) sand nourishment along 6,800 feet of beach. The proponent also requested a Waiver under the MEPA regulations, which was granted, to allow Phase I work to proceed in advance of the preparation of the Environmental Impact Report. The new Phase I work included removing the 550-foot-long section of collapsed seawall as well as the 450-foot-log section that was previously proposed for rubble-toe protection and replacing these with a 930-foot-long stone revetment, which will be located approximately 21 feet landward from the originally proposed project.

The current NPC requests an expansion of the work to be completed under the Phase I Waiver granted in January, 2005. The proposed expansion of work change includes the construction of 2,000 linear feet of Seawall Toe Protection (STP) designed to improve the stability of a vulnerable section of the seawall along the middle section of the Nantasket Beach Reservation, beach access improvements, minor seawall repairs, and beach and dune nourishment.

I propose to grant the Phase I Waiver, which is an expansion of the Phase I Waiver granted in January, 2005. This Waiver will allow the first phase of the project to proceed to the state permitting agencies prior to completion of the Draft and Final EIRs for the entire project, as detailed in a separate Draft Record of Decision (ROD) issued today. As detailed in the Draft ROD, and in accordance with Section 11.11(4) of the MEPA regulations, I find that the potential environmental impacts of Phase I are insignificant; ample and unconstrained infrastructure exists to support Phase I of the project; the project is severable such that Phase I does not require the implementation of any future phases; and the state agency actions on Phase I will contain conditions that ensure due compliance with MEPA.

The proponent, the Department of Conservation and Recreation (DCR), has been working to expedite the reinforcement of the middle section of the seawall to protect the structural stability and avoid further deterioration. The northern and southern sections have already been reinforced. I note, however, that the Nantasket Board of Selectmen has recently voted to request that the work on the seawall toe protection in the middle reach of the Nantasket seawall be postponed. DCR will move forward with improvements to beach access ways along the southern area of the seawall. The improvements are expected to be completed by early July, 2007.

The proponent continues to work closely with an interagency team comprised of representatives from DEP, CZM, the Division of Marine Fisheries, and the Executive Office of

Environmental Affairs and has participated in several recent coordination meetings regarding the proposed project change work. As part of the project, I advise the proponent to conduct pre- and post-construction surveys to monitor conditions at the site. CZM recommends, and I concur, that the post-construction surveys be conducted on a quarterly basis for a minimum of 2 years and then on an annual basis until the beach nourishment component of the project is implemented, and also immediately following any ten-year (or greater) return frequency storm event in order to provide sufficient information regarding the effects of the project on the beach. The survey reports should be provided to CZM within one month following completion of the survey. The proponent should continue to consult with CZM to develop a monitoring protocol.

In its comments, the Massachusetts Historical Commission has determined that the project change will have no "adverse effect" (36 CFR 800.5(b) and 950 CMR 71.07(2)(b)(2)) upon the historical characteristics on the Hull Shore Drive/Nantasket Avenue National Register Historic District.

The project is still subject to the preparation of a mandatory EIR, as detailed in the scope contained in the Certificate on the Environmental Notification Form issued on January 25, 2002.

December 15, 2006
Date

Robert W. Golledge, Jr.

Comments received:

11/22/06	Office of Coastal Zone Management
11/24/06	Massachusetts Historical Commission
12/07/06	MA Division of Marine Fisheries

RWG/ACC/acc

ATTACHMENT A4

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114

Deval Patrick
GOVERNOR

Timothy Murray
LIEUTENANT GOVERNOR

Ian Bowles
SECRETARY

Tel: (617) 626-1000
Fax: (617) 626-1181
http://www.mass.gov/envir

January 12, 2007

FINAL RECORD OF DECISION

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Department of Conservation and Recreation
DATE NOTICED IN MONITOR	: November 8, 2006

As Secretary of Environmental Affairs, I have reviewed this project pursuant to the Massachusetts Environmental Policy Act (M.G.L. c.30, ss. 61-62H) and Section 11.11 of the MEPA regulations (301 CMR 11.00), and hereby **grant a waiver** (as defined below), allowing the project to proceed to the state permitting agencies prior to completion of the Draft and Final Environmental Impact Reports (EIRs) for the entire project.

Project Description

In January, 2005 the proponent submitted a Notice of Project Change (NPC) which addressed two separate changes to the project: a Temporary Seawall Fortification (TSF) that was constructed in the summer of 2004 under emergency authorizations from DEP, the MEPA Office and the Hull Conservation Commission for an area of the seawall most prone to failure; and the division of the project into three phases: 1.) replacement of the northern section of seawall with an approximately 930-foot-long new stone revetment; 2) repairs to the remainder of the existing seawall; and 3) sand nourishment along 6,800 feet of beach. The proponent also requested a Waiver under the MEPA regulations, which was granted, to allow Phase I work to proceed in advance of the preparation of the Environmental Impact Report. The new Phase I work included removing the 550-foot-long section of collapsed seawall as well as the 450-foot-log section that was previously proposed for rubble-toe protection and replacing these with a 930-foot-long stone revetment, which will be located approximately 21 feet landward from the originally proposed project.

The current NPC requests an expansion of the work to be completed under the Phase I

Waiver granted in January, 2005. The proposed expansion of work change includes the construction of 2,000 linear feet of Seawall Toe Protection (STP) designed to improve the stability of a vulnerable section of the seawall along the middle section of the Nantasket Beach Reservation, beach access improvements, minor seawall repairs, and beach and dune nourishment. The proponent has requested a Phase 1 Waiver to allow this work to proceed in advance of the preparation of the Environmental Impact Report.

The Department of Conservation and Recreation (DCR), the proponent, has been working to expedite the reinforcement of the middle section of the seawall to protect the structural stability and avoid further deterioration. The northern and southern sections have already been reinforced. I note, however, that the Nantasket Board of Selectmen has recently voted to request that the work on the seawall toe protection in the middle reach of the Nantasket seawall be postponed. DCR will move forward with improvements to beach access ways along the southern area of the seawall. The improvements are expected to be completed by early July, 2007.

Criteria for a Phase I Waiver

Section 11.11 of the MEPA regulations provides that the Secretary may waive any provision or requirement of 301 CMR 11.00 not specifically required by MEPA, and may impose appropriate and relevant conditions or restrictions, provided that the Secretary finds that strict compliance with the provision or requirement would: a) result in undue hardship to the proponent, unless based on delay in compliance by the proponent; and b) not serve to minimize or avoid damage to the environment.

In the case of a partial waiver of a mandatory EIR review threshold that would allow the proponent to proceed to Phase I of the project prior to preparing an EIR, this finding shall be based on one or more of the following circumstances: 1) the potential environmental impacts of Phase I are insignificant; 2) ample and unconstrained infrastructure and services exist to support Phase I; 3) the project is severable, such that Phase I does not require the implementation of any other future phases; and 4) the agency action on Phase I will contain conditions that ensure due compliance with MEPA.

Findings

Based upon the information submitted by the proponent and after consultation with the relevant state agencies, I find that Phase 1 of the project will result in potential environmental benefits because it will halt further deterioration of the backshore and prevent the further deterioration of existing facilities and infrastructure. Therefore, I find that strict compliance with the mandatory EIR requirement would a) result in undue hardship to the proponent; and b) not serve to minimize or avoid damage to the environment.

In addition, I find that:

1) The potential environmental impacts of Phase I are insignificant.

2) Ample and unconstrained infrastructure exists to support Phase I of the project because it will be constructed on state property and prevent the further deterioration of existing facilities and infrastructure.

3) The project is severable such that Phase I does not require the implementation of any

future phases.

4) The state agency actions on Phase I, in this case a 401 Water Quality Certification and Chapter 91 License from DEP, will contain conditions that ensure due compliance with MEPA.

Based on these findings, it is my judgment that the waiver request has merit and meets the tests established in Section 11.11. Therefore, I hereby grant the Phase I waiver.

January 12, 2007
Date

Ian A. Bowles

Comments received:

No comments received

IAB/ACC/acc

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114-2524

MITT ROMNEY
GOVERNOR
KERRY HEALEY
LIEUTENANT GOVERNOR
ELLEN ROY HERZFELDER
SECRETARY

Tel. (617) 626-1000
Fax. (617) 626-1181
http://www.mass.gov/envir

March 3, 2005

FINAL RECORD OF DECISION

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Department of Conservation and Recreation
DATE NOTICED IN MONITOR	: December 22, 2004

Pursuant to the Massachusetts Environmental Policy Act (MEPA) (G.L.c.30, ss. 61-62H) and Section 11.06 of the MEPA regulations (301 CMR 11.00), I have reviewed the Notice of Project Change (NPC) and request for a Phase I waiver submitted on this project. I propose to grant a Phase 1 Waiver, allowing the first phase of the project to proceed to the state permitting agencies prior to completion of the Draft and Final Environmental Impact Reports (EIRs) for the entire project.

Project Description

As described in the Notice of Project Change (NPC), the project change entails two separate changes to the project:

- an emergency Temporary Seawall Fortification (TSF) that was constructed in the summer of 2004; and
- the division of the project into three phases:

I. replacement of the northern section of seawall with an approximately 930-foot-long new stone revetment;
II. repairs to the remainder of the existing seawall; and
III. sand nourishment along 6,800 feet of beach.

The proponent has requested a Phase 1 Waiver to allow this work to proceed in advance of the preparation of the Environmental Impact Report. The new Phase 1 includes removing the 550-foot-long section of collapsed seawall as well as the 450-foot-long section that was previously proposed for rubble-toe protection and replacing these with a 930-foot-long stone revetment, which will be located approximately 21 feet landward from the originally proposed project.

In the period since I issued the Draft Record of Decision, DCR has initiated emergency repairs to a 210-linear-foot section of seawall, extending northwards from the southern limit of the previously identified Phase 1 work area. For the purposes of this Record of Decision, I will consider these emergency repairs to be part of the Phase 1 work and will not require them to be the subject of further review under MEPA.

Criteria for a Phase I Waiver

Section 11.11 of the MEPA regulations provides that the Secretary may waive any provision or requirement of 301 CMR 11.00 not specifically required by MEPA, and may impose appropriate and relevant conditions or restrictions, provided that the Secretary finds that strict compliance with the provision or requirement would: a) result in undue hardship to the proponent, unless based on delay in compliance by the proponent; and b) not serve to minimize or avoid damage to the environment.

In the case of a partial waiver of a mandatory EIR review threshold that would allow the proponent to proceed to Phase I of the project prior to preparing an EIR, this finding shall be based on one or more of the following circumstances: 1) the potential environmental impacts of Phase I are insignificant; 2) ample and unconstrained infrastructure and services exist to support Phase I; 3) the project is severable, such that Phase I does not require the implementation of any other future phases; and 4) the agency action on Phase I will contain conditions that ensure due compliance with MEPA.

EOEA #12668 Final Record of Decision 03/03/05

Findings

Based upon the information submitted by the proponent and after consultation with the relevant state agencies, I find that Phase 1 of the project will result in potential environmental benefits because it will halt further deterioration of the backshore and prevent the further deterioration of existing facilities and infrastructure. Therefore, I find that strict compliance with the mandatory EIR requirement would a) result in undue hardship to the proponent; and b) not serve to minimize or avoid damage to the environment.

In addition, I find that:

1) The potential environmental impacts of Phase I are insignificant, particularly when weighed against the potential environmental benefits. Although the new stone revetment would affect approximately 2,805 square feet of intertidal habitat, encroachment into the intertidal zone will be reduced by locating the revetment 21 feet landward from the existing seawall footprint. Construction of the revetment will also halt further deterioration of the backshore.

2) Ample and unconstrained infrastructure exists to support Phase I of the project because it will be constructed on state property and prevent the further deterioration of existing facilities and infrastructure.

3) The project is severable such that Phase I does not require the implementation of any future phases.

4) The state agency actions on Phase I, in this case a 401 Water Quality Certification and Chapter 91 License from DEP, will contain conditions that ensure due compliance with MEPA.

Based on these findings, it is my judgment that the waiver request has merit and meets the tests established in Section 11.11. Therefore, I hereby grant the Phase I waiver.

March 3, 2005
Date

Ellen Roy Herzfelder

ERH/RAB/rab

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114-2524

MITT ROMNEY
GOVERNOR
KERRY HEALEY
LIEUTENANT GOVERNOR
ELLEN ROY HERZFELDER
SECRETARY

Tel. (617) 626-1000
Fax. (617) 626-1181
http://www.mass.gov/envir

January 21, 2005

CERTIFICATE OF THE SECRETARY OF ENVIRONMENTAL AFFAIRS
ON THE
NOTICE OF PROJECT CHANGE
AND REQUEST FOR PHASE I WAIVER

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Department of Conservation and Recreation
DATE NOTICED IN MONITOR	: December 22, 2004

Pursuant to the Massachusetts Environmental Policy Act (G. L. c. 30, ss. 61-62H) and Section 11.06 of the MEPA regulations (301 CMR 11.00), I hereby determine that this project continues to require the preparation of an Environmental Impact Report (EIR).

As described in the Environmental Notification Form (ENF) reviewed in January, 2002, the proposed project involves a phased storm damage protection project along Nantasket Beach. As originally proposed, Phase I involved:

- repairs to an existing 5,400-foot-long section of seawall;
- replacement of a 550-foot-long section of collapsed seawall; and
- rubble toe protection of a 450-foot-long section of seawall located immediately to the north of the collapsed section.

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Phase 2 involved the placement of approximately 280,000 cubic yards (cy) of sand along the 6,800-foot-long beach.

The project is subject to environmental review pursuant to 301 CMR 11.03 (3)(a)(1)(b) of the MEPA regulations because it involves alteration of more than ten acres of wetlands other than Bordering Vegetated Wetlands. The project will require a 401 Water Quality Certification and a Chapter 91 License from the Department of Environmental Protection (DEP) and may require Federal Consistency Review by the Office of Coastal Zone Management (CZM). The project also requires a Programmatic General Permit from the U.S. Army Corps of Engineers and an Order of Conditions from the Hull Conservation Commission (and hence a Superceding Order of Conditions from DEP if the local Order is appealed). Because DCR is an agency of the Commonwealth, MEPA jurisdiction extends to all aspects of the project that may cause significant Damage to the Environment.

As described in the Notice of Project Change (NPC), this MEPA filing addresses two separate changes to the project:

- a Temporary Seawall Fortification (TSF) that was constructed in the summer of 2004 under emergency authorizations from DEP, the MEPA Office and the Hull Conservation Commission for an area of the seawall most prone to failure; and
- the division of the project into three phases:
  - I. replacement of the northern section of seawall with an approximately 930-foot-long new stone revetment;
  - II. repairs to the remainder of the existing seawall; and
  - III. sand nourishment along 6,800 feet of beach.

The NPC serves to satisfy compliance with Section 11.13 of the MEPA regulations, as it describes the emergency condition and the measures taken to abate it (the TSF), as well as supporting evidence to demonstrate that the actions taken are the minimum necessary to abate the emergency condition.

DCR has requested a Waiver under the MEPA regulations to allow Phase I work to proceed in advance of the preparation of the Environmental Impact Report. The new Phase I includes removing the 550-foot-long section of collapsed seawall as well as the 450-foot-log section that was previously proposed for

rubble-toe protection and replacing these with a 930-foot-long stone revetment, which will be located approximately 21 feet landward from the originally proposed project.

I propose to grant the Phase I Waiver, allowing the first phase of the project to proceed to the state permitting agencies prior to completion of the Draft and Final EIRs for the entire project, as detailed in a separate Draft Record of Decision (ROD) issued today. As detailed in the Draft ROD, and in accordance with Section 11.11(4) of the MEPA regulations, I find that the potential environmental impacts of Phase I are insignificant; ample and unconstrained infrastructure exists to support Phase I of the project; the project is severable such that Phase I does not require the implementation of any future phases; and the state agency actions on Phase I will contain conditions that ensure due compliance with MEPA.

The proposed changes to Phase I of the project were coordinated through a task force comprised of representatives from DEP, CZM, the Division of Marine Fisheries, and the Executive Office of Environmental Affairs. As part of the project, CZM recommends that pre- and post-construction surveys of the beach be conducted to monitor conditions at the site. The post-construction surveys should be conducted on a quarterly basis for a minimum of two years, and immediately following a significant storm event, in order to provide sufficient information regarding the effects of the project on the beach. DCR should consult with CZM to develop a monitoring procedure.

In its comments, the Massachusetts Historical Commission stated that it is unable to determine if Phase I of the project will adversely affect the Hull Shore Drive/Nantasket Avenue National Register Historic District. Phase I, which entails relocating the seawall landward by 21 feet, will encroach on the existing sidewalk. MHC has requested the opportunity to review detailed cross-section and elevation plans showing existing and proposed conditions for the sidewalk and handicapped ramp. I expect that DCR will work with MHC to ensure that any adverse effects to the National Register District are avoided, minimized or mitigated.

EOEA #12668 NPC Certificate 01/21/05

The project is still subject to the preparation of a mandatory EIR, as detailed in the scope contained in the Certificate on the Environmental Notification Form issued on January 25, 2002. The EIR should also report on the status of the two issues noted above.

January 21, 2005
Date

Ellen Roy Herzfelder

Comments received:

01/13/05 Office of Coastal Zone Management
01/19/05 Massachusetts Historical Commission

ERH/RAB/rab

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
100 Cambridge Street, Suite 900
Boston, MA 02114-2524

MITT ROMNEY
GOVERNOR
KERRY HEALEY
LIEUTENANT GOVERNOR
ELLEN ROY HERZFELDER
SECRETARY

Tel. (617) 626-1000
Fax (617) 626-1181
http://www.mass.gov/envir

January 21, 2005

DRAFT RECORD OF DECISION

PROJECT NAME	: Nantasket Beach Coastal Storm Damage Protection Project
PROJECT MUNICIPALITY	: Hull
PROJECT WATERSHED	: Boston Harbor
EOEA NUMBER	: 12668
PROJECT PROPONENT	: Department of Conservation and Recreation
DATE NOTICED IN MONITOR	: December 22, 2004

Pursuant to the Massachusetts Environmental Policy Act (MEPA) (G.L.c.30, ss. 61-62H) and Section 11.06 of the MEPA regulations (301 CMR 11.00), I have reviewed the Notice of Project Change (NPC) and request for a Phase I waiver submitted on this project. I propose to grant a Phase 1 Waiver, allowing the first phase of the project to proceed to the state permitting agencies prior to completion of the Draft and Final Environmental Impact Reports (EIRs) for the entire project.

Project Description

As described in the Notice of Project Change (NPC), the project change entails two separate changes to the project:

- an emergency Temporary Seawall Fortification (TSF) that was constructed in the summer of 2004; and
- the division of the project into three phases:

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I. replacement of the northern section of seawall with an approximately 930-foot-long new stone revetment;
II. repairs to the remainder of the existing seawall; and
III. sand nourishment along 6,800 feet of beach.

The proponent has requested a Phase 1 Waiver to allow this work to proceed in advance of the preparation of the Environmental Impact Report. The new Phase 1 includes removing the 550-foot-long section of collapsed seawall as well as the 450-foot-log section that was previously proposed for rubble-toe protection and replacing these with a 930-foot-long stone revetment, which will be located approximately 21 feet landward from the originally proposed project.

Criteria for a Phase I Waiver

Section 11.11 of the MEPA regulations provides that the Secretary may waive any provision or requirement of 301 CMR 11.00 not specifically required by MEPA, and may impose appropriate and relevant conditions or restrictions, provided that the Secretary finds that strict compliance with the provision or requirement would: a) result in undue hardship to the proponent, unless based on delay in compliance by the proponent; and b) not serve to minimize or avoid damage to the environment.

In the case of a partial waiver of a mandatory EIR review threshold that would allow the proponent to proceed to Phase I of the project prior to preparing an EIR, this finding shall be based on one or more of the following circumstances: 1) the potential environmental impacts of Phase I are insignificant; 2) ample and unconstrained infrastructure and services exist to support Phase I; 3) the project is severable, such that Phase I does not require the implementation of any other future phases; and 4) the agency action on Phase I will contain conditions that ensure due compliance with MEPA.

Findings

Based upon the information submitted by the proponent and after consultation with the relevant state agencies, I find that Phase 1 of the project will result in potential environmental benefits because it will halt further deterioration of the

backshore and prevent the further deterioration of existing facilities and infrastructure. Therefore, I find that strict compliance with the mandatory EIR requirement would a) result in undue hardship to the proponent; and b) not serve to minimize or avoid damage to the environment.

In addition, I find that:

1) The potential environmental impacts of Phase I are insignificant, particularly when weighed against the potential environmental benefits. Although the new stone revetment would affect approximately 2,805 square feet of intertidal habitat, encroachment into the intertidal zone will be reduced by locating the revetment 21 feet landward from the existing seawall footprint. Construction of the revetment will also halt further deterioration of the backshore.

2) Ample and unconstrained infrastructure exists to support Phase I of the project because it will be constructed on state property and prevent the further deterioration of existing facilities and infrastructure.

3) The project is severable such that Phase I does not require the implementation of any future phases.

4) The state agency actions on Phase I, in this case a 401 Water Quality Certification and Chapter 91 License from DEP, will contain conditions that ensure due compliance with MEPA.

Based on these findings, it is my judgment that the waiver request has merit and meets the tests established in Section 11.11. Therefore, I propose to grant the Phase I waiver. This Draft Record of Decision shall be published in the next issue of the *Environmental Monitor* for a fourteen-day comment period, after which I shall reconsider, modify, or confirm the waiver.

January 21, 2005
Date

Ellen Roy Herzfelder

ERH/RAB/rab

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
OFFICE OF COASTAL ZONE MANAGEMENT
251 Causeway Street, Suite 800, Boston, MA 02114-2136
(617) 626-1200 fax: (617) 626-1240

RECEIVED
JAN 13 2005
MEPA

MEMORANDUM

TO: Ellen Roy Herzfelder, Secretary, EOEA
ATTN: Rick Bourre, MEPA Unit
FROM: Susan Snow-Cotter, Acting Director, CZM
DATE: January 7, 2005
RE: EOEA 12668 – Nantasket Beach Coastal Storm Damage Protection Project NPC; Hull

The Massachusetts Office of Coastal Zone Management (CZM) has completed its review of the above-referenced Notice of Project Change (NPC), noticed in the Environmental Monitor dated December 22, 2004, and does not recommend the preparation of an Environmental Impact Report for work performed as part of the NPC. The NPC describes changes to a storm damage protection project originally proposed by the Department of Conservation and Recreation (DCR) in an Environmental Notification Form dated December 26, 2001. The project as proposed in the NPC includes the Temporary Seawall Fortification completed in August 2004, construction of a stone revetment along the northern section of the seawall, rehabilitation of the existing seawall, and beach and dune nourishment.

CZM has worked with DCR as part of the interagency team described in the NPC to evaluate the alternatives for this site. As part of the project, CZM recommends that pre- and post-construction surveys of the beach conditions be conducted to monitor conditions at the site. The post-construction surveys should be conducted on a quarterly basis for a minimum of 2 years, and immediately following a significant storm event, in order to provide sufficient information regarding the effects of the project on the beach. CZM offers its continued assistance to DCR in developing a monitoring protocol.

The project may be subject to CZM federal consistency review to determine consistency CZM's enforceable program policies. For further information on this process, please contact Alex Strysky, Project Review Coordinator, at 617-626-1219 or visit the CZM web site at www.state.ma.us/czm/fcr.htm.

SSC/rh/jdb

cc: Jason Burtner, CZM South Shore Regional Coordinator
Rebecca Haney, CZM
James Sprague, Section Chief, Northeast Regional Office, MA DEP
Ben Lynch, Acting Section Chief, Waterways Program, MA DEP
Joe Orfant, DCR
Chris McCabe, Hull Town Manager
Margo Clerkin, Hull Conservation Agent

Appendix B

Coastal Engineering and Shore Protection Alternatives Assessment (2010)

Woods Hole Group and Louis Berger Group, 2010

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Final Report, Tasks 3 and 4

Coastal Engineering and Shore Protection Alternatives Assessment

Prepared for

Massachusetts Department of Conservation and Recreation

Prepared by

Woods Hole Group, Inc. *and* The Louis Berger Group, Inc.

February 2010

NANTASKET BEACH SEAWALL REPAIR AND RESERVATION MASTER PLAN SERVICES

COASTAL ENGINEERING AND SHORE PROTECTION ALTERNATIVES ASSESSMENT

Final Report, Tasks 3 and 4

Prepared for:

Massachusetts Department of Conservation and Recreation
Planning and Engineering Division
251 Causeway Street
Boston, MA 02114

Prepared by:

Woods Hole Group, Inc.
81 Technology Park Drive
East Falmouth, MA 02536

and

The Louis Berger Group, Inc.
75 Second Avenue, Suite 700
Needham, MA 02494

Submitted by the Louis Berger Group, Inc. to the Massachusetts Department of Conservation and Recreation for Contract DSP 080 P99-1979-D2A.

February 2010

ABSTRACT

Nantasket Beach is located in the Town of Hull, Massachusetts. The southern portion of the beach is part of the Nantasket Beach Reservation, operated by the Department of Conservation and Recreation (DCR). The DCR portion of Nantasket Beach has experienced ongoing erosion. Although the erosion rates have been relatively minor (less than -1.0 feet/year), this erosion, coupled with a lack of a significant sediment supply, has been significant enough that there is little to no high tide beach along a majority of the DCR portion of Nantasket Beach. The alongshore sediment transport rates are also relatively small (between 10,000 - 50,000 cubic yards per year). Evaluation of the coastal processes indicated that the average annual net movement of sand is from south to north, although sand does move in both directions depending on the wave climate. However, the cobble portion of the sediment distribution generally moves only during stronger northern and north-eastern approaching storms, resulting in a net transport from north to south. In the recent past, repairs to the seawall and fortification of the wall were needed in the northern and southern sections of the wall following large storms. Currently, the remaining unprotected mid-section of the wall is also at risk for damage and possible failure.

An alternatives investigation was undertaken to provide shore protection for the DCR property and adjacent Town and private property, and to provide economic and recreational benefits to the surrounding communities. Aside from No-action, alternatives included the following:

- Seawall toe protection (similar to the southern portion of the seawall)
- Revetment (similar to the northern portion of the seawall)
- Beach nourishment (without rocks, with toe protection, or with revetment)
- Construction of new seawall 30 feet back, with revetment, and sand dune
- Removal of seawall, providing protection with beach nourishment alone.

The preferred alternative is Seawall Toe Protection with Beach Nourishment for the following reasons:

- **Seawall is Necessary and Beneficial:** Leaving the seawall in place is the most cost-effective solution for satisfying the need for protection of the Nantasket Beach Reservation and upland resources owned by DCR, the Town of Hull, and private owners.
- **Strengthening of Seawall with Toe Protection:** Toe protection in front of the mid-section of the seawall would strengthen the seawall and provide reliable protection for the seawall during large storms. Rocks should be covered by sand during nourishment. The combined seawall and toe protection also provides a second line of defense after the nourished beach is put in place.
- **Beach Nourishment:** The beach is a valuable resource for the citizens of Hull and other surrounding communities, and is actively used by residents, particularly in the summer. Although toe protection and the seawall alone can provide adequate protection, beach nourishment is required to meet the recreational, economic, and overall storm damage protection goals of the project. Therefore, beach nourishment should be a component of the solution.
- **Sediment Source for Nourishment:** Sand can be supplied from readily available land sources in eastern Massachusetts. However, an offshore sand source would be significantly more cost-effective than a land source. While offshore sources have so far not been permitted in Massachusetts, efforts should be made at the State-level to establish an offshore source for Nantasket, as well as other coastal communities in Massachusetts.

In summary, the recommended alternative provides the most shore protection and recreational benefits and is the most cost-effective. Shore protection efforts are planned to be combined with upland improvements of the Reservation to enhance the recreational and economic value of this asset in the Commonwealth.

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List of Key Abbreviations

Berger	The Louis Berger Group, Inc.
CAC	Citizens Advisory Committee
cm	centimeters
cy, cyds	cubic yards
cy/yr	cubic yards per year
DCR	Massachusetts Department of Conservation and Recreation
DEP	Massachusetts Department of Environmental Protection
ft	feet
ft/yr	feet per year
km	kilometers
LIDAR	LIght Detection And Ranging
l/s-m	liter per second for each meter of beach front
MA	Massachusetts
m	meter
mm	millimeter
MHW	Mean High Water
MLW	Mean Low Water
MTL	Mean Tide Level
NGVD	National Geodetic Vertical Datum of 1929
NOAA	National Oceanographic and Atmospheric Administration
PEP	Prefabricated Erosion Prevention
USACE	United States Army Corps of Engineers
WHG	Woods Hole Group, Inc.

Note

This report represents a joint report for Tasks 3 (Expanded Alternatives Assessment Study) and Task 4 (Beach Nourishment Optional Services) of the Project entitled *"Nantasket Beach Seawall Repair and Master Plan Services"*, contracted to the Louis Berger Group, Inc. (Contract DSP 080 P99-1979-D2A). The Department of Conservation and Recreation issued the Notice-to-Proceed for this contract on February 28, 2006. The Woods Hole Group is a subcontractor to the Louis Berger Group under this contract.

Generally, the Louis Berger Group was responsible for engineering, socioeconomic, permitting, and environmental aspects of this report. The Woods Hole Group was responsible for all aspects related to coastal processes as they relate to shoreline protection. Specific contributions to this report were provided primarily as follows:

Chapter 1: Introduction	Woods Hole Group/Louis Berger Group
Chapter 2: Background Geology and History	Woods Hole Group
Chapter 3: Historical Shoreline Change	Woods Hole Group
Chapter 4: Wave Climatology and Transformation	Woods Hole Group
Chapter 5: Sediment Transport	Woods Hole Group
Chapter 6: Development of Alternatives	
Sections 6.1 to 6.2	Woods Hole Group
Section 6.3	Louis Berger Group
Chapter 7: Coastal Protection Alternative Analysis	
Sections 7.1 to 7.2	Woods Hole Group
Sections 7.3 to 7.5	Louis Berger Group
Chapter 8: Sand Source Investigation	Woods Hole Group
Chapter 9: Summary and Conclusions	Woods Hole Group/Louis Berger Group

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EXECUTIVE SUMMARY

Nantasket Beach is located in the Town of Hull, Massachusetts. The southern portion of the beach is part of the Nantasket Beach Reservation, operated by the Department of Conservation and Recreation (DCR). The beach is a valuable resource for the citizens of Hull and other surrounding communities, and is actively used by residents, particularly in the summer.

Over the years, the DCR portion of Nantasket Beach has been eroding. Beach erosion is relatively slow. However, repairs to the seawall and fortification of the wall were needed in the northern and southern sections of the wall following large storms. Currently, the remaining unprotected mid-section of the wall is also at risk for damage.

As part of the study commissioned by the DCR entitled "Nantasket Beach Seawall Repair and Master Plan Services", this report examines the coastal processes relevant for Nantasket Beach. This information, along with other site specific data and information, was used to develop and analyze eight alternatives for shoreline protection of the Nantasket Beach Reservation.

COASTAL PROCESSES

Wave refraction and diffraction result in an uneven distribution of wave energy along the coast that affects sediment transport in the region. Wave propagation data across the continental shelf and to the shoreline revealed areas of increased erosion or areas of increased energy. The refraction and diffraction mechanisms also result in changes in the offshore wave direction that appear to significantly influence the rate and direction of sand movement along Nantasket Beach for specific wave conditions. On an annual basis, increased wave energy exists along the DCR portion of Nantasket Beach, with an area of increased wave energy located at the northern portion of their section of coastline (the location of the previous seawall failure).

Areas of accretion and erosion develop along entire Nantasket Beach due to the irregular offshore bathymetry and thus, the uneven distribution of wave energy. There are regions along Nantasket Beach where the net sediment transport is to the south, and others where the net sediment transport is to the north. In either case, the rates are relatively small.

Net sediment transport in the DCR portion of Nantasket Beach is from south to north with the average rate of transport of approximately 4,000 to 5,000 cy/yr, and maximums varying between approximately 13,000 and 50,000 cy/yr. However, during certain wave conditions, sand will also move from north to south.

Cobbles in the DCR portion of Nantasket Beach are only transported during the stronger northern and north-eastern approach waves, which have enough energy to mobilize the cobble component of the Nantasket shoreline. The more commonly occurring, but lower energy, eastern and southern waves cannot mobilize the cobble. Therefore, the net transport of cobble is from north to south, while the net transport of sand (which is mobilized for all wave approach directions) is from south to north.

There is a lack of sediment supply for the DCR portion of Nantasket Beach due to the combination of the net northward sediment movement and the limited sediment supplied by regions to the south (due to the Atlantic Hill headland). Therefore, on an average annual basis, the DCR portion of the beach is erosional.

ALTERNATIVES FOR SHORELINE PROTECTION

Alternatives for shoreline protection were assessed with participation and review by the Citizens Advisory Committee (CAC), members of the Town of Hull, and resource agencies. Eight alternatives were developed:

- **Alternative 1: *No Action.*** This alternative would consist of taking no action at Nantasket Beach and making no changes to the existing seawall or fronting beach.

- **Alternative 2: *Seawall Toe Protection.*** This alternative would add stone toe protection in front of the existing seawall in areas where no current toe protection exists (i.e., mid-section of the seawall). Toe protection is similar to a small revetment that would be placed seaward of the existing seawall. This alternative has been implemented along the southern section of the Nantasket Beach seawall.

- **Alternative 3: *Seawall with Revetment.*** This alternative would place a revetment in front of the existing seawall, providing added protection not only for the existing seawall and upland infrastructure, but also providing an improved wave dissipation structure when compared to a vertical concrete seawall.

- **Alternative 4: *Beach Nourishment.*** This alternative would consist of adding a beach nourishment directly seaward of the existing seawall with no modifications or changes to the seawall itself.

- **Alternative 5: *Seawall Toe Protection and Beach Nourishment.*** This alternative is a combination of Alternatives 2 and 4, where toe protection would be placed in front of the mid-section of the seawall and then the beach nourishment would be placed on top of the toe protection, extending seaward by approximately 180 to 200 feet.

- **Alternative 6: *Seawall with Revetment and Beach Nourishment.*** This alternative is a combination of Alternatives 3 and 4, where a revetment would be placed in front of the mid-section of the seawall and then the beach nourishment would be placed in front of the revetment, extending seaward by approximately 180 to 200 feet.

- **Alternative 7: *Retreat and Construct New Seawall, Revetment, and Dune***. This alternative would remove and demolish the existing seawall, retreat approximately 30 feet landward, construct a new seawall, fronting revetment, and place a dune-like feature in front of the new seawall. Existing parking areas and infrastructure (e.g., MJM bathhouse) would need to be demolished or moved as part of this alternative.

- **Alternative 8: *Remove Seawall and Beach Nourishment.*** This alternative would remove and demolish the existing seawall and replace the seawall with a natural dune and fronting beach nourishment. The dune would also utilize ACT ProTecTubes™ as a core of the dune. A significant amount of landward area would be required to create a stable dune system, and this would require removal of nearly all of the current parking areas, roadways, a significant number of public reservation buildings, as well as some business properties and buildings.

RECOMMENDED ALTERNATIVE

The recommended alternative was selected based on five key points:

1. The Nantasket Beach Seawall is Necessary and Beneficial

Although seawalls are not always the most ideal coastal protection method, in heavily developed areas, seawalls are very effective. For example, the value of a sound seawall was demonstrated in Galveston, Texas, during the passage of Hurricane Ike on September 14, 2008. The portions of Galveston located landward of the seawall experienced minimal damage, while areas without seawall protection or other coastal protection measures were significantly damaged and/or destroyed. The Nantasket Beach seawall has been in place since approximately 1915, and has been an effective protection measure throughout the years. The protective values alone provided by the seawall justify its presence in a highly developed and urban setting like Nantasket.

Additionally, leaving the seawall in place is the most cost-effective solution for satisfying the need for protection of the Nantasket Beach Reservation and upland resources owned by DCR, the Town of Hull, and private owners. The existing seawall is structurally sound, but has been compromised by the continued erosion of the beach, which has rendered the initially designed support inadequate. Specifically, the seawall no longer extends far enough into the subsurface to remain stable. Therefore, the existing seawall needs additional support through beach nourishment, toe stabilization, or both (see Point 4 below). Utilizing the current location of the seawall, coupled with a nourishment project, maintains upland area for community Master Plan improvements and layouts. Therefore, it is recommended that the existing seawall be a component of the solution at its current location.

2. Beach Nourishment is a Key Component

Nantasket Beach is a valuable, convenient recreational resource in the area and is one of the few large urban beaches in the Boston area. Nantasket Beach is very accessible, in part due to its available parking facilities. The popularity of the beach may increase with potential accessibility options such as better public bus connections, potential ferry connection, etc. Due to its open-ocean setting with an absence of rivers and major stormwater outfalls entering the beach, the beach has consistently good water quality even immediately after large storm events. However, currently because of the limited beach berm, beach visitors need to leave the beach during high tide. Therefore, beach nourishment is an important component for shoreline protection. Beach nourishment will significantly improve its recreational value, increase the storm damage protection, and provide increased economic return. Ultimately, Nantasket Beach should remain a viable recreational beach, which means that a useable, sandy beach environment needs to be

provided to service a variety of beachgoers (e.g., surfers, sunbathers, families, swimmers, etc.) It is recommended that the preferred alternative should include a beach nourishment component.

3. Sediment Source for Nourishment

All feasible and preferred alternatives include beach nourishment. Therefore, important consideration needs to be given to potential sediment sources. Basically, sediment can be obtained from either an offshore borrow source, dredging of a navigational channel, and/or an upland source. A subaqueous borrow source is typically the most cost-effective option and provides a good source of beach compatible material once a suitable site is identified. However, recent experience has shown that obtaining permits to mine offshore material is a lengthy, costly process and may ultimately be unsuccessful. For example, DCR has recently tried to obtain permits to mine an offshore borrow site for nourishing Winthrop Beach, MA. The permitting process has taken over 10 years and has currently been unsuccessful. Considering that the offshore sand source was recently denied for the nourishment of Winthrop Beach, an upland-based source may be a feasible option for Nantasket Beach, at least for the foreseeable future. An offshore borrow site for Nantasket could be a difficult pursuit, at minimum resulting in a significant time commitment and delaying possible nourishment of Nantasket beach for at least 5 years.

Although significantly more expensive, based on the results of the technical assessment and modeling performed, an upland-based sediment source does appear technically feasible for nourishing Nantasket Beach. However, there are some limitations using a multi-year nourishment approach as well. If multi-year upland nourishment is selected, Nantasket Beach and the current seawall would be vulnerable to potential damage from a single storm event for a number of years. Until enough sediment (approximately 30%) is supplied to the beach, Nantasket and the seawall would remain vulnerable over these initial seasons (approximately 5 to 6 years for a reasonable upland sourced construction rate).

Therefore, it appears any sand source will leave the seawall and Nantasket exposed for the next few years. The offshore source will likely take years to permit and get approval, while upland sources will take numerous years to construct, while being exposed to storm events. Without some sort of seawall fortification, the seawall will remain at risk for the next 5 to 6 years if sand nourishment alone is the solution. Therefore, it is recommended that beach nourishment be coupled with some seawall fortification measure, with the intent that the fortification method provides insurance against storm events and does not take the place of beach nourishment. This is discussed further in Point 4 below.

4. Strengthen Seawall with Toe Protection and Start Nourishment from Upland Source(s)

At present the seawall is at risk of failure in the mid-section during a large storm. The USACE (2006) determined that the elevations in front of the seawall shall not be less than the following in order to provide adequate support:

- No-storm condition: 7 feet
- 100-year storm conditions: 9 feet

At times, elevations in front of the unprotected mid-section of the wall have decreased to an elevation below 7 feet, such as during the October 18, 2006 survey. In addition, undercutting by waves during the December 1992 storm resulted in the collapse of a section of the seawall. This stretch of the beach was closed off for many years until the wall was recently repaired.

Nourishing the beach with sand from an ocean-source can be done rapidly over one season, thus limiting the exposure of the seawall to the risk of collapse during a severe storm. However, as discussed, the potential availability of an ocean-based sand source may take numerous years to permit, leaving the seawall and the Nantasket Beach Reservation vulnerable during this time. Additionally, nourishing the beach from upland sources, although feasible, would also leave the seawall and Nantasket vulnerable for a number of years. For example, based on an assessment of feasible scenarios, nourishing the beach with 700,000 cy of sand will require approximately nine to ten years (at 75,000 cy/year) and the added sand will not provide adequate protection for the seawall for the first 5 years, until sufficient sand has been added to the beach.

It is recommended that seawall fortification (specifically toe protection) be included in the preferred solution. Once adequate volumes of sand are placed on the beach, rocks would be covered by sand. Thus, the beach would be similar in appearance as nourishment without added toe protection in the mid-section of the seawall. Additionally, the toe protection would provide a second line of defense during major storms.

The added protection of is also recommended given the changes in global climate over the last decades. Specifically, while official NOAA rates for annual sea level increases have been incorporated in our analyses, other predictions indicate that even greater increases may be possible over the next century.

5. Pursue an Offshore Sediment Source for Long-term Nourishment

A commitment by DCR to nourish the beach implies that the beach will require renourishment in the future, as the sand will erode over time. Using upland sources for sand is significantly more expensive than using ocean sources. Therefore, we consider it important, and fiscally wise, to pursue an appropriate sand borrow site for beach nourishment. An approved offshore borrow site would also allow for cost-effective and rapid future nourishments for Nantasket Beach.

Affected communities and organizations such as the CAC can assist in furthering the goal of having an appropriate offshore site authorized. It is likely that using offshore sand sources will have lower overall environmental impacts and a lower carbon-footprint than using land sources, considering issues such as air quality, noise, traffic, etc.

Further, identifying and permitting an appropriate offshore borrow site will not just be important for Nantasket Beach but also for other beaches and its surrounding communities in the Commonwealth.

Conclusion

The technical team recommends Alternative 5 for the preferred Alternative at Nantasket Beach. Alternative 5 (toe protection and nourishment) should be coupled with short-term nourishment from an upland source and long-term offshore nourishment. This solution provides immediate protection for the seawall and upland infrastructure, as well as a second line of defense when needed. An offshore sand source should be pursued vigorously as it will also be needed by other coastal communities in the Commonwealth in the future.

Shore protection with beach nourishment, coupled with planned improvements of the upland portion of the Nantasket Beach Reservation, will considerably enhance the value of this important recreational asset in the Commonwealth. Despite its urban setting, the beach has excellent water quality, and should continue to be enjoyed by the greater community, as it has been over its long and storied past.

1.0 INTRODUCTION

Nantasket Beach is located in the Town of Hull, Plymouth County, Massachusetts (Figure 1-1). It lies approximately 4 miles southeast of the main entrance to Boston Harbor and approximately 12 miles east-southeast of Boston on the southeast shoreline of Massachusetts. Nantasket Beach is a crescent beach approximately 3-1/2-miles long which extends from two natural headlands, Allerton Hill to the northwest and Atlantic Hill to the southeast. The beach is oriented in a northwest-to-southeast direction and is exposed to the open waters of Massachusetts Bay and the Atlantic Ocean. The northerly portion of Nantasket Beach is primarily residential with private home and cottages paralleling the shoreline. Coastal dunes and other shoreline protection measures (stone revetments and jersey barriers) are intermittent along the northern portion of Nantasket Beach. The southern portion of the beach (Figure 1-2) comprises the Massachusetts Department of Conservation and Recreation (DCR) Nantasket Beach Reservation, which spans 1.3 miles of coastline and encompasses 26 acres and is a heavily used public beach. Along this portion of the beach where there is public access, a roadway runs parallel to the beach, and there are parking lots, a bath house, and other recreational facilities to support beachgoers in the area. A reinforced concrete seawall (approximately 4,500 feet in length) backs the beach in this area, which helps to retain and protect the upland facilities and infrastructure.

Nantasket Beach is a valuable resource from both a commercial and recreational standpoint. The beach and the associated waterfront amenities serve as the defining feature for the Town of Hull and represent a significant draw for visitors and summer residents. Through time, Nantasket Beach has become one of the region's most valued recreational and natural resources, and is currently one of the busiest beaches in Greater Boston. The beach, the walking areas directly behind the seawall and adjacent commercial establishments offer numerous recreational activities and direct access to beach services (restaurants, hotels, bath houses, etc.). However, the beach, specifically the southern portion, has been eroding for over 150 years (Chapter 3). Although the rate of erosion has been relatively slow, the beach width has been significantly reduced compared to historical widths, to the point where there is no useable beach during high tides in the mid- and southern parts of the Reservation (Figure 1-3). In addition, the loss of sediment fronting the seawall that spans the DCR portion of Nantasket Beach has resulted in a destabilization of the structure. The seawall, originally constructed in the early 1900's, was designed to be supported by material on the seaward side of the structure. Now that a significant portion of this material has eroded, the structural stability of the seawall has been compromised. Recent storms have resulted in continued loss of the beach, and in certain cases (e.g., December 1992 storm), failure of seawall sections. Currently, the beach continues to narrow and the seawall remains at risk. Consequently, the Massachusetts Department of Conservation and Recreation (DCR) is concerned about the viability of the beach for recreational use and the ability of the seawall to continue to provide upland protection. As such, DCR sought to identify the most cost-effective, long-term course of action to remedy this urgent situation.

Figure 1-1. Nantasket Beach in Hull, Massachusetts. The DCR Reservation is located between the arrows.

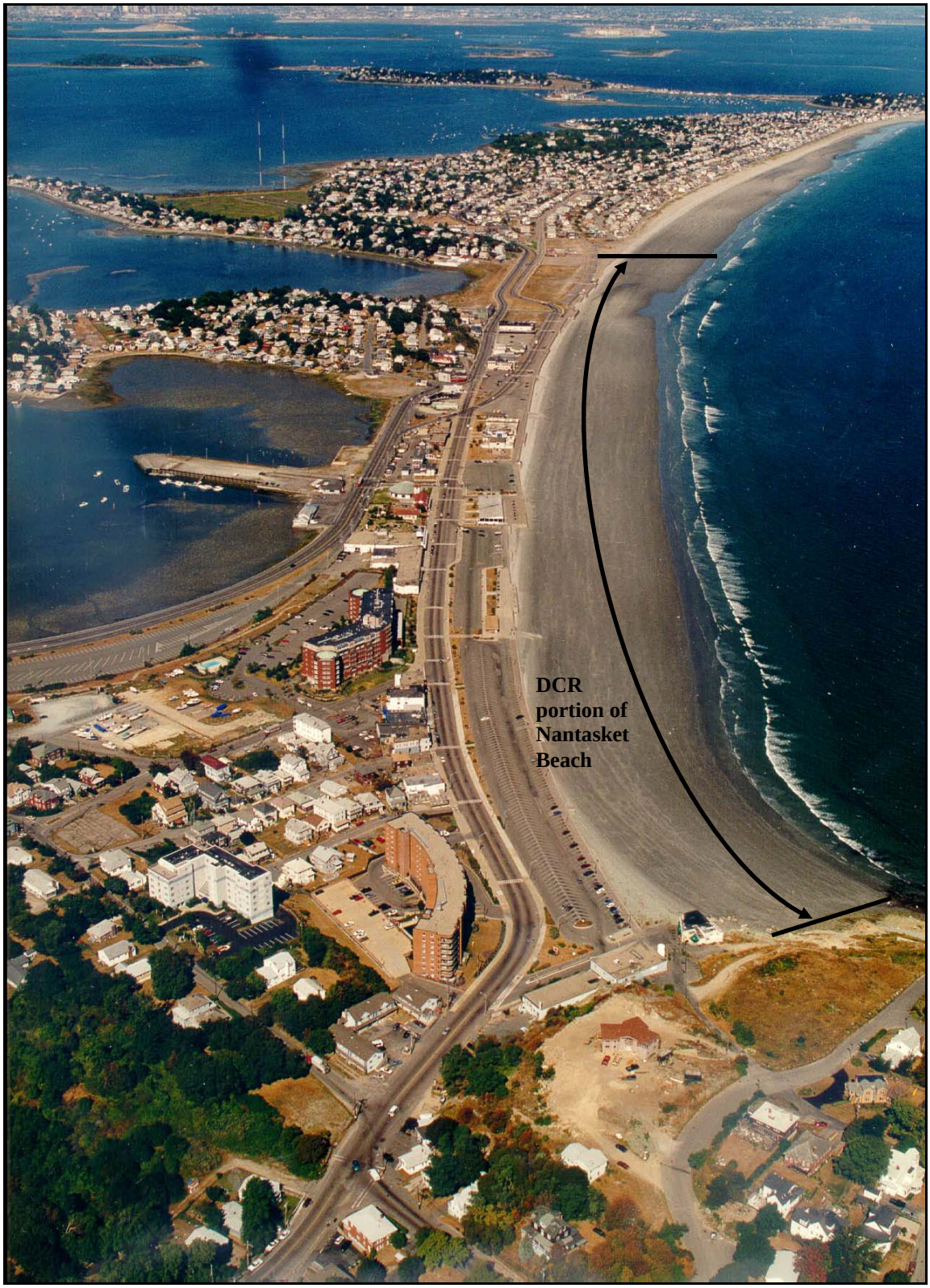

Figure 1-2. Aerial view of the southern, DCR portion of Nantasket Beach at low tide.

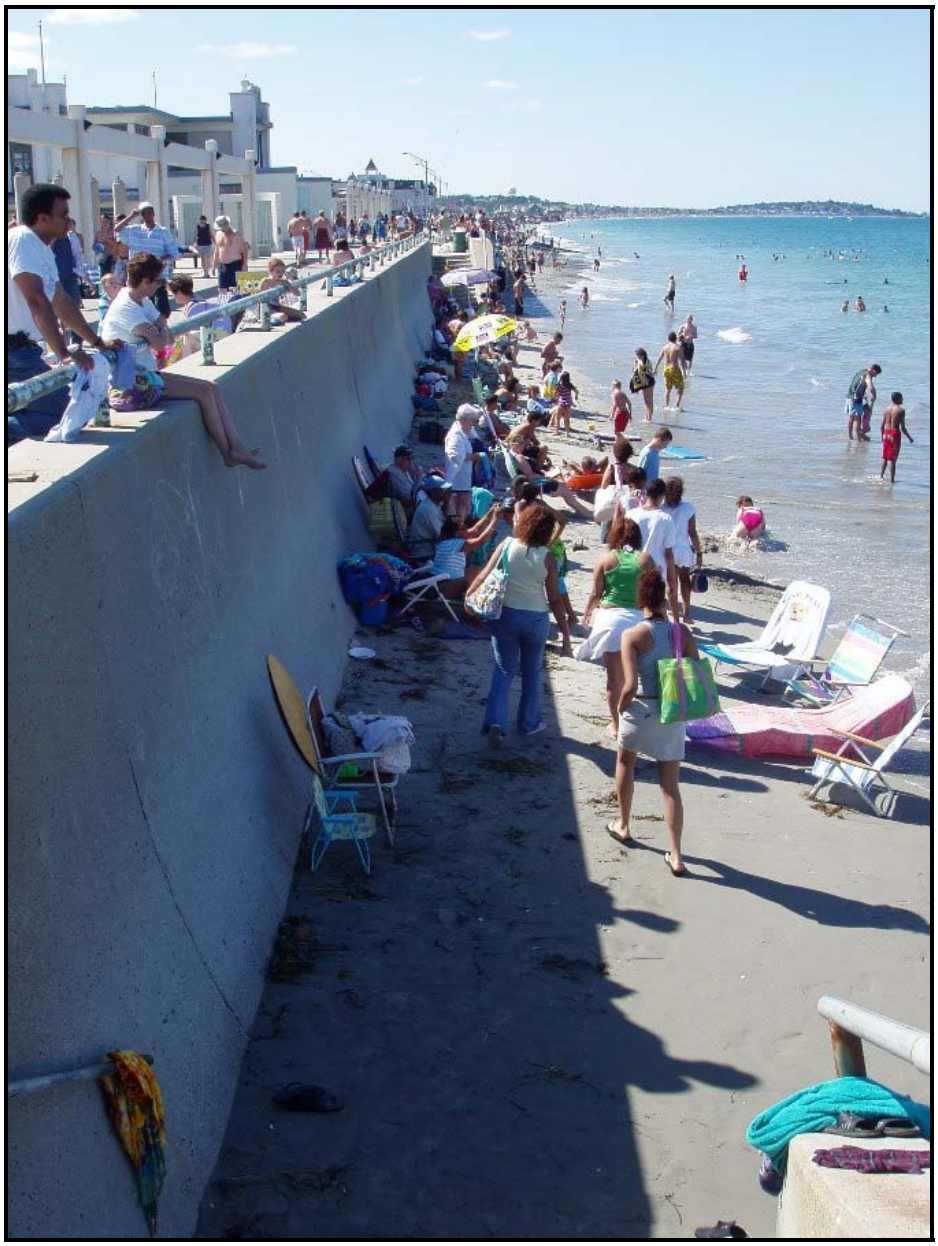

Figure 1-3. The condition of Nantasket Beach during a typical high tide.

The present study was undertaken at the request of the DCR. This coastal processes and engineering feasibility evaluation was conducted by Woods Hole Group, located in Falmouth, Massachusetts. Woods Hole Group was a subconsultant to the Louis Berger Group, Inc. based from their Needham, Massachusetts office. The overall study was focused on assessing the coastal processes that act on Nantasket Beach, identifying and evaluating the feasibility of alternative solutions, determining the potential impacts on Nantasket Beach and the surrounding environment, and making recommendations as to the preferred solution.

The proposed project consists of three primary elements, although other tasks were completed as part of the overall evaluation. These primary elements include:

1. A coastal processes and engineering feasibility study, including evaluation of existing conditions and identification and evaluation of potential alternatives for Nantasket Beach.

2. A Reservation Master Plan that evaluates the regional area and develops a master plan for the Nantasket Beach infrastructure that meets the community and regional goals.

3. A draft and final Environmental Impact Report (EIR) for the expanded alternatives assessment of both the coastal alternatives and the master plan redevelopment alternatives. The EIR will identify potential adverse impacts and any necessary mitigation, and ultimately support the selection of a recommended course of action.

The purpose of the coastal processes and engineering feasibility evaluation presented herein was to evaluate the existing coastal processes that currently act on Nantasket Beach, as well as assess potential alternatives that may be viable solutions to stabilize the seawall and improve recreational ability at Nantasket Beach. The study focuses on evaluating the physical processes (concentrating on the wave and current environment) occurring within the vicinity of Nantasket Beach in order to assess potential alternatives that may be used to create a long-term solution along the shoreline. The feasibility evaluation consisted of some limited field data collection, numerical modeling of coastal processes, an alternative evaluation, and a preliminary sand source investigation. The study ultimately evaluates the performance of each of the alternatives and the ability to provide a sustainable beach. Numerical modeling results are used to complete a detailed alternatives analysis. All elements of the project are geared towards arriving at a technically feasible, cost-effective, and long-term solution at Nantasket Beach.

The report follows a logical step-by-step process that presents the components of the coastal processes study, as well as the alternatives considered and evaluated in the feasibility evaluation. The report is organized and divided into the following main chapters.

- Chapter 2 briefly describes the history of Nantasket Beach, including the geology of the region and the previous coastal engineering that has been conducted along the coastline. In essence, Chapter 2 sets the backdrop for the study.

- Chapter 3 presents the historical shoreline change analyses that have previously been completed of the Nantasket Beach littoral system. The shoreline change analysis was used to estimate magnitude and direction of sediment transport, monitor the historic impact of engineering modifications to the region, examine geomorphic variations in the coastal zone, and verify the numerical nearshore and sediment transport models.

- Chapter 4 presents the results of the wave transformation modeling effort. Wave modeling is detailed and utilized to propagate the waves towards Nantasket Beach. Chapter 4 presents the development, verification, and results of the transformation scale modeling effort.

- Chapter 5 presents the results of the sediment transport modeling, including sediment movement during both average annual conditions and larger storm events.

- Chapter 6 details the development of the alternatives to be evaluated, summarizes the alternatives considered in the alternatives analysis, and presents the methodology for assessment of the various alternatives. Chapter 6 also eliminates alternatives that are not technically feasible or have a significant environmental impact.

- Chapter 7 presents the final results of the alternative analysis. The ultimate goal of the overall project is to create a beach system that provides storm damage protection and recreational use. Therefore, an assessment of the performance of each of the final alternatives is presented. This section addresses also socio-economic benefits, permitting, and costs.

- Chapter 8 presents a preliminary investigation of potential sand sources for nourishing Nantasket Beach. The chapter includes identification of the source sites, with specific emphasis on the feasibility and performance of potential land based sources.

- Finally, Chapter 9 presents the conclusions of the study and a final summary.

2.0 BACKGROUND GEOLOGY AND HISTORY

The present configuration of Nantasket Beach can be attributed to a series of shoreline processes and several former drumlin (elongate-shaped glacial hill) islands. In geological terms, Nantasket Beach is known as a complex tombolo, which is a coastal feature that forms when several islands and the mainland are interconnected by a complex series of land bridges. In this case, Nantasket Beach unites several former drumlin islands and the mainland (Johnson and Reed, 1910). The existing spit of land consists of several drumlins, including Hampton Hill, Sagamore Hill, White Head, Strawberry Hill, Allerton Hill, and Telegraph Hill as shown in Figure 2-1. In addition to glaciation and coastal processes, human interaction and development has had a significant influence on the existing formation and topography of the area.

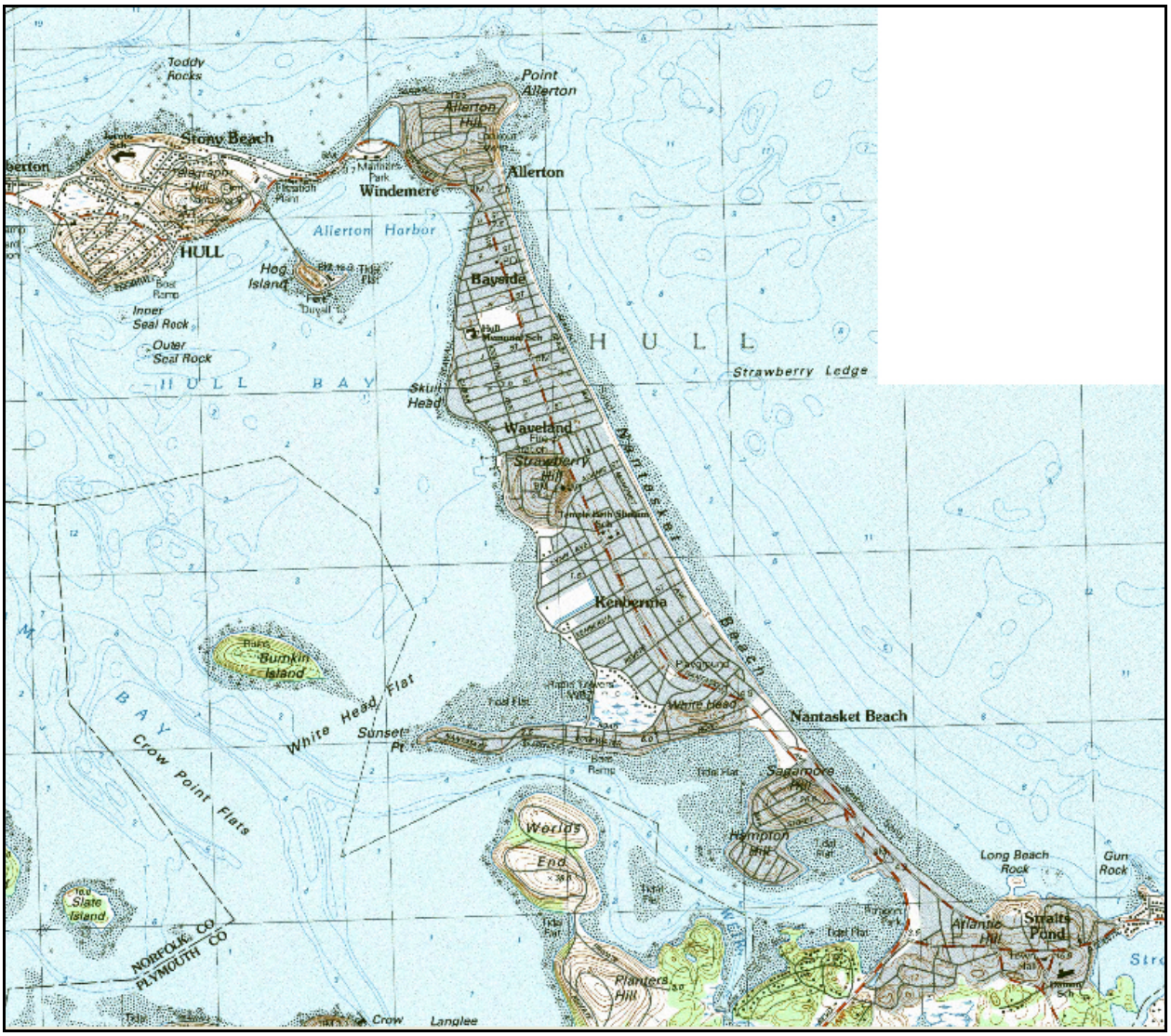

Figure 2-1. USGS topographic map of Nantasket Beach (Mass GIS).

2.1 GEOLOGY OF NANTASKET BEACH

Significant information relating to the geology and history of Nantasket Beach is available within many previous reports and studies of the project area. In particular, the USACE Coastal Engineering and Processes Study (USACE, 2003) summarizes much of the work and historical knowledge to date, and was used as the primarily resource for understanding the history of the region.

The New England region is largely composed of moderate to thick surficial deposits of glacial origin overlying bedrock. New England has been glaciated several times and the coast experienced as many as four major periods of glaciation, ranging from Nebraskan to Wisconsinan in age (FitzGerald et al., 1994). The best geological record exists for the deposits left behind by the most recent glaciation, called the Wisconsinan Stage, which ended about 8,000 years ago. Retreat of the glaciers in southeastern New England began around 18,000 to 14,000 years ago.

Most of the surficial sediments in the Nantasket area are composed of glacial deposits of ice-contact till and stratified drift (sand and gravel outwash, with minor silt, clay, and till), swamp deposits, and beach deposits. As previously discussed, Allerton Hill, Strawberry Hill, Sagamore Hill, and Hampton Hill are all examples of drumlins, which are composed of variable materials, sometimes mantled over bedrock, or composed wholly of either rock or glacial drift deposits. Glacial till is the poorly-sorted, non-homogeneous material deposited at the base of the glacier (lodgment till), or alternatively, deposited as material within the ice sheet which melted out as it was let down on the existing landscape (ablation till). The term “stratified drift” encompasses the generally well-sorted sand and gravel deposited by glacial melt water either on an outwash plain in front of an ice sheet, or in glacio-fluvial environments under, within, on top of, or adjacent to an ice sheet.

The work of Johnson and Reed conducted in 1910 preserved much of the historical geologic record of Nantasket Beach as they were able to map abandoned marine cliffs and beach ridges prior to further development of the area. Based on an examination of the ancient beach ridges at Nantasket Beach, the size and alignment of the marine cliffs cut into the drumlins, and offshore profiles, Johnson and Reed (1910) concluded that five drumlins were once located east of Nantasket Beach (north of Atlantic Hill). Through erosional forces exerted by tidal fluctuations and wave action together with a slowly varying sea level these drumlins eroded and the sediments were transported and deposited among the other drumlin islands to form the complex tombolo system that makes up Nantasket Beach today. As such, the Nantasket barrier form evolved around a series of drumlins that served as anchor points. Johnson and Reed (1910) also suggested that historically, Nantasket Beach has been largely an accretionary feature.

To further the discussion on the derivation of Nantasket Beach, FitzGerald et al. (1994) presented their observation that the amount of sand that would have been available from the drumlins is insufficient to account for the volume of the spit of land which makes up Nantasket Beach. They also noted that the sediment of the drumlins is also quite different from the fine, well-sorted sand that comprises much of the material at Nantasket Beach. In addition, Nantasket Beach is adjacent to a major offshore sand deposit (FitzGerald et al., 1990). This led to their suggestion that the sediments of Nantasket Beach were derived from several intercepted

drumlins and other glacial deposits located offshore that were then reworked onshore late during the Holocene transgression. The existence of Nantasket Beach can then be attributed to the erosion and redistribution of sediment from the existing drumlins as well as the drumlin remnants offshore.

2.2 HISTORY OF NANTASKET BEACH

Nantasket Beach has also been significantly influenced by anthropogenic activities throughout the years. Anthropogenic impacts and infrastructure development have been significant contributors to the current configuration of Nantasket Beach. The first public house was constructed in 1826 and subsequently, numerous recreational structures were constructed during the 1800s. These structures were typically wood buildings constructed on wood pilings combined with wood bulkheads to restrict tidal flow under the structures (USACE, 1949). In 1880, a railroad was constructed which ran along the barrier spit and prior to 1900, riprap (3-4 cubic foot stone) was added along the seaward edge of the railroad to provide protection from coastal storms. This riprap is still in place north of and within the DCR Reservation, most of which has been buried by the fill placed behind the existing seawall (USACE, 1949).

During the 1900s, concrete seawalls were constructed to protect portions of the Nantasket Beach shoreline within the DCR Reservation. One of the first concrete seawalls on record was constructed in 1916 in front of the bath-house facility (approximate 1,425-foot long section between profiles 9 and 10 in Figure 2-2). Ten to twelve years later another portion of the seawall was constructed in front of the Rockland Café and Nantasket Pavilion, which existed at the time between profiles 8 and 9 in Figure 2-2. Additionally, a concrete bulkhead was constructed in 1920 (between profiles 7 and 8 in Figure 2-2) to protect the Nantasket Hotel. Another portion of seawall was constructed in 1915 to protect the Tivoli Pavilion (between profiles 6 and 7 in Figure 2-2). Additional concrete seawalls were built to protect the northerly and southerly parking areas. The seawall fronting the southern parking area (between profiles 4 and 6 in Figure 2-2) began construction in 1915, with a portion being completed in 1927. The seawall fronting the northern parking area (north of profile 10 in Figure 2-2) was constructed in sections from 1926 to 1938 to a total length of approximately 2,500 feet. The seawalls built during this time were unreinforced concrete gravity-type walls with an effective top elevation ranging from 18.2 to 19.6 feet relative to mean low water (USACE, 1949). Access stairs to the beach were intermittent along the seawall. According to the USACE Beach Erosion Control Report (1949), the seawalls protecting the buildings withstood storm attacks but overtopping did occur on occasion, causing damage to the buildings. The 1949 report also stated that the wall in front of the southern parking area was in good condition with the occurrence of minor spalling, while the wall fronting the northern area suffered damage north of profile 13 (Figure 2-2). The damage along this northerly portion of the seawall required two sections to be demolished and rebuilt (with reinforced concrete), one in 1941 and another in 1944 (USACE, 1949). The seawalls built during this time period existed in essentially the same locations as they do today.

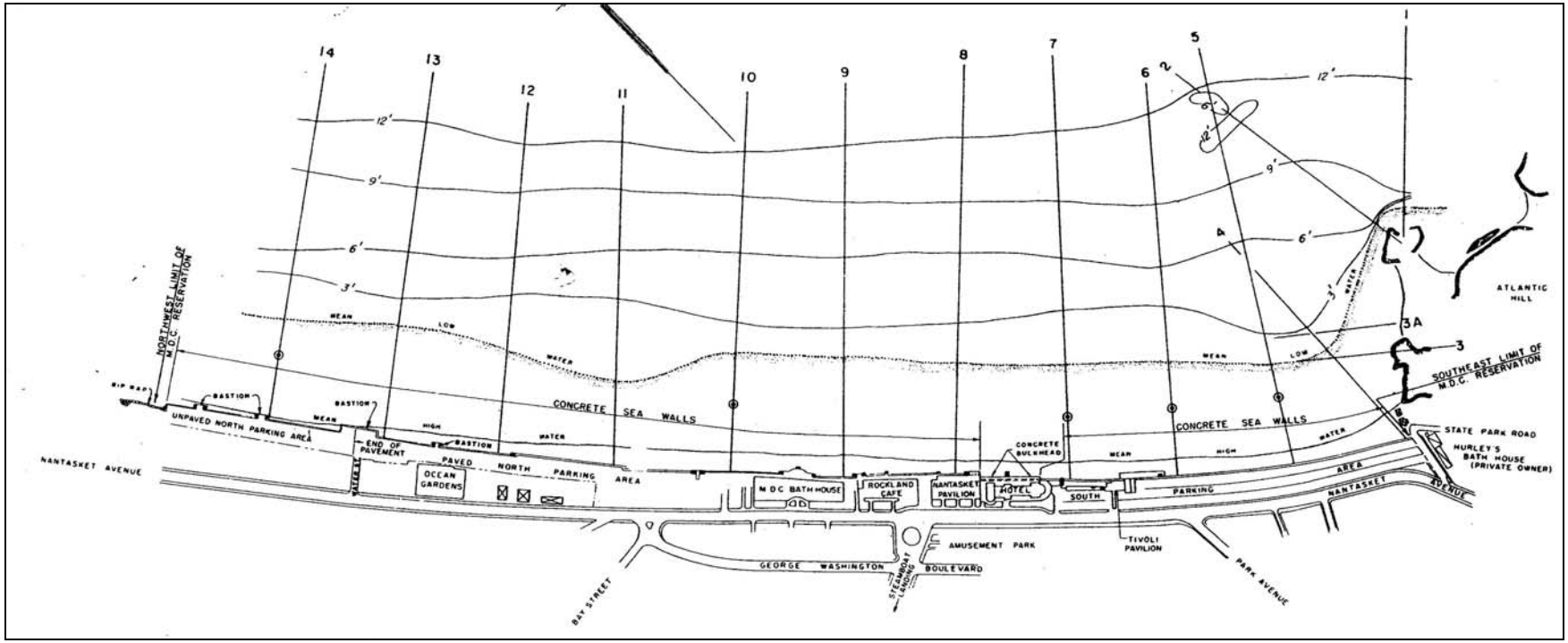

Figure 2-2. DCR 1949 plan of existing structures at Nantasket Beach (USACE, 1949).

Further development and construction of shoreline protection occurred in the latter half of the 1900s. A first aid and comfort station was constructed in 1959 just south of Phipps Street at the northern end of the DCR Reservation (area 1 shown in Figure 2-3). Additionally, a riprap revetment was constructed in 1949 to an elevation of 18.2 feet relative to mean low water (area 2 shown in Figure 2-3). In 1965, a concrete cap was constructed on the northernmost 125 feet of seawall within area 3 shown in Figure 2-3. Portions of the seawall (within areas 5 and 7 shown in Figure 2-3) were reconstructed in the late 1950s and early 1960s (USACE, 1968). The 1968 Beach Erosion Control Report (USACE, 1968) stated that overall the shoreline protection structures were in good condition except for a portion of the seawall within area 3 (Figure 2-3).

During the 1970s to 1990s, the shore protection measures including the seawalls, riprap revetments, access ramps, stairs, and walkways all experienced a gradual deterioration due to storm events and associated natural forces (USACE, 1993). In addition, the beach elevation in front of the seawall lowered due to increased erosion, the natural depletion of sand sources, and the removal of sediments/cobble due to beach manicuring/maintenance procedures (USACE, 1968; Hayes et al, 1973; and USACE, 1993). This reduction in beach elevation reduced its effectiveness in offering protection and increased the potential for the seawall to be undermined. During the nor'easter "Halloween Storm" of October 30-31, 1991 and a subsequent nor'easter which occurred on December 11-12, 1992, the seawall within the DCR Reservation suffered significant damage resulting in the failure and weakening of a 650-foot section of the wall (USACE, 2002). This produced increased wave overtopping and flooding of backshore areas.

Numerous reports and studies of Nantasket Beach have been conducted over the past 50-60 years. Cooperative beach erosion control studies were conducted by the DCR and the USACE (USACE, 1949; USACE, 1968). A study of erosion processes at the DCR beaches was conducted by Hayes, which presents the causes for erosion and proposes recommendations for remediation (Hayes et al, 1973). In addition, a report was prepared in 1980 for the Disaster Recovery Team, Commonwealth of Massachusetts by the Camp Dresser and McKee, Inc. entitled "Evaluation of Coastal Protection Measures at Nantasket in Hull, MA, Volumes 1 and 2". This report details the damage which occurred during the February 1978 storm.

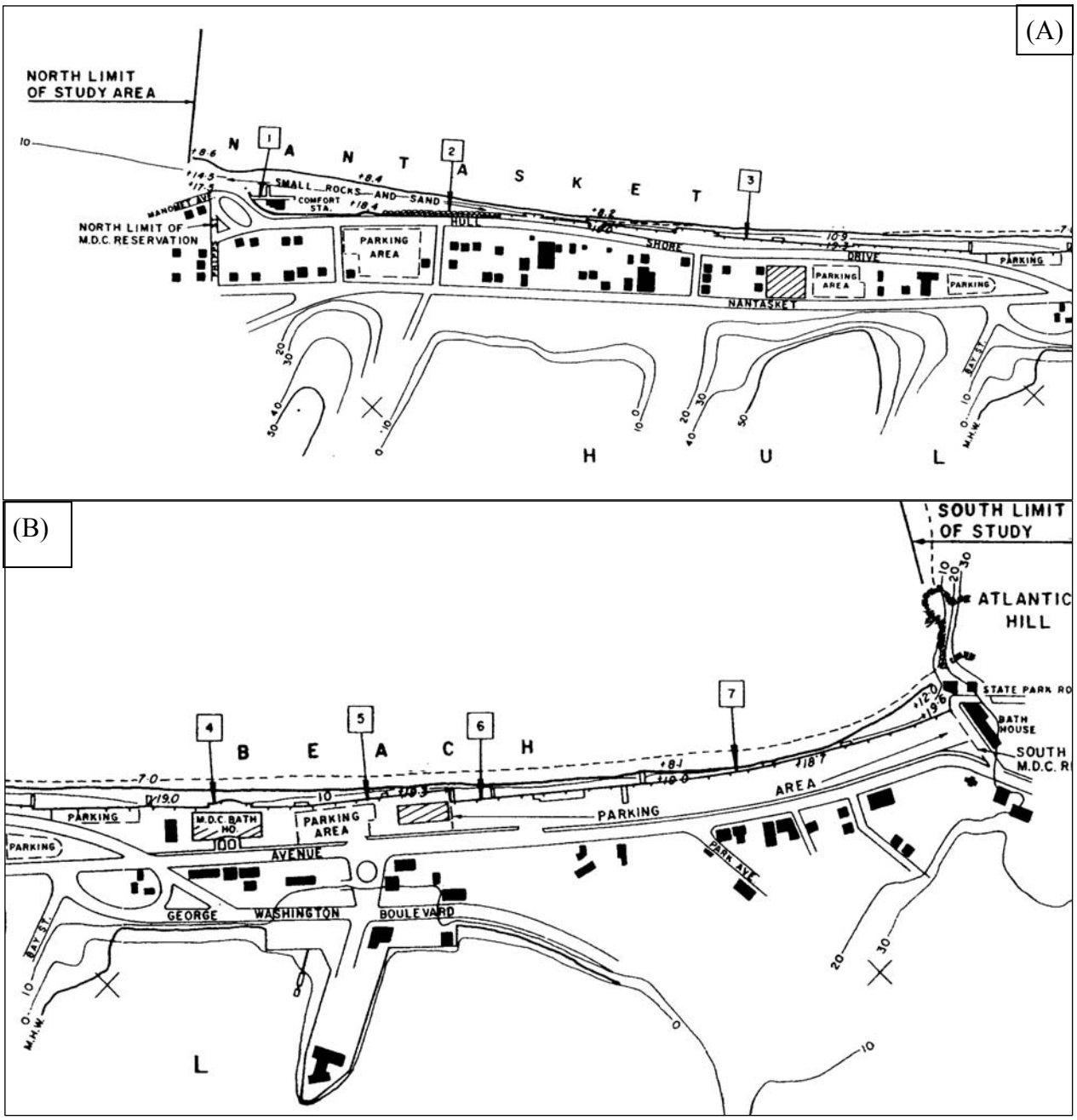

Figure 2-3. MDC 1968 plan of existing structures at Nantasket Beach (USACE, 1968). Panel (A) is the northern portion of the DCR Reservation and Panel (B) is the southern portion of the Reservation.

The nor'easter storms and subsequent failure of the wall in the early 1990s prompted the DCR to re-engage the USACE for an evaluation of the existing shore protection measures at Nantasket Beach. The Section 103 Shore Protection and Erosion Control Reconnaissance Report (USACE, 1993) details the damage that occurred to the seawall, screens potential alternative solutions, and proposes a protection plan consisting of beach fill for further study. The USACE conducted a survey of the DCR seawall in 2000 to provide details on the structural condition of the seawall, stairs, ramps and sidewalk, as well as provide potential cost estimates for repairs (USACE, 2000). Subsequent to the condition survey, the USACE submitted a 50% Progress Submission Report to the DCR in February of 2001 for replacing and repairing designated portions of the 5,500 linear foot concrete seawall (USACE, 2001). A draft feasibility and environmental assessment was then issued by the USACE in August of 2002 as part of the Section 103 Coastal Storm Damage Reduction Project for Nantasket Beach, MDC Reservation (USACE, 2002). This feasibility study recommended a 50-foot sand fill nourishment project with periodic renourishment coupled with a complete reconstruction of the portion of seawall damaged in the December 1992 storm. This feasibility study (USACE, 2002) also examined other alternative solutions including: 1) an offshore breakwater, 2) a revetment, and 3) elevating the structures. In 2003, the USACE completed an Alternatives/Analysis Study (USACE, 2003), which examined a wide range of alternatives and analyzed the shore protection system for Nantasket Beach as a whole. This 2003 study updated the recommendations made in the 2002 Feasibility Study (USACE, 2002) and the Seawall Repair Study (USACE, 2000).

In December of 2003, subsequent to the USACE 2003 Alternatives/Analysis Study, two coastal storms (December 6th and 7th) inflicted damage and undermined sections of the concrete seawall. A USACE analysis recommended emergency repairs as a 2000 linear foot section of the structure was deemed unstable (Winkelman and Jones, 2005; USACE, 2004a). In August of 2004, a stone revetment was constructed along this portion of the seawall (approximately 2,000 feet in a southerly direction from the Mary Jeanette-Murray Bathhouse) as a temporary, emergency mitigation measure.

In recent years, work has continued by DCR and the USACE in support of the Section 103 Coastal Damage Reduction Project for Nantasket Beach. Two additional studies, a Sand Fill Transportation Study (USACE, 2004b) and a Nantasket Beach (Sediment) Characterization Study (USACE, 2006) were completed most recently. In addition, a first phase of bolstering the coastal protection was implemented, where approximately 930 feet of the northernmost portion of the seawall was replaced and protected with a stone revetment. This included the portion of the seawall that collapsed during the 1992 storms. Most recently, other major repairs have also been made to the access stairs and ramps where needed.

3.0 HISTORICAL SHORELINE CHANGE

In a physical system like that of Nantasket Beach, the geological and historical perspective is an important piece of understanding the past history of the region, determining the effects of the physical processes that have acted on the coastline throughout the years, and providing insight into the future. Regional geomorphic change is the evolution of depositional environments and topographic features over extended periods of time. Aerial photographs, topographic surveys, and hydrographic surveys of coastal and nearshore morphology provide data for quantifying regional geomorphology and change. Coastal shoreline change and digital bathymetric data for the same region, but different time periods, produce a method for determining the physical changes of a region and providing valuable information on potential sediment movement within a region. Existing shoreline change information for Nantasket Beach was used to provide a historical perspective and examine geomorphic variations in the coastal zone. In addition, this shoreline change information was used in ground-truthing the numerical sediment transport model.

Shoreline change analysis, which is a computer-based shoreline mapping methodology used to compile and analyze changes in historical shoreline position, can be determined by accurately quantifying the distance between historical shoreline positions from different time periods after they are placed on the same scale and geographic reference. A new shoreline change analysis was not completed as part of this study. Rather, previous shoreline changing mapping efforts were used and are briefly summarized in this chapter.

3.1 MCZM HISTORICAL SHORELINE CHANGE

Figure 3-1 presents the rates of historic shoreline change between 1847 and 1994 throughout the Nantasket Beach region as determined by Thieler et al. (2001) completed for Massachusetts Coastal Zone Management. The black line shows the rate of shoreline change for the entire time frame (1847 to 1994) where a negative rate of shoreline change represents erosion in terms of ft/yr, while a positive rate of shoreline change represents accretion in terms of ft/yr. Although a significant portion of the Nantasket shoreline has been relatively stable with small rates of erosion or accretion within the relative error of the analysis methodology itself, there are some distinctive areas of erosion and accretion along the shoreline. The area along the DCR portion of Nantasket Beach is clearly erosional as historical rates of erosion range between approximately 0.5 feet to 1.0 feet per year (ft/yr). The area directly north of the DCR portion of the Beach, between Sagamore Hill and Malta Street, is relatively stable with minor changes. The most significant area of accretion occurs between Malta Street and Prospect Avenue, with an accretion rate of up to approximately 0.5 ft/yr). Farther north, from Prospect Avenue to P Street, the beach is again stable, or possibly slightly erosional. Finally, the northern portion of Nantasket Beach, just south of Allerton Hill is primarily accretional. Most of the long-term historic rates are relatively small (less than 1.0 ft/yr), and in general indicate that the shoreline has been relatively stable, and in some cases (for rates less than ± 0.5 ft/yr) are likely within the error bounds of the analysis.

Figure 3-1. Rates of historic shoreline change between 1847 and 1994 as determined by Massachusetts Coastal Zone Management (2001).

3.2 SOUTH SHORE HAZARDS ATLAS

In addition to the long-term historical shoreline change, a more recent study of shoreline change for Nantasket Beach was conducted in 2005 as part of the Massachusetts Office of Coastal Zone Management South Shore Coastal Hazard Atlas. This study examined rates of shoreline change over a more contemporary time frame between the years of 1938 and 2001. Figure 3-2 presents the rates of shoreline change as determined in this study (Ramsey et al., 2005). The results are presented as small bars along the shoreline, with cooler colors (blues and greens) indicating shoreline accretion (+ ft/yr) and hotter colors (yellows and reds) indicating shoreline erosion (- ft/yr). Black bars represent areas that fall within ±0.5 ft/yr and therefore do not indicate either strong erosion or accretion. The majority of Nantasket Beach is relatively stable, as depicted by these black bars (small rate of change of ± 0.5 ft/year, within the statistical uncertainty of the analysis). There are distinct areas of erosion and accretion, however, as indicated by the yellow and green bars in Figure 3-2 that correspond to the areas of erosion and accretion shown in the longer term shoreline change analysis (Figure 3-1). The southern portion of Nantasket Beach, which comprises the DCR reservation, is erosional, with rates on the order of -1 ft/yr. A small area of accretion exists in the Malta to Prospect Street region, and a larger area exists in the northern portion of Nantasket Beach from H Street to U Street where the rate of change is accreting approximately +1 to +2 ft/yr. These accretionary areas also correspond reasonably well with the longer-term historical shoreline change trends presented in Figure 3-1.

Previous reports and the geologic history have all indicated the shoreline at Nantasket Beach has been relatively stable over the past 300 years (USACE, 1949; Hayes et al, 1973; and Brenninkmeyer, 1976). It has been suggested that this may be partially attributed to the presence of the remnant drumlins offshore. Therefore, a majority of the Nantasket shoreline indicates a general stability over time; however, the previous studies also indicate that the DCR portion of the shoreline has been erosional, both pre and post seawall construction, while the northern section of the Nantasket shoreline has shown the most consistent accretion. This long-term, relatively low, erosion rate has led to a loss of material in the DCR portion of Nantasket Beach. The shoreline has retreated to the point where there is no longer a beach during high tide at the DCR reservation and the seawall that protects the upland infrastructure is also at an increased level of risk for failure.

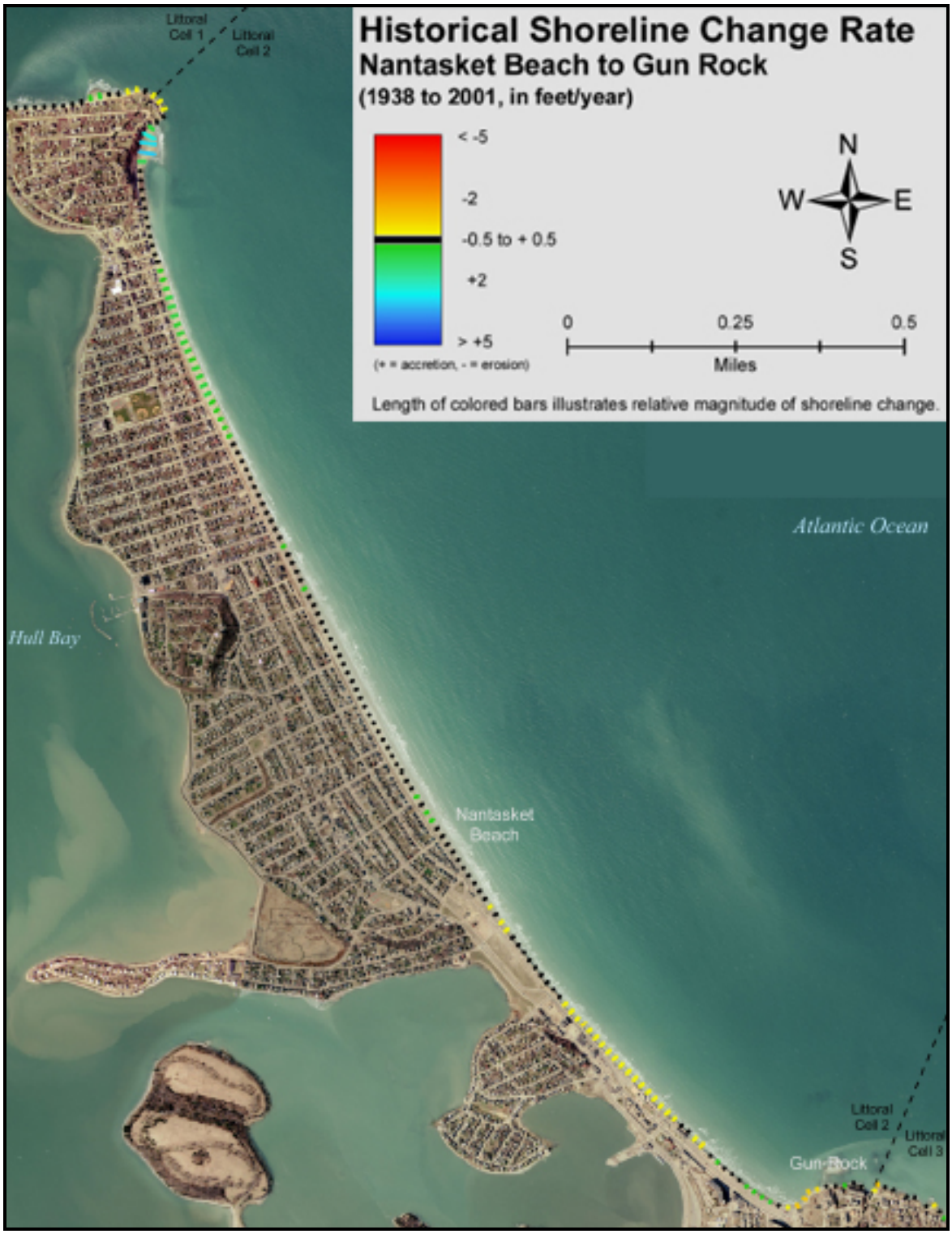

Figure 3-2. Rates of historic shoreline change between 1938 and 2001 as determined by Ramsey et al. (2005).

4.0 WAVE CLIMATOLOGY AND TRANSFORMATION

4.1 ANALYSIS APPROACH

The impact of waves in the nearshore environment, specifically on shorelines that are highly populated or serve significant recreational and/or economic benefits (such as Nantasket Beach), is one of the key reasons to understand wave propagation, transformations, and predictions for site-specific areas. The impact of waves on nearshore processes and shoreline change is highly dependent on the offshore wave climate and the transformation of waves propagating to the shoreline. Subsequently, as the waves interact with the coastline, the wave-induced currents are a major component of sediment transport and shoreline change. Therefore, a key component of understanding the areas of erosion and accretion along Nantasket Beach is determining the nature of the wave field both offshore and in the nearshore region.

Ocean wave energy is comprised of a large variety of waves moving in different directions and with different frequencies, phases, and heights. These waves undergo significant modifications as they advance into the coastal region, interact with the sea floor, and eventually reach land. The ocean climate also changes temporally with seasonal modulations. The variability in offshore wave climate, the transformations occurring as waves propagate landward, and the temporal modulations, all result in significant fluctuations in the quantity and direction of sediment transport in the coastal zone. Therefore, in almost all cases, using a single representative wave height, frequency, and/or direction is not the most accurate technique for assessing the wave climate and, subsequently the sediment transport at the coastline. In many cases, even using a representative averages or ranges of wave conditions may not accurately capture the actual processes that impact the coastline.

This chapter evaluates the wave climate offshore Nantasket Beach and the transformations waves experience as they propagate towards the coastline. To quantify the wave impact along the shoreline, site-specific wave conditions were determined using bathymetric and topographic data, wind data, wave data, and a numerical wave transformation model. Wave transformation models provide predictive tools for evaluating various forces governing wave climate and sediment transport processes. For example, wave refraction and diffraction may have a significant effect on the impacts waves have on a shoreline. Wave refraction and diffraction generally result in an uneven distribution of wave energy along the coast that affects sediment transport in the region. Wave modeling results provide information on wave propagation across the continental shelf and to the shoreline, revealing areas of increased erosion (“hot spots”) or areas of increased energy. The refraction and diffraction mechanisms also result in changes in the offshore wave direction that may significantly influence the rate and direction of sand movement. Therefore, the quantitative information provided from the numerical model can be used to explain the physical processes that dominate a region and to furnish appropriate recommendations/solutions for each stretch of coast.

A detailed description of the procedures used to compute the wave conditions along the Nantasket Beach shoreline is presented within this chapter, with a focus on the application and results of wave transformation numerical modeling. A spectral wave model, STWAVE, was

used to propagate random waves from an offshore location to the nearshore region and to investigate potential changes to the wave field caused by the bathymetry.

4.2 WAVE MODEL DESCRIPTION

The spectral wave model STWAVE version 4.0 (Smith, Sherlock, and Resio, 2001), developed by the U.S. Army Corps of Engineers Waterways Experiment Station, was employed to evaluate changes in wave propagation across the nearshore region fronting Nantasket Beach. STWAVE is a steady state, spectral wave transformation model, based on a form of the wave action balance equation of Jonsson (1990) and is regularly used, and widely accepted in coastal design and studies. The model can simulate wave refraction and shoaling induced by changes in bathymetry and by wave interactions with currents. The model also includes wave breaking, wave growth, and influences of wave white capping on the distribution and dissipation of energy in the wave spectrum. STWAVE simulates the behavior of a random sea surface by describing wave energy density as a function of direction (directional spectrum) and frequency (frequency spectrum). The two-dimensional wave spectrum is discretized into separate wave components, which constitute an essential part of the input for STWAVE. Through a combination of the various wave directions and frequencies, STWAVE is able to simulate the behavior of a natural, random sea. In addition, detailed analysis and selection of input spectra allows the model to assess the impact of different seasonal conditions, varying wave approach pathways, and storms. By simulating numerous wave components that propagate towards the Nantasket shoreline, a spectral wave model is superior to a monochromatic wave model, which would include only one specific wave. A comprehensive discussion of the theoretical background of STWAVE can be found in Smith, Sherlock, and Resio (2001).

The STWAVE model also allows for grid nesting (Smith and Smith, 2002). Grid nesting involves using multiple grids to transform waves from an offshore location to nearshore and coastal regions. A coarse (lower-resolution) offshore STWAVE grid is used to transform the waves to the boundary of a nearshore STWAVE grid with a higher spatial resolution. The nearshore grid is considered the “nested” grid. The output wave spectra from the coarse grid are saved at several locations and interpolated onto the nearshore grid boundary. Grid nesting is a useful technique for larger regional applications where a coarse grid is sufficient offshore while complex bathymetry and current fields in the nearshore require a finer resolution grid to give a more accurate simulation of the wave field and wave-induced currents.

Using offshore wave data from the Nantasket Beach region, appropriate offshore wave conditions were developed and used as input data to specify the wave boundary conditions for the STWAVE model (discussed in Section 4.4). Then, using local bathymetry, three separate grids were created, each with a different resolution (discussed in Section 4.3). Using the grid nesting methodology, the model was able to propagate waves to the Nantasket Beach region at the coastline.

4.3 BATHYMETRY AND GRID GENERATION

Existing bathymetric data in the vicinity of Hull were acquired from two government sources (the National Oceanographic and Atmospheric Administration [NOAA], and the U.S. Army Corps of Engineers [USACE]). In addition, a contemporary survey was performed in the nearshore region to supplement the existing data. Topographic LIDAR survey data were also

obtained from a government source (NOAA Coastal Services Center) to help define the coastline and shoreward features. The various data sources were combined to create grids that consist of a mesh of points with resolutions ranging from 100 meters (328 feet) in the offshore grid to 10 meters (33 feet) in the nearshore grid. The model domain, which includes two subgrids, encompasses the entire shoreline of Nantasket Beach in Hull, MA and extends offshore to a water depth of approximately 70 meters (230 feet). The orientation of the reference grids was selected to closely represent a shore parallel contour line, while the offshore boundary was chosen at a water depth deep enough that waves would not sense the seafloor, and to align with the location of the offshore wave information.

4.3.1 Existing Bathymetric/Topographic Information

NOAA Bathymetric Data

Existing National Oceanographic and Atmospheric Administration (NOAA) data were obtained from the National Ocean Service (NOS) Office of Coast Survey Hydrographic Survey Geophysical Data System (GEODAS). The GEODAS data can readily be obtained online at http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html. Ten (10) separate bathymetric surveys were combined to define the seafloor topography offshore of Nantasket Beach. The ten surveys and the year when they were performed are:

- Hingham Bay and Nantasket Beach (1940)
- Approaches to Boston Harbor (1940)
- Outer Boston Harbor (1945)
- Black Rocks, Massachusetts Bay (1952)
- Cohasset-Scituate, Minots Ledge to Marble Head (1953)
- Cohasset Harbor (1953)
- Stellwagen Ledges (1953)
- Massachusetts Bay (1967)
- Outer Approaches to Boston Harbor (1969)
- Cohasset, Massachusetts Bay (1970)

The compilation of these surveys was used to provide data for grid creation in the offshore regions. Figure 4-1 presents the complied NOAA bathymetric data for the region offshore Nantasket Beach. Although many of these surveys are from the middle of the century, these data were only used in the deeper waters well offshore of Nantasket Beach, where bathymetric change, if occurring at all, is minimal. In addition, if a there were multiple observations at the same location, the most recent bathymetric value was assigned in the model grid. To define the nearshore regions, where bathymetric changes are potentially more probable, contemporary surveys were utilized, as described below.

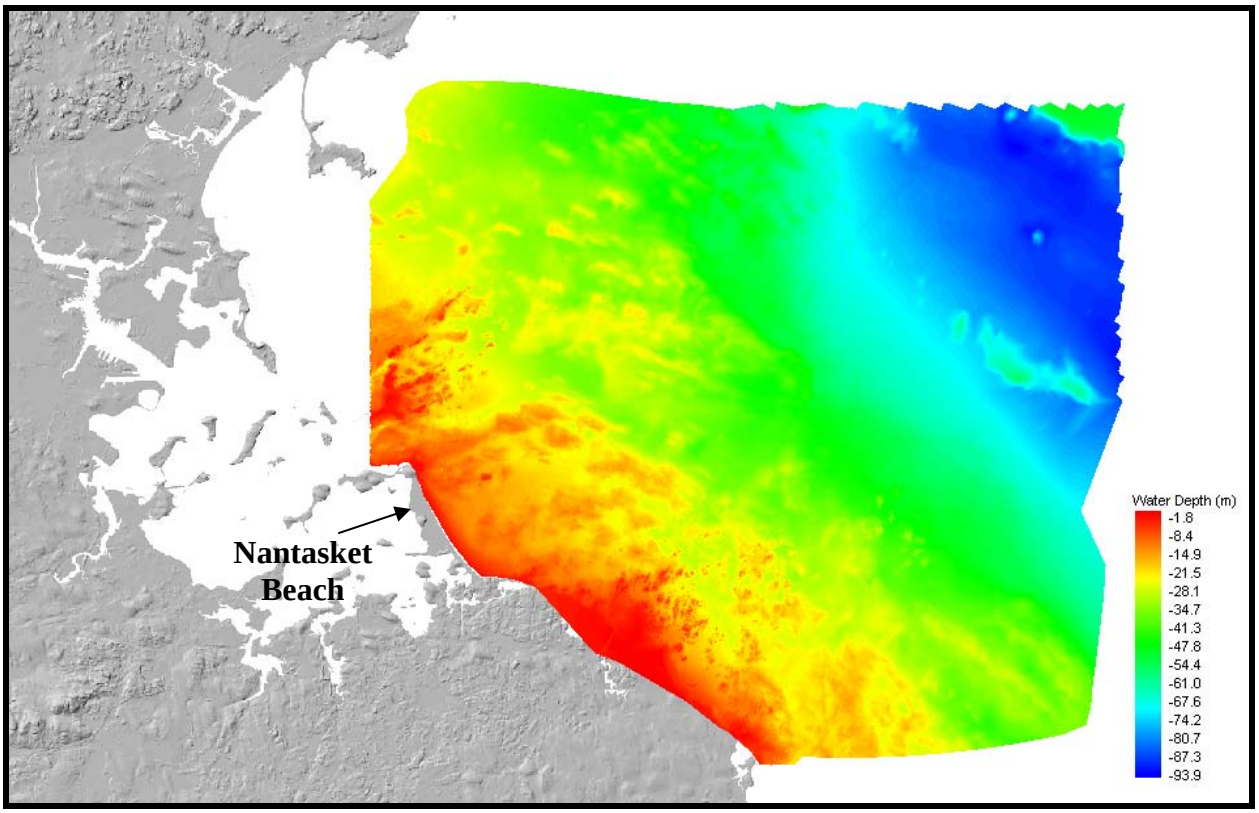

Figure 4-1. NOAA bathymetry offshore Nantasket Beach (meters relative to Mean Tide Level [MTL]). Not to be used for navigational purposes.

NOAA Coastal Services Center LIDAR Survey

Existing topographic data were acquired from the Coastal Services Center (CSC). LIDAR (LIght Detection And Ranging) survey data are readily available on the World Wide Web at http://www.csc.noaa.gov/crs/tcm/. The CSC completed a survey of the Nantasket Beach region on September 27, 2000 as part of their efforts to map coastal change. LIDAR is an active sensor, similar to radar, which transmits laser pulses to a target and records the time it takes for the pulse to return to the sensor receiver. Laser beach mapping involves using this pulsed laser ranging system mounted onboard an aircraft to measure ground elevation and coastal topography. The data were collected in partnership with the CSC, the NASA Wallops Flight Facility, the U. S. Geological Survey (USGS) Center for Coastal and Regional Marine Geology, and the NOAA Aircraft Operations Center. Figure 4-2 presents a map of the LIDAR data obtained along the shoreline of Nantasket Beach. The LIDAR data represents a more recent data set that helped to establish the coastline in creating the grids as well as to define coastal structures and features.

USACE Shoreline Profiles

In order to supplement the shallower nearshore regions in the model domain, a USACE cross-shore profile data set was utilized. The USACE data were obtained from survey work completed in September of 2005 as part of the 2005 Nantasket Beach Characterization Study (USACE, 2006). The USACE data were collected using real time kinematic (RTK) GPS for both the shore-

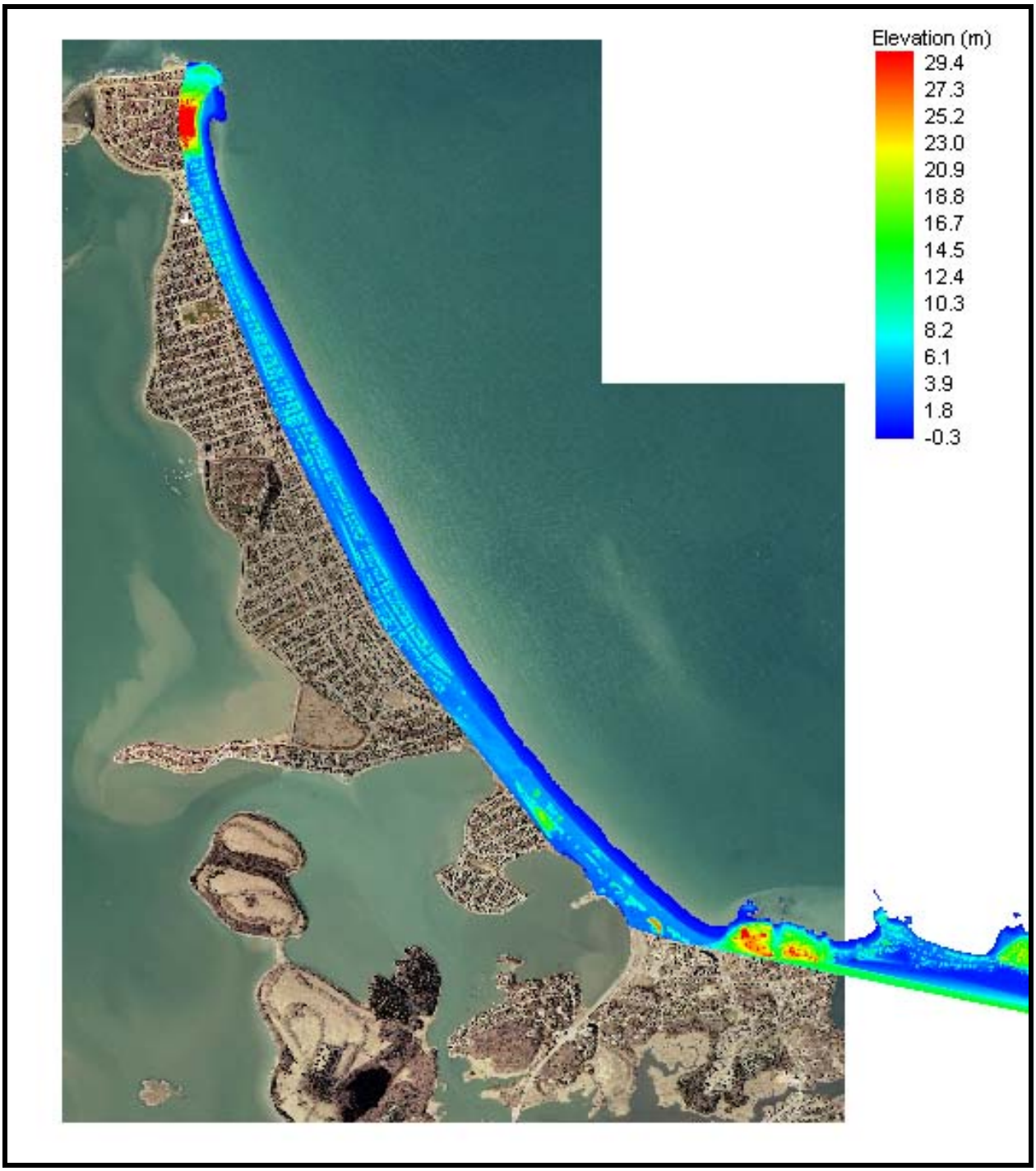

Figure 4-2. CSC LIDAR topography data (meters relative to MTL).

based and hydrographic portions of the survey. Eight cross-shore profiles were surveyed extending from the dune or seawall to a water depth of 35 feet (10.7 meters) NAVD88 or a distance of 5,500 feet (1,676 meters), whichever came first. The horizontal and vertical accuracies for the shore-based survey were +/-1.0 and +/-0.2 feet, respectively, while the hydrographic survey horizontal and vertical accuracies were +/-3.0 and +/-0.2 feet, respectively. The USACE survey profile lines are shown in Figure 4-3.

Figure 4-3. USACE cross-shore profile survey transects.

4.3.2 2006 Site Survey

In order to supplement the existing bathymetric and topographic information, a field survey was conducted by CLE Engineering, Inc. as a part of this project in the most critical nearshore region (DCR Nantasket Beach Reservation). Topographic data were obtained in a shore-based survey that extended along the shoreline from Phipps Street to Atlantic Hill and across the shoreline from 10 feet landward of George Washington Boulevard to 500 feet (152 meters) seaward of the existing seawall structure. In addition, a hydrographic survey was completed along the same extent of shoreline to approximately 1,000 feet (304.8 meters) offshore. Results of the survey are presented in Figure 4-4.

4.3.3 Grid Generation

To simulate wave propagation from the offshore observation locations to the nearshore region of Nantasket Beach, grid nesting was used within STWAVE to provide for an adjustable level of resolution (more detail in the nearshore region). In STWAVE, a grid consists of a mesh of points with dimensions NI and NJ, as shown in Figure 4-5. At each point within the grid domain, water depth, as well as ambient current data, can be specified. Reference points are separated by spacing DX (x-direction) and DY (y-direction). For the Nantasket Beach simulation, three separate grids were created: an offshore grid, an intermediate grid, and a nearshore grid. The modeling grids were created using the bathymetric data sets discussed in the previous sections. The offshore boundary of the offshore grid was chosen at the location where the offshore wave data was acquired, at a water depth deep enough that waves would not sense the sea floor. The orientation of the grids was selected to closely represent a shore-parallel contour line. The grids were rotated to be closely perpendicular to the shoreline, such that a comprehensive range of directional approaches could be simulated. STWAVE is a half plane model (directional approaches relative to a 180-degree half plane). Therefore, rotation of the grid allowed for simulation of all wave approach directions for the Nantasket Beach shoreline that would impact potential sediment transport (waves arriving from 329 to 149 degrees relative to true North).

The offshore boundary of the offshore grid was selected to fall at the WIS 52 wave station (Section 4.4), at approximately the 70 meter (229.7 feet) depth contour. The offshore grid ranges 22 km (13.7 miles) in the cross-shore (x) direction and 17 km (10.6 miles) in the alongshore (y) direction, having a cell size of 100 m by 100 m (328 ft by 328 feet; NI=221, NJ=170). Interpolated depths at each grid intersection point were obtained from the bathymetric data in the gridding process. Figure 4-6 shows the offshore bathymetric grid, for which the offshore boundary was rotated approximately 31 degrees counter-clockwise from true north to be closely oriented with the shoreline.

An intermediate grid was created with the offshore boundary located at approximately the 30-meter contour. The grid has a cell size of 25 meters (82 feet) and extends 9,075 meters (29,774 feet) in the cross-shore direction and 6,175 meters (20,259 feet) alongshore (NI=363, NJ=247). Figure 4-7 shows the bathymetric grid for the intermediate region. The offshore extent of the grid was selected to fall seaward of the majority of the bathymetric features that can be observed offshore Nantasket Beach. Due to the presence of these features, this intermediate grid with good spatial resolution was developed to capture the effects of the changing bathymetry on the wave field.

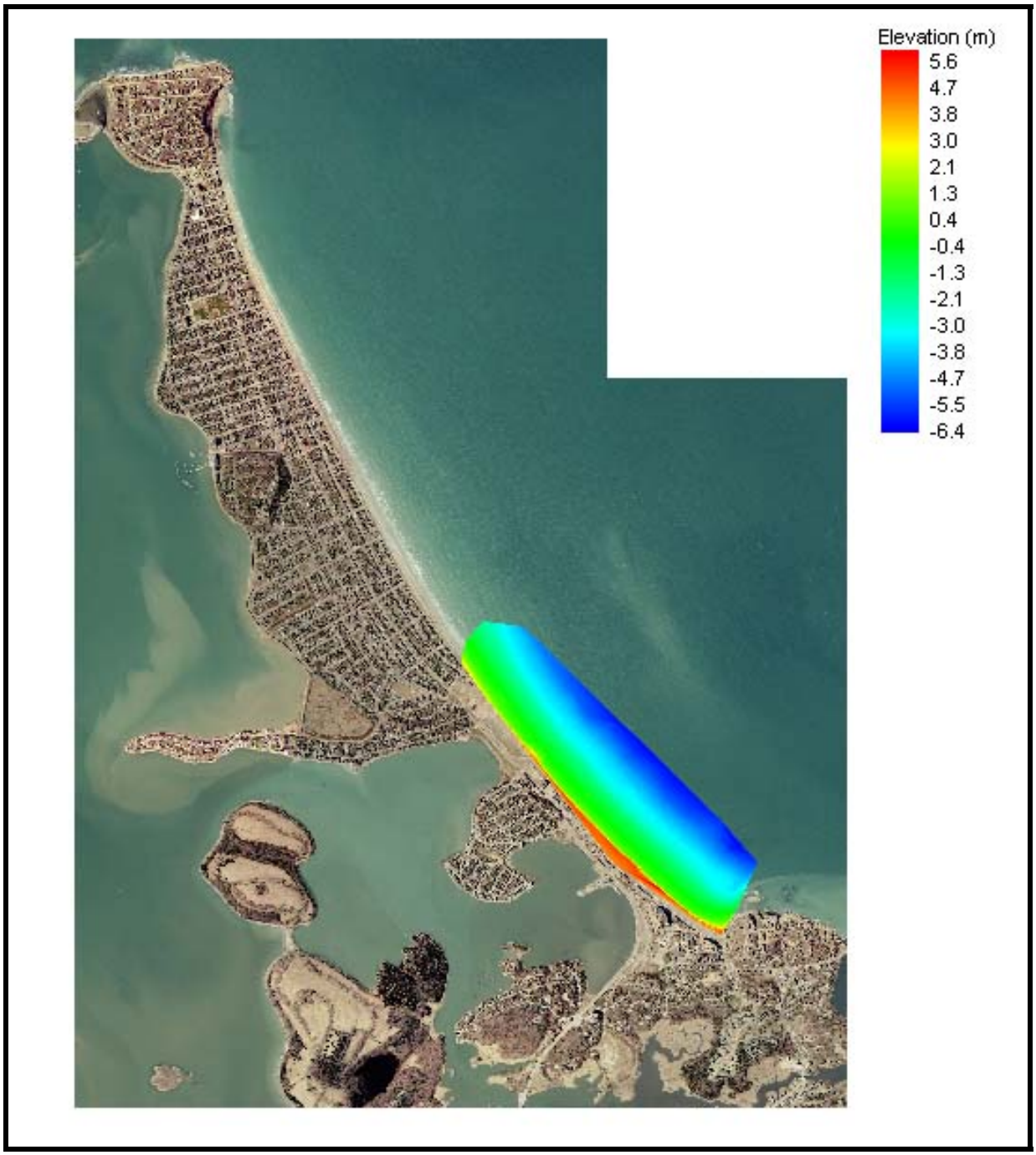

Figure 4-4. 2006 bathymetry and topography data (collected by CLE Engineering) in the vicinity of Nantasket Beach DCR Reservation (meters relative to MTL). Not for navigational purposes.

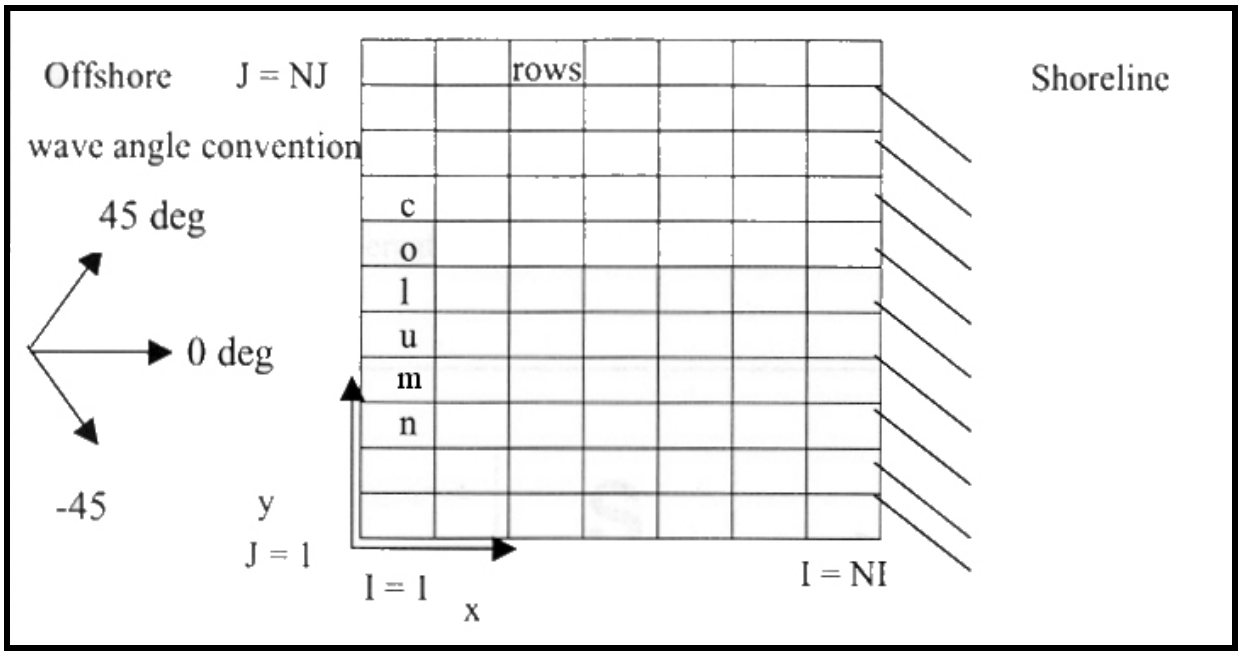

Figure 4-5. Illustration of reference grid notation (Smith, Sherlock, and Resio, 2001).

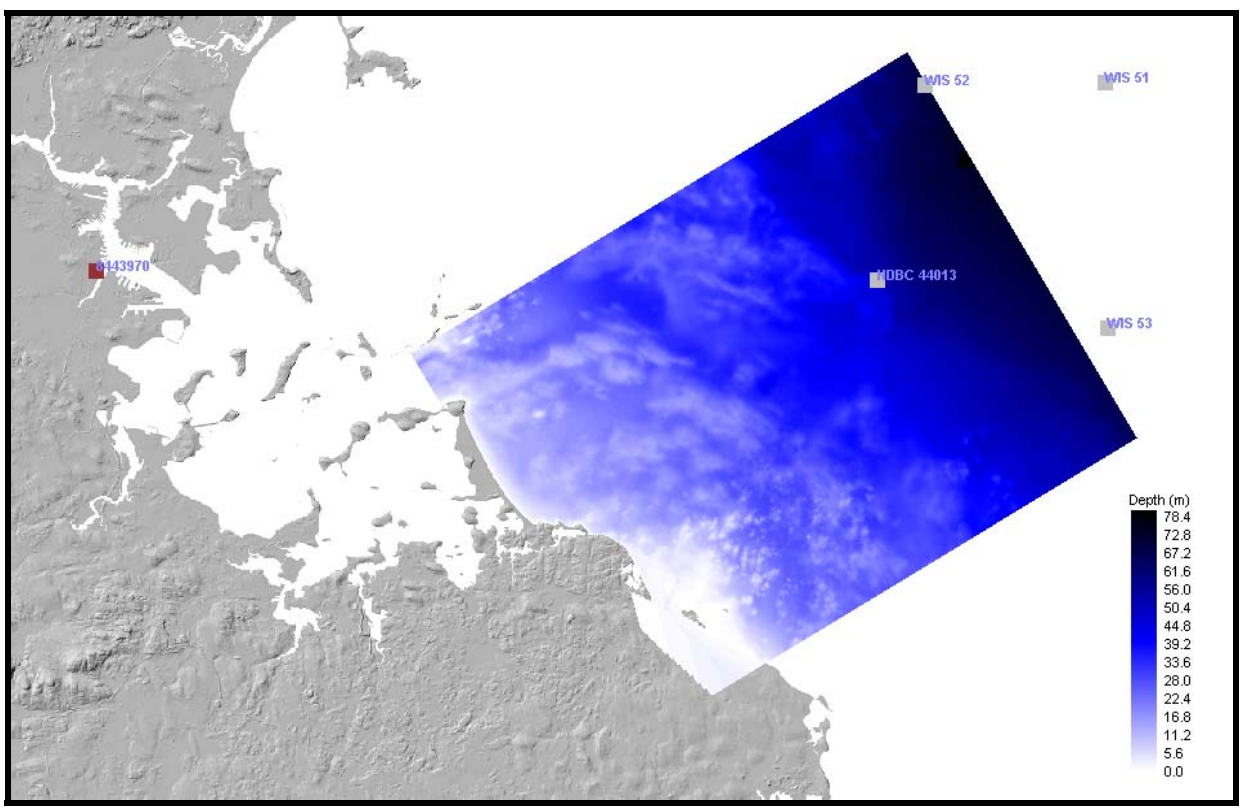

Figure 4-6. Offshore bathymetric modeling grid. Depths are in meters relative to MTL. Not for navigational purposes.

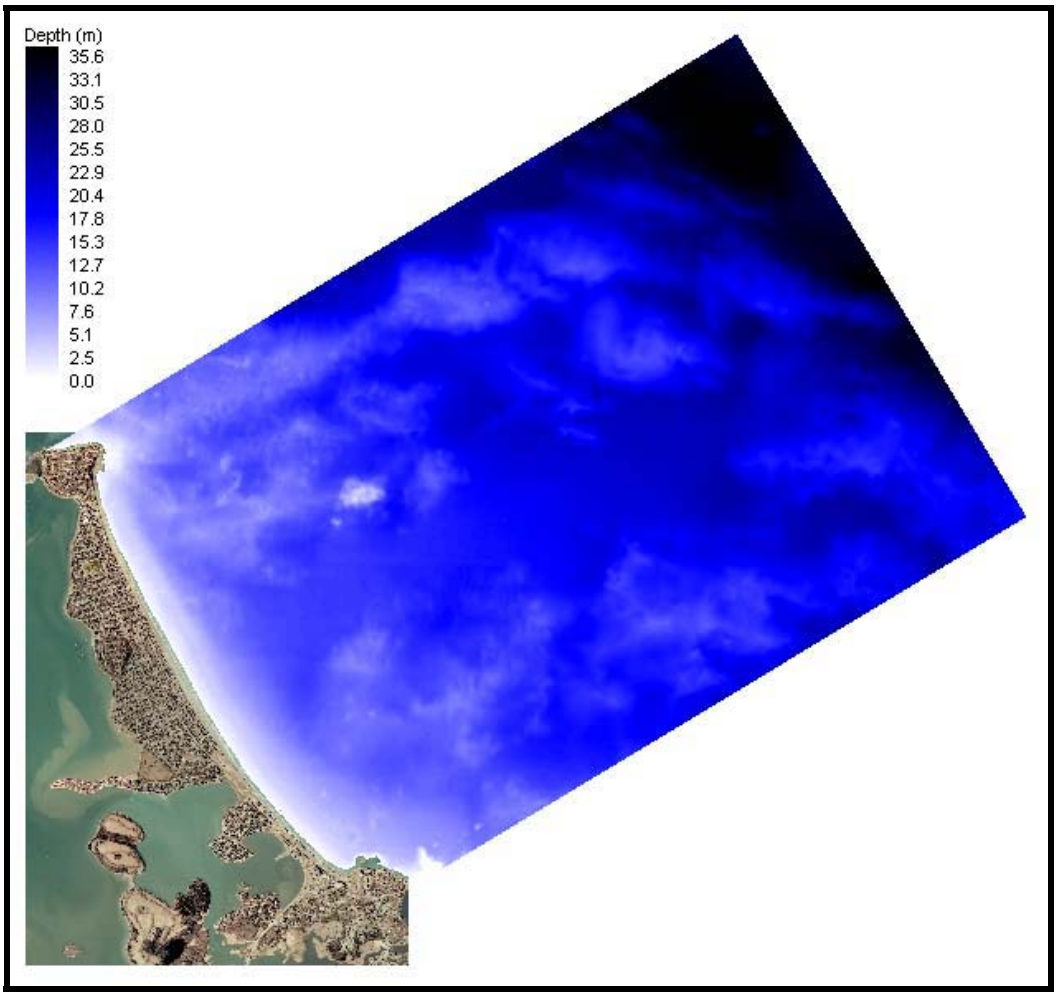

Figure 4-7. Intermediate bathymetric modeling grid. Depths are in meters relative to MTL. Not for navigational purposes.

The bathymetric features in closer proximity to Nantasket Beach are more clearly displayed in Figure 4-8, where the depth contours are limited to 0 to 13 meter (0 to 42.7 feet) range (referenced to MTL) and certain named features are identified. In the northern portion of the grid, Thieves Ledge, with depths of 10-11 meters (32.8-36.1 feet), is the most prominent offshore feature offshore Allerton Hill. Ultonia Ledge extends from Allerton Hill as part of the submerged headland formation in the nearshore with depths of 8-9 meters (26.2-29.5 feet). The most visible, shallow feature is Harding Ledge, a rocky formation offshore the northern portion of Nantasket Beach with depths of 2-3 meters (6.6-9.8 feet). Directly offshore Strawberry Hill is Strawberry Ledge, a nearshore formation with depths of 8-9 meters (26.2-29.5 feet). Unnamed bathymetric features exist offshore the southern portion of Nantasket Beach, offshore of the DCR reservation. Another rocky formation exists at the start of the Black Rocks near the southern boundary of the grid, offshore Atlantic Hill and Gun Rock with depths of 8-9 meters (26.2-29.5 feet). All of these offshore features influence the waves as they propagate towards Nantasket Beach. As such, a high resolution nearshore grid was specified to gain better resolution in the nearshore region for sediment transport calculations. The grid extends 1,920 meters (6,298 feet) in the cross-shore direction, and 6,170 meters (20,237 feet) alongshore, having a high resolution

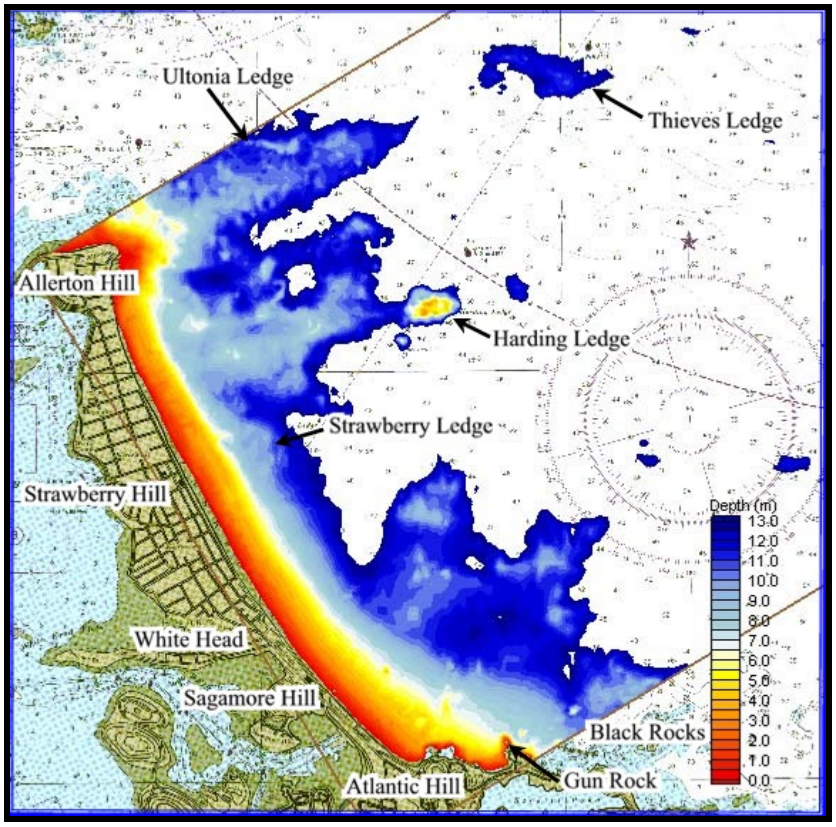

Figure 4-8. Bathymetric features offshore Nantasket Beach. Depths are in meters relative to MTL. Not for navigational purposes.

cell size of 10 meters (33 feet). The offshore extent of the grid was selected to include the 7 meter (23 foot) contour along the entire length of shoreline. The nearshore grid is further discussed along with the sediment transport model in Chapter 5.

4.4 WAVE CHARACTERISTICS AND INPUT SPECTRA

A key component of accurate wave modeling is the analysis and selection of input wave data. The results derived from numerical wave transformation modeling, as well as the subsequent movement of sediment in the coastal zone, are controlled by the selected wave input conditions. This section describes the offshore wave climate and selection of input wave parameters for the wave transformation modeling.

4.4.1 Offshore Wave Climate

For this project, the Wave Information Study (WIS) time series of wave and wind data were used to describe the wave climate offshore the Nantasket Beach region. Long-term time series of wave climate observations are typically not available for most shorelines, and although National Data Buoy Center (NDBC) station 44013 exists offshore Nantasket Beach in 55 meters (180 feet) of water (Figure 4-6), the buoy is not equipped to measure wave directionality, which is crucial to developing wave spectra that accurately characterize the wave climate. The WIS,

performed by the USACE, has met a critical need for wave information in coastal engineering studies since the 1980s and is widely accepted for design purposes for United States shorelines by many coastal engineers and scientists. WIS contains time series information of spectrally-based, significant wave height, peak period, peak direction, and wind speed and direction produced from a computer hindcast (prediction) model. The hindcast wave model, WISWAVE (Resio and Tracy, 1983) is simulated using wind information (speed and direction) at selected coastal locations around the United States. The model predicts wave climate based on local/regional wind conditions. Wave measurements made by NOAA during the 1980s made verification of the WIS results possible by comparing the statistics and the distributions of wave heights and periods from different time periods (Hubertz et al., 1993). The availability of long-term records makes WIS data attractive when considering average or seasonal wave conditions. Since the data are widespread and continuous, adoption of the generally accepted WIS data for development of spectral wave conditions is applicable. Previous studies and design projects have used WIS data as an accurate measure of wave climate and input to nearshore wave transformation models (Kraus et al., 1988; Byrnes et al., 1999; Byrnes et al., 2000). Although direct, *in situ* measurements might show some difference in detail, the WIS data set provides an accepted and widely used long-term wave data set, which is a significant improvement over representing the sea state with a single wave condition. In addition, this WIS data used in this study were validated to actual wave height observations at the NOAA 44013 station to verify the relative performance of the WIS and STWAVE models.

The WIS stations were evaluated for this study are shown in Figure 4-6 near the offshore boundary of the modeling domain. Three WIS stations were evaluated to help understand the spatial variability of wave conditions offshore Nantasket Beach and to ensure appropriate selection of wave input conditions. Each WIS station has 20-years worth of spectral wave data, spanning from 1980 to 1999. Figure 4-6 also indicates the location of NDBC station 44013, which provided wave height measurements within the model domain for wave model verification purposes (Section 4.5). Table 4-1 presents a summary of the relevant wave stations used in this study. The most recent WIS simulations (Phase III-type) were used for this study and provide wave parameter results every hour for a twenty-year time period (1980-1999). The Phase III-type WIS data represent the most up-to-date wave generation and wave parameter development and are considered more accurate than the older Phase I-type and Phase II-type data sets. Details on the differences between the various Phases of USACE wave generation can be found on the WIS website (http://frf.usace.army.mil/wis/wis_main.html). Each WIS station is located near the offshore boundary of the modeling domain in 40 to 63 meters (131 to 207 feet) of water depth.

Table 4-1. Summary of relevant stations in the modeling domain.

Station	NDBC 44013	WIS 51	WIS 52	WIS 53
Latitude	42.35°N	42.42°N	42.42°N	42.33°N
Longitude	70.69°W	70.58°W	70.67°W	70.58°W
Depth (m)	55	40	63	56
Time Period (yrs)	1985-2005	1980-1999	1980-1999	1980-1999

The three 20-year WIS data sets offer a synopsis of the wave climate offshore of Nantasket Beach. A closer examination of the data identifies the variability in wave energy and approach direction, parameters that typically have a significant impact on sediment movement in the nearshore. Figure 4-9 presents wave rose plots, which illustrate the distribution of significant wave height, for each of the WIS stations. The grayscale colors indicate the magnitude of the wave height, the circular axis represents the direction of wave approach (coming from) relative to True North (0 degree), and the extending radial lines indicate percent occurrence within each magnitude and directional band. The majority of the waves are shown to be arriving from north-northeast to south-southeast. The direction and magnitude of the 20-year wave data are similar throughout stations 51-53; therefore, there is little spatial variability in wave climate among the WIS stations. The lack of spatial variation can be further illustrated by the comparison of the mean wave period distribution (Figure 4-10), the percent occurrence directional distribution (Figure 4-11), and the percent wave energy directional distribution (Figure 4-12). Figures 4-10 through 4-12 only present wave directions that propagate towards Nantasket Beach, where 90 degrees represents a shore-normal wave (perpendicular to the shoreline). For each of these parameters, there is little variation between the individual WIS Stations. Since each WIS station near the domain boundary has similar wave data, Station 52, which is located most directly offshore Nantasket Beach, was selected as the offshore wave data source to generate spectral input conditions.

Offshore, the most common wave approach direction is from the east (90 degrees in Figure 4-9 or 120-130 degrees in Figure 4-11, which represents direction relative to the rotated model domain). The most wave energy is associated with waves coming from the northeast (70-80 degrees in Figure 4-12). Figure 4-13 compares the basic percent occurrence and the percent energy across the directional distribution for WIS station 52. The percent occurrence distribution simply presents the percent of time waves come from each direction, while the percent energy presents the amount of energy coming from each direction. The asymmetry between the distributions indicates that although there are a lower percentage of waves arriving from the northeast than the east, the northeast waves are more energetic. This can be explained by the high number of nor'easter storms that are common to the New England area. Therefore, to properly represent the offshore wave conditions that drive the wave model and help estimate longshore sediment transport at Nantasket Beach, it is clear that the wave conditions cannot be defined by one single set of wave parameters, or even by a series of specific wave conditions, but rather a compilation of a variety of waves that occur over a longer time frame. It is also likely that the wave field experiences significant changes as the waves advance towards the coastline. The results of the wave transformation modeling will explore the changes that occur to the wave distribution as they propagate towards the coast, and specifically in the vicinity of the Nantasket Beach and the DCR reservation.

Rather than selecting the most common wave heights and directions, a detailed analysis was conducted to compile and summarize the existing WIS data into detailed input spectra for the wave transformation model. Each spectral simulation contains distinct differences in the distribution of wave energy between directional and frequency bands, and consequently produces varying impacts in the transformation and sediment transport patterns.

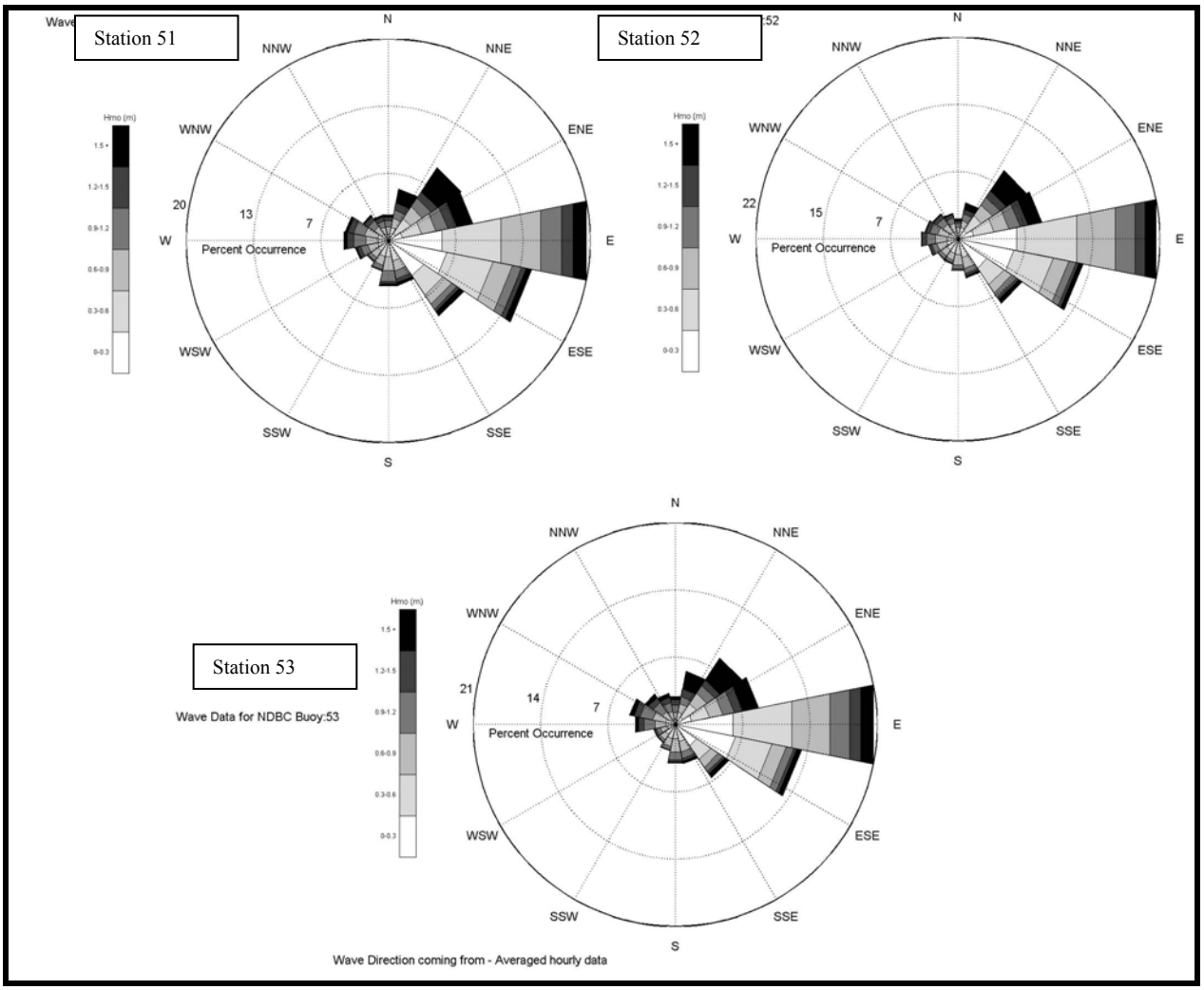

Figure 4-9. Twenty-year, hourly-averaged wave roses for WIS Stations 51-53. Wave height in meters.

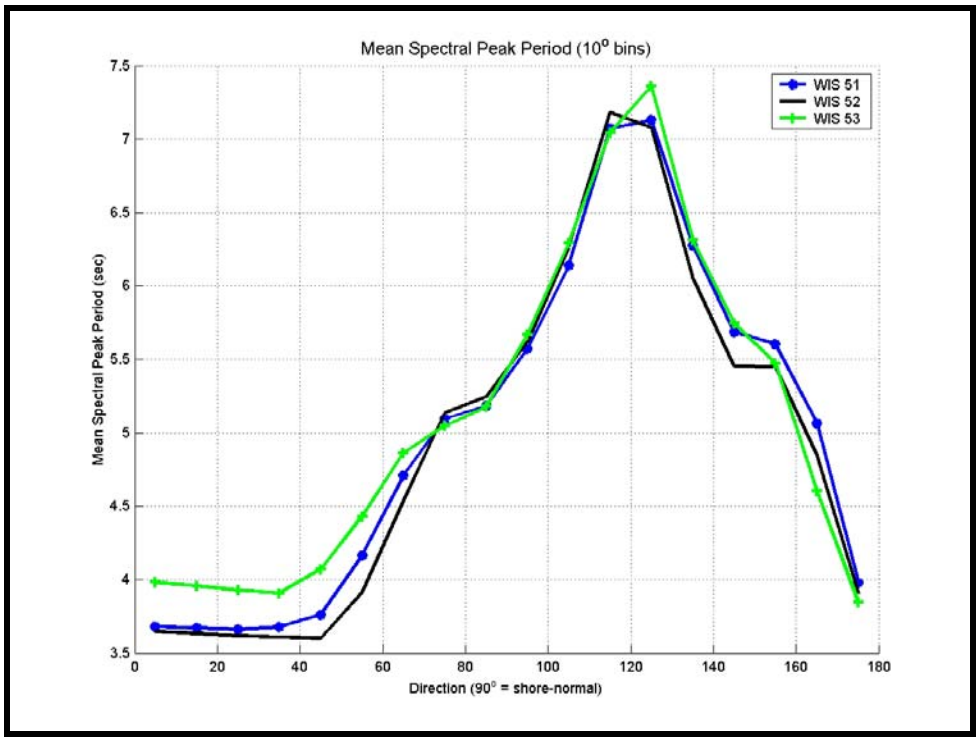

Figure 4-10. Directional distribution (wave directions propagating onshore in 10 degree bins) of mean wave period for WIS Stations 51-53.

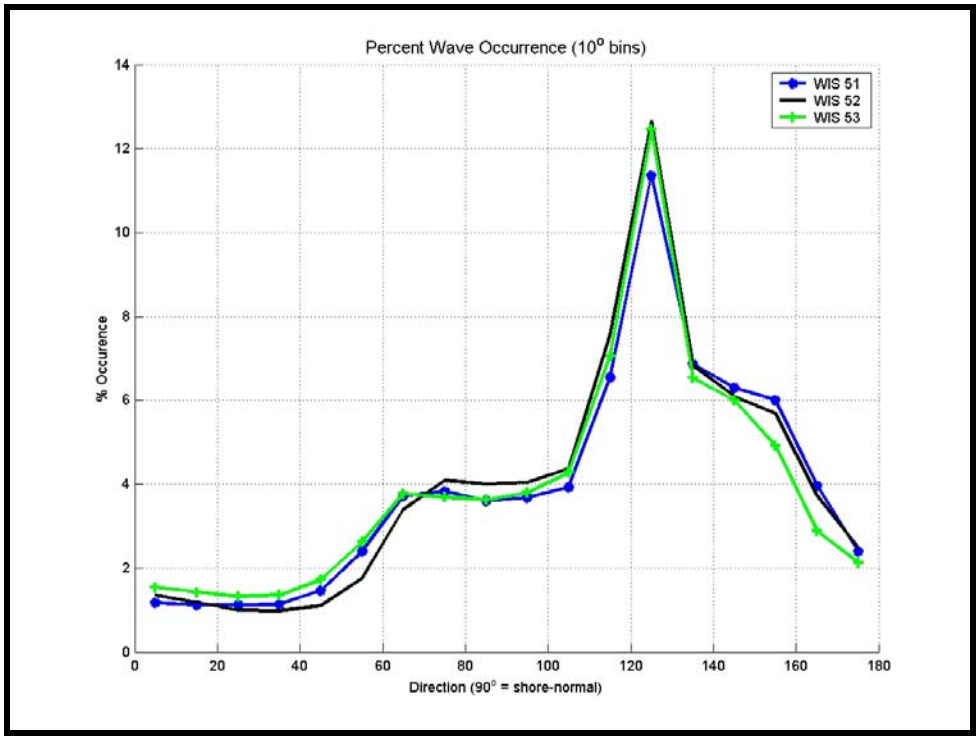

Figure 4-11. Directional distribution (wave directions propagating onshore in 10 degree bins) of percent wave occurrence for WIS Stations 51-53.

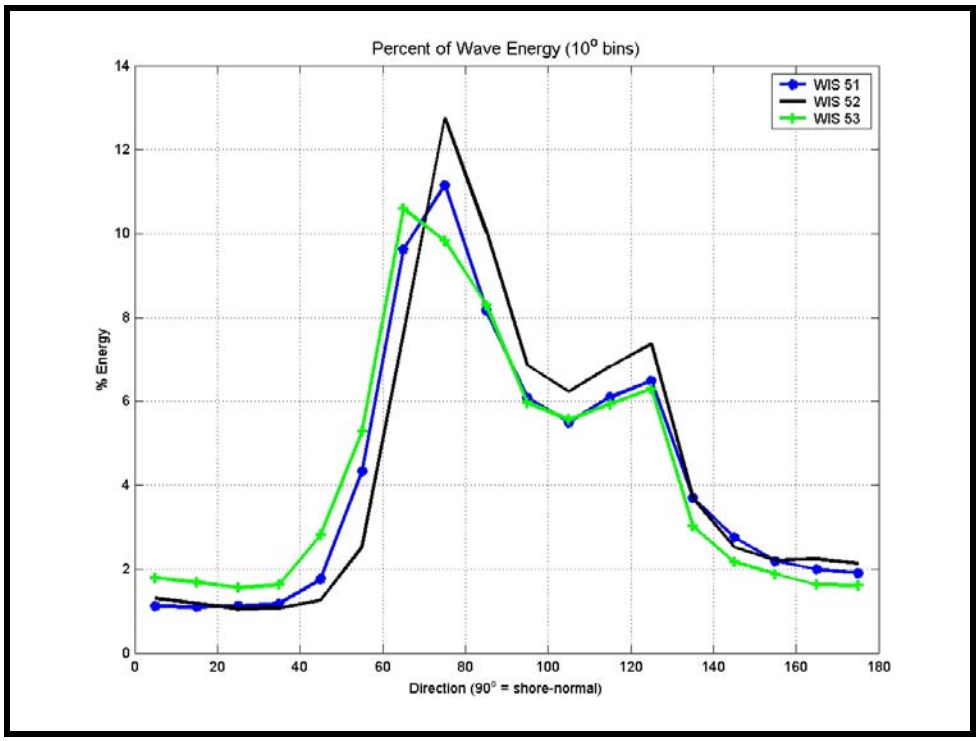

Figure 4-12. Directional distribution (wave directions propagating onshore in 10 degree bins) of percent wave energy for WIS Stations 51-53.

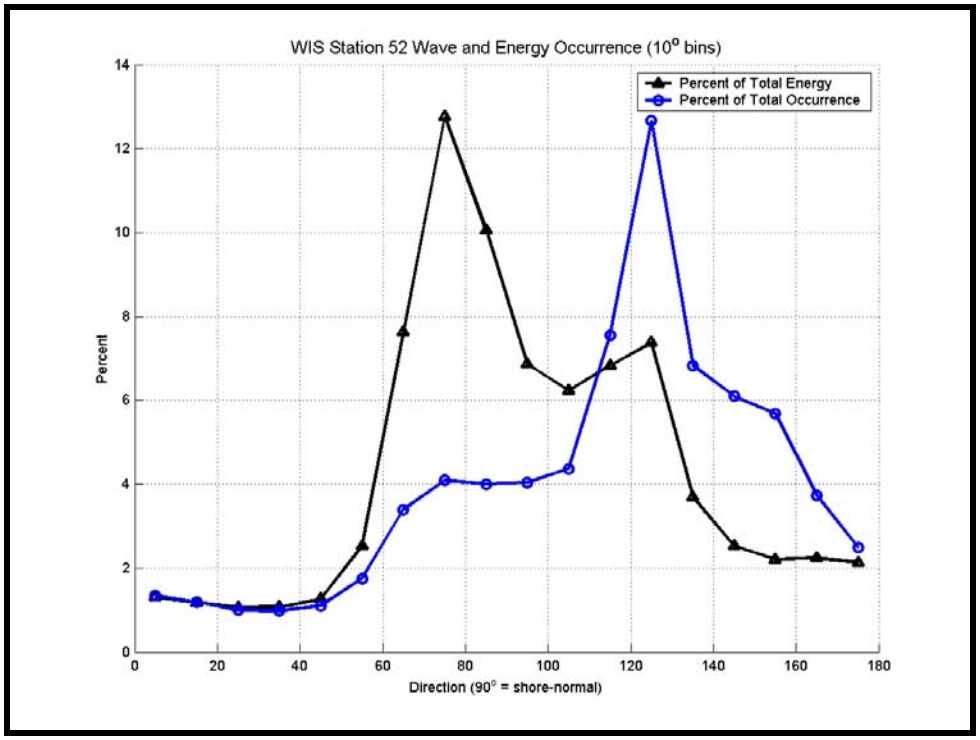

Figure 4-13. Comparison of percent occurrence and the percent energy across the directional distribution for WIS station 52.

4.4.2 Input Wave Conditions

STWAVE requires input of a directional wave spectrum, which represents the distribution of wave energy in the frequency and direction domains. The two-dimensional wave spectrum is given as the product of the energy and directional spectra. The directional spreading function provides the relative magnitude of directional spreading of wave energy, while the frequency spectrum provides the absolute value of wave energy density. Input wave conditions were developed for average annual conditions, a representative year (simulation of every hour during 1987), and specific storm events.

Average Annual Directional Approaches

In order to determine long-term wave conditions and wave statistics at the coastline, as well as for potential use in sediment transport calculations, spectral data from WIS Station 52 were used to derive energy-conserving annual average directional spectrum. Data were segregated by direction of approach, and an energy distribution, as a function of frequency, was generated from all the waves in each directional bin. The energy associated with each frequency was then summed to create an energy distribution for each approach direction. In essence, a representative two-dimensional spectrum was generated for each approach directional bin based on the sum of all the WIS spectra approaching from that mean direction. This can then be combined with the percentage of occurrence to create a long-term (20 year) evaluation of wave impacts at the shoreline. This energetic directional bin approach has been successfully utilized in transformation modeling (Byrnes et al., 2000; Woods Hole Group, 2008) and identifies all potential approach direction, including those that may occur only a small percentage of time during a typical year, but potentially have significant impacts on the shoreline and sediment transport (e.g., the higher wave energy approaches from the northeast). Table 4-2 presents the cases that were simulated in STWAVE to represent the complete wave climate offshore of Nantasket Beach. The table also presents the percent occurrence and wave energy associated with each approach direction. The frequency and directional energy spectra were tailored to match the energy distribution of each approach bin that occurred in the WIS data. Therefore, the directional and frequency distributions matched the data directly. Each of the directional bins presented in Table 4-2 were simulated in the wave transformation model.

Since STWAVE is a half-plane model, only waves propagating towards the coastline are represented. Waves that may be reflected from the coastline and waves that are generated by winds blowing offshore are not included. Waves headed offshore would represent a calm period along the coastline, and this period of time is also presented in Table 4-2.

Representative Year Simulation

In addition to the average annual directional spectra presented in Table 4-2, which are derived from 20 years of WIS hindcast wave data, a full year long time span was also simulated to provide additional insights into the wave field transformations and the wave statistics in the vicinity of Nantasket Beach. Simulations of an entire year of wave data, where wave spectra is simulated every hour, provide a significant data set in the nearshore zone that represents the annual wave climate. A representative year of wave data was selected by comparing individual year statistics to the overall 20-year wave statistics. This comparison allows for selection of a

representative year of wave data with wave heights, periods, directions, and energy similar to the magnitude and form of the entire 20-year wave data set. Figure 4-14 shows the percentage of wave energy that occurred in each year over the 20-year period, from 1980 to 1999. Figure 4-15 shows the distribution of wave energy averaged for each directional bin over the 20-year time period compared to the same directional distribution for 1987. Figure 4-15 indicates that the directional distribution of energy for 1987 compares well to the 20-year energy distribution. Therefore, 1987 was selected as a representative year for simulation. Associated wind data were included with the wave spectra as input into the wave transformation model. Therefore, both the waves generated in the regions outside of the model grid (Atlantic Ocean) and locally generated wind waves are included in the simulation. Tidal data obtained from NOAA station 8443970 located in Boston Harbor were also included as input to the year-long simulation to correctly represent fluctuations in the water elevation.

The simulation of every hour during 1987 was also used to verify the performance of the STWAVE wave transformation model. Modeled wave transformation results for 1987 were compared to the observed wave heights at NDBC station 44013. The validation of the wave model is presented in detail in Section 4.5.

Table 4-2. Input conditions and scenarios for the wave transformation numerical modeling.

Directional Bin (0°=N)	Approach Direction	% Occurrence	% Wave Energy	Sig. Wave Height (m)	Sig. Wave Height (ft)	Peak Period (sec)	Peak Direction (0°=N)
329 to 351.5	NNW	2.14	2.11	0.87	2.84	3.6	342.2
351.5 to 14	N	2.23	2.44	0.89	2.94	3.6	2.7
14 to 36.5	NNE	4.74	7.77	1.01	3.31	4.1	27.8
36.5 to 59	NE	9.10	25.88	1.21	3.98	5.1	47.7
59 to 81.5	ENE	9.74	14.72	0.89	2.92	6.1	70.7
81.5 to 104	E	22.58	14.67	0.60	1.97	7.0	92.4
104 to 126.5	ESE	13.57	5.77	0.45	1.48	5.6	115.0
126.5 to 149	SE	6.40	3.95	0.54	1.76	4.8	133.9
Calm	--	29.49	--	--	--	--	--

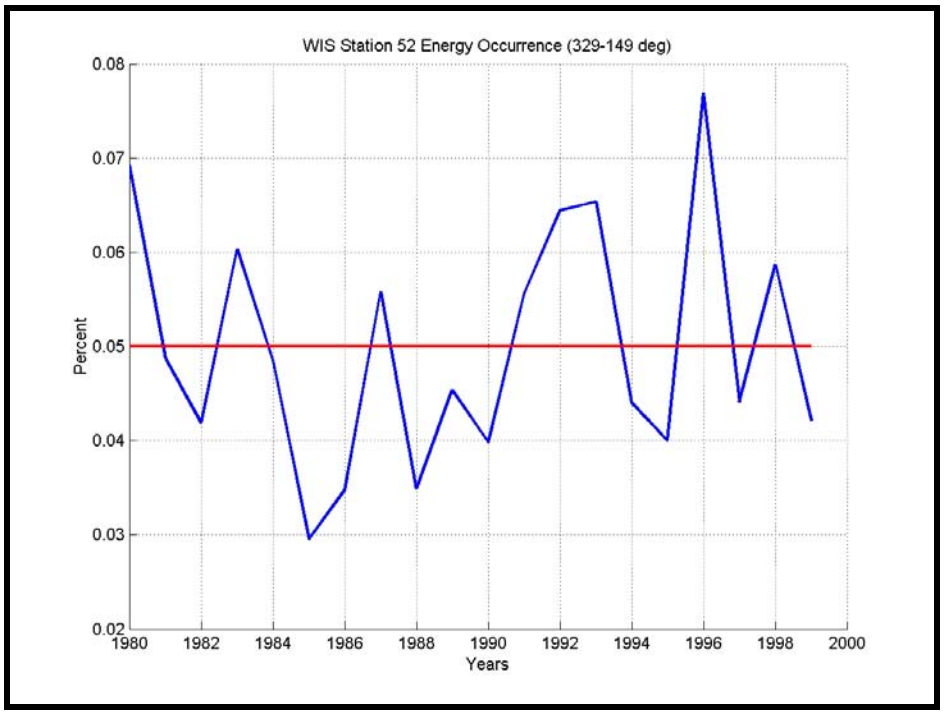

Figure 4-14. Percent energy occurring each year over the 20 years at WIS station 52 (blue line) with average percentile indicated by red line (for wave directions propagating onshore, 329 through 149 degrees where 0°=N).

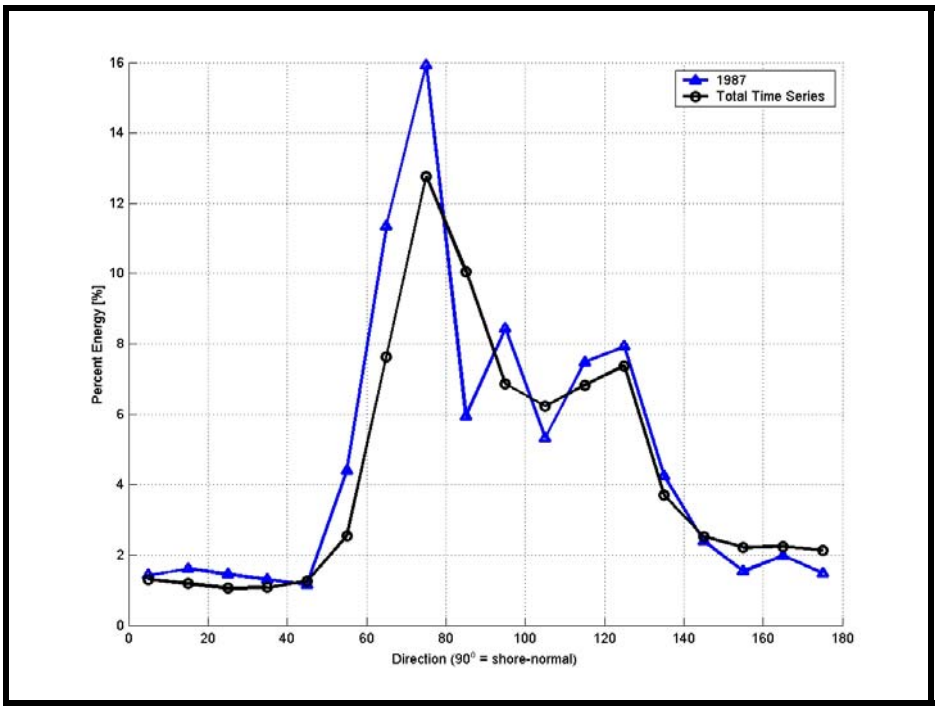

Figure 4-15. Comparison of the percent energy across the directional distribution (wave directions propagating onshore in 10 degree bins) for 1987 (blue line) and for the 20 years of wave data (black line) at WIS station 52.

High Energy Events

Since high-energy events have a significant impact on many physical processes (and in most cases significantly contribute to sediment transport), it is crucial to include storm simulations in the wave modeling to determine extreme storm wave characteristics and assess the associated potential impacts on the shoreline along Nantasket Beach. High energy events were evaluated by reviewing existing literature on hurricanes and northeast storms that affected the coast of Massachusetts and by performing an analysis of storm events from the WIS data.

Several historical storm events in the New England area over the past century have had an impact on Nantasket Beach. The New England Hurricane of 1938 was a Category 3 hurricane on the Saffir-Simpson Scale that caused extensive damage along the coastlines of Connecticut, Rhode Island, and Massachusetts. The Blizzard of '78 was another infamous storm that produced heavy coastal flooding and hurricane-strength winds. More recently, in the past 25 years, other storms that have had an impact on the New England coastlines include: Hurricane Gloria in 1985, Hurricane Bob in 1991, the "Perfect Storm" in October of 1991, a no-named Northeaster storm in December of 1992, the "Storm of the Century" in March of 1993, the Blizzard of '96, and the April Fools' Day Blizzard in 1997. Selected storm events were simulated in the wave transformation model based on available data and the historical impact on Nantasket Beach. Some of the more famous historical storms (e.g., the Blizzard of '78) did not have limited data coverage, and therefore were not selected for simulation.

Wave data from the WIS 52 Station was used to conduct an analysis of storm events. The wave data were examined and high-energy wave events were characterized based on a set of criteria. A storm event was defined when the significant wave height was greater than 3 meters (9.8 feet) for at least 12 hours. Separate events were defined by requiring a window of 18 hours between wave heights that exceeded the 3 meter (9.8 feet) threshold value. The high-energy wave events were then cross-referenced with a list of known historical storm events for the New England area.

In addition, return-period storm event conditions (10-year, 50-year and 100-year) were developed in order to provide a complete array of extreme events that could be expected to occur at this location. The return-period storm wave heights were determined using the Generalized Extreme Value (GEV) method. This method provides reliable estimates of extremes without assuming the distribution type is known (Resio, 1989). The GEV method uses asymptotic methods to fit sampled maxima to the tail of a parent distribution, whose characteristics are estimated from the original sample. The original sample was taken from the WIS 52 data set. Table 4-3 presents the wave heights estimated by GEV. The return period storms peak wave periods were derived using the following relationship (USACE 2002b) for extreme wave parameters:

$$T_p = \sqrt{10.25 H_{mo}} \tag{4-1}$$

where H_{mo} is the extreme wave height. Since the exact wave direction of extreme events is unknown for return-period storms, the most common storm approach and highest energetic direction (northeast 45°) was assumed based on the average approach direction of all the storms

in the hindcast data. Therefore, a 45° approach was selected to represent the return period storms, since it represented the average direction of the storms found within the WIS 52 data set.

Storm surge values were also included in the wave modeling simulation to represent the increased water level experienced during the passage of a large storm event. Elevated water levels, even with moderate wave heights, can result in significant erosion along the shoreline. Surge values reported by a variety of sources were used to determine the water level associated with these storm events. For return-period storms, storm surge data were taken from Tidal Flood Profiles of the New England Coastline (USACE, 1988). For the known specific storm events, storm surge elevations were determined from the NOAA station 8443970 located in Boston Harbor and local observations and historical accounts.

Table 4-3 presents the storm events and their associated wave and storm surge characteristics. Storm spectra were developed for the STWAVE simulations from these storm parameters using standard parametric methods (e.g., TMA spectra, $\cos^n$ directional distribution), since the observed spectra during these events are unknown.

Table 4-3. Extreme storm event characteristics offshore Nantasket Beach used to define input spectra.

Storm Event	Significant Wave Height (m)	Significant Wave Height (ft)	Peak Wave Period (sec)	Avg. Wave Direction (degrees)	Storm Surge (m above MTL)
10-year	7.0	23.0	10.2	45	2.71
50-year	8.6	28.2	11.3	45	2.96
100-year	9.3	30.5	11.8	45	3.05
Perfect Storm (10/31/1991)	5.6	18.4	10.0	49	2.80
Nor'easter (Dec. 11-14, 1992)	7.6	24.9	12.5	62	2.75
April Fools' Day Blizzard (April 1, 1997)	6.4	21.0	11.1	42	2.14

4.5 MODEL VALIDATION

In order to verify the performance of the wave model, model results were compared to the wave measurements from NDBC station 44013 for every hour of 1987. Figure 4-16 shows comparisons of the modeled (red) and measured (blue) wave heights for 1987, with each panel presenting a quarter of a year of data. Figure 4-17 shows a comparison of the modeled (red) and measured (blue) wave period for 1987, with each panel also presenting a quarter of a year of data. Portions of the time series without a blue line indicate time periods when the NDBC station was not recording. Visually, the modeled wave heights compare favorably to the observations, and specific wave and storm events were accurately simulated, as well as calm periods. Both average and storm conditions are well represented throughout the entire year. For example, the large event in the middle of November is accurately predicted, as is the entire month of July (smaller waves). The comparison of the modeled and observed wave periods shows there are greater discrepancies, but the simulated wave periods generally follow the trend of the observations. In order to quantify the model performance, error statistics (bias and root-mean-square error) were used to quantify the performance of the wave model.

The bias and root-mean-square (RMS) error are defined as follows where n is the number of P data points:

$$Bias = \frac{\sum (P_{measured} - P_{simulated})}{n} \tag{4-2}$$

$$RMS\ Error = \sqrt{\frac{\sum (P_{measured} - P_{simulated})^2}{n}} \tag{4-3}$$

The error statistics computed for the model results and observations made at NDBC station 44013 are shown in Table 4-4. Bias is a measure of the average deviation of the measured values from the simulated values. A positive bias means the model is under predicting while a negative bias means, on average, the model over predicted the results. The performance of the model can be evaluated using the RMS error value. The smaller the RMS error value, the better the model performed. The computed statistics show that the model is slightly under predicting wave height and period at the NDBC station, but the deviation is relatively small. The modeled wave height is within 0.15 meters (0.5 feet) of the observed values, while the wave period is within 0.14 seconds. The RMS error indicates that the model does a better job at simulating the wave height than the wave period.

Table 4-4. Computed error statistics for simulated and observed wave parameters at NDBC 44013.

	Wave Height (m)	Wave Period (s)
Bias	0.15	0.14
RMS Error	0.44	2.18

4.6 NEARSHORE WAVE TRANSFORMATION MODELING RESULTS

4.6.1 Average Annual Directional Approaches

Model simulations were performed for the typical wave conditions represented by the directional bin spectra presented in Table 4-2. Wave focusing and divergence occur at several locations throughout the modeling domain, which results in variations in the wave energy propagating towards the coastline of Nantasket Beach for each directional bin.

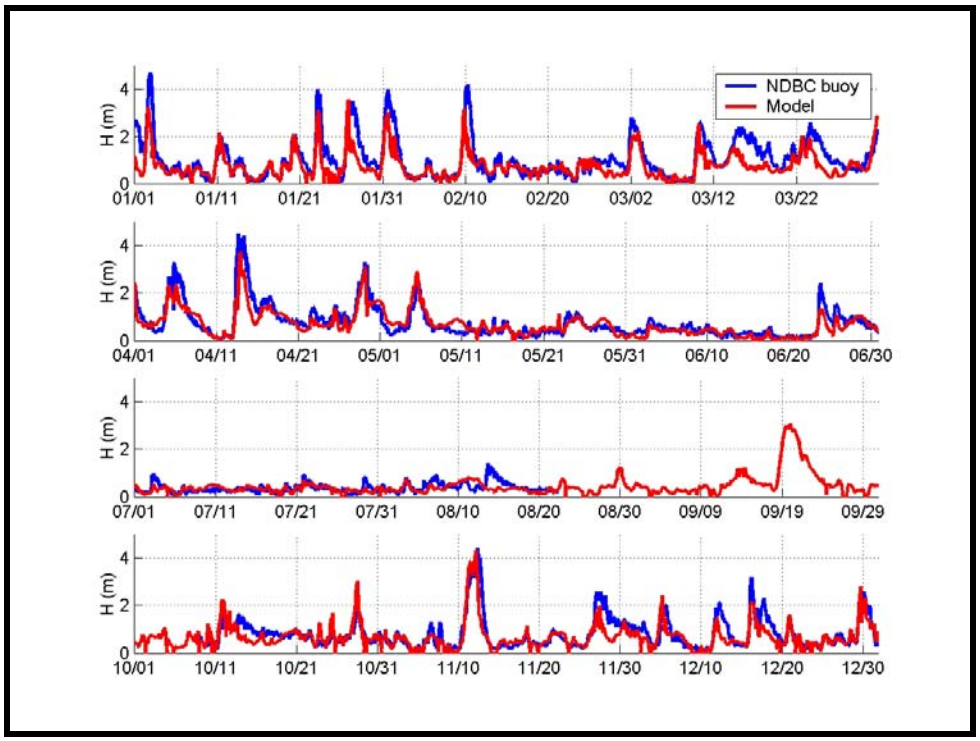

Figure 4-16. Comparison of observed (blue line) and modeled (red line) wave height (m) for 1987 at NDBC station 44013.

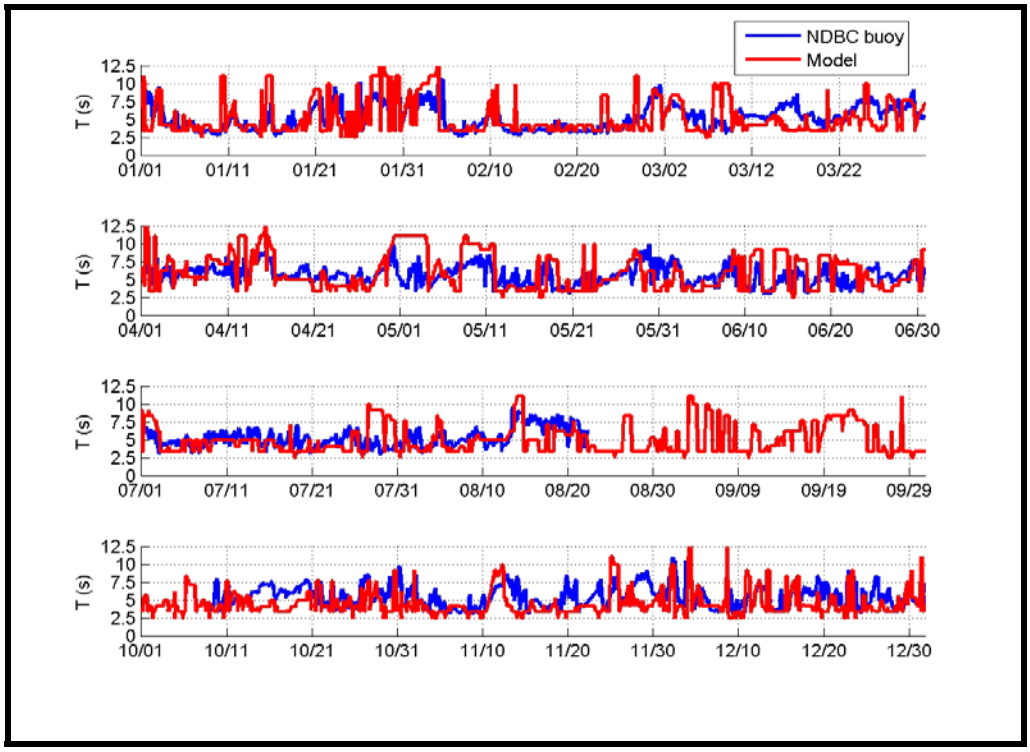

Figure 4-17. Comparison of observed (blue line) and modeled (red line) wave period (s) for 1987 at NDBC station 44013.

Figure 4-18 illustrates STWAVE results for the intermediate grid modeling domain, for waves approaching from the northeast (36.5 to 59 bin), the most energetic approach direction of the typical condition cases. The color map corresponds to the distribution of significant wave height (meters) throughout the modeling domain. Reds indicate higher wave heights, while blues indicate small wave heights. The model simulation was conducted at depths and shoreline positions corresponding to mean water level. Arrows on the figure represent the modeled wave direction as they propagate and approach the shoreline. The directions become more shore-normal as the waves get closer to the coastline and are affected by the irregular bottom bathymetry. The last visible arrow row indicates significant redirection towards the coastline, as the waves become more shore-normal. Figures for all approach directions for the intermediate grid modeling domain are presented in Appendix A.

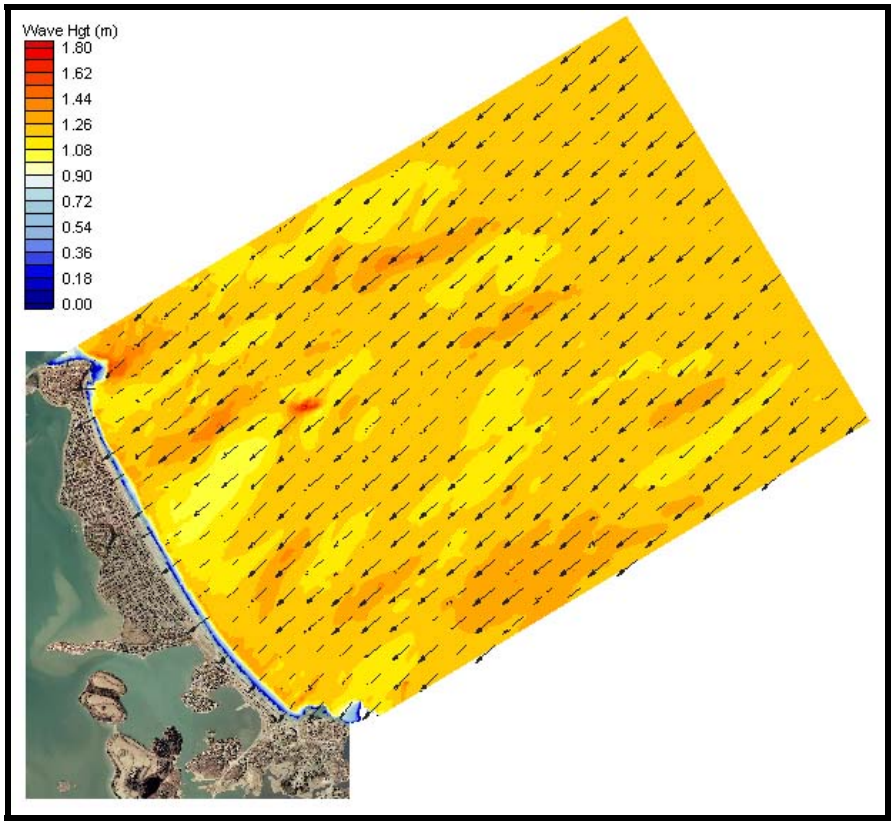

Figure 4-18. Spectral wave modeling results for a northeast approach direction (36.5-59 degree bin). Wave height is presented in meters.

Figure 4-18 shows how the bathymetric features along the Nantasket shoreline affect wave energy for this specific approach direction. For example, wave focusing is shown to occur at Allerton Hill due to wave refraction. To the south, wave shadowing is shown to occur in lee of Ultonia Ledge and Allerton Hill. In between Ultonia Ledge and Harding Ledge, larger waves are allowed to penetrate toward the shoreline (as illustrated by the darker orange region). With its shallow water depths, Harding Ledge causes wave shoaling and diffraction offshore Strawberry Hill. The wave energy in lee of Harding Ledge is reduced, as is shown by the pale

yellow coloring extending from Harding Ledge southwest toward the coastline. Offshore the DCR region, south of White Head, more wave energy is allowed to penetrate toward the shoreline as can be observed by the dark orange streaks and dark orange region close to the shoreline. Of course, this example only represents one specific approach direction, and all average annual approach directions must be considered to represent the overall dynamics along Nantasket Beach. The variability in the wave climate is clearly indicated by the differences in nearshore wave patterns arising from the various input spectra approach directions. In order to arrive at an accurate estimation of the sediment transport in the region, results from the wave model can be used to generate the sediment transport flux. This includes waves coming from all directions and having various wave heights and periods. Figures for the remaining approach directions for the Nantasket Beach region are presented in Appendix A.

4.6.2 High-Energy Events

The wave transformation model was also used to simulate high energy events, as discussed in Section 4.4.2. The simulation of specific storm events was important to quantify the short-term impacts that occur during these energetic scenarios. Sediment transport along the coastline can be significant during these short episodic events. Figures 4-19, 4-20 and 4-21 show the spectral wave model results for the 10-, 50-, and 100-year return period storm events, respectively. Wave heights are significantly higher than the annual average directional cases, as the offshore wave heights range from 6.7 m (22 feet) for the 10-year storm to 8.5 m (28 feet) for the 100-year storm. All storm event model results are plotted using the same color scale for wave height so that a comparison of the storm waves offshore Nantasket Beach can be made. The storm event spectral model results were passed along to the nearshore, refined model grid to assess direct impacts on Nantasket Beach, as they were for the annual average directional bin cases.

Figures 4-22 through 4-24 show the spectral wave model results from the April Fools' Day Blizzard (April 1, 1997), Perfect Storm (October 31, 1991), and the Nor'easter storm (Dec. 11-14, 1992) simulations, respectively. The wave model results in each figure are plotted on the same color scale as the return period storm model results were, for inter-comparison. The waves associated with the April Fools' Day Blizzard and the Perfect Storm are similar to those simulated for a 10-year return period event with the April Fools' Day storm having the largest offshore waves (exceeding 7 meters or 23 feet). The simulation of the Nor'easter storm which occurred in December of 1992 produced the largest waves offshore of Nantasket Beach (up to 8.9 meters or 29.2 feet) due to the larger wave period and the wave orientation (62 degrees relative to North), which is close to shore-normal.

Overall, the storm simulations show that the region offshore of Nantasket beach can become a high-energy environment conducive to large wave events (both in wave height and period). These large wave events, although short-lived, can potentially have the most impact on the shoreline of Nantasket beach in mobilizing sediments and inflicting damage on the existing coastal infrastructure.

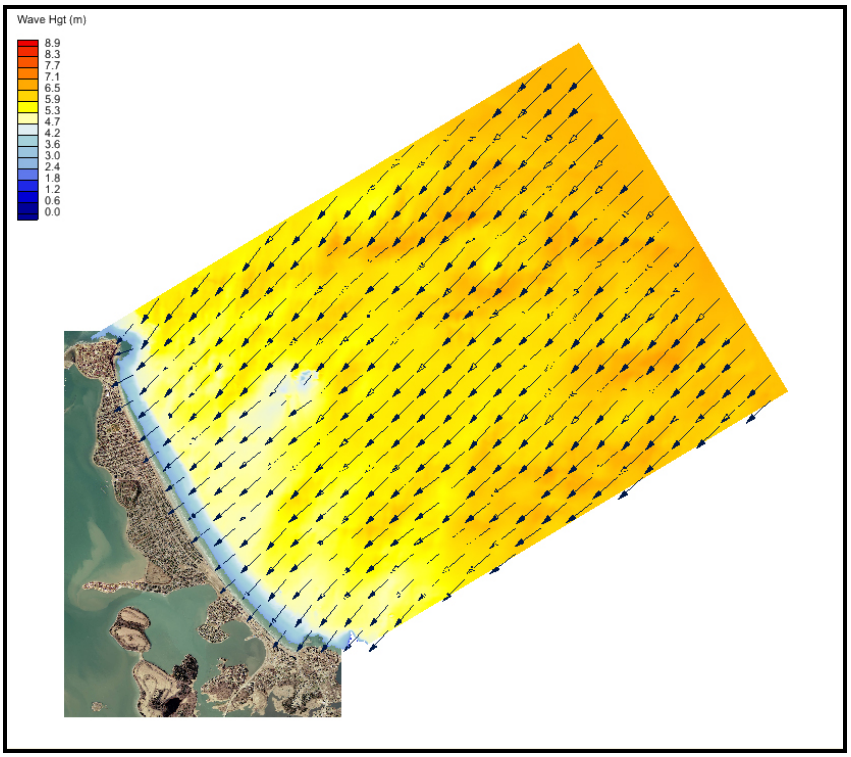

Figure 4-19. Spectral wave modeling results for a 10-year return period storm in the Nantasket Beach region. Wave height is presented in meters.

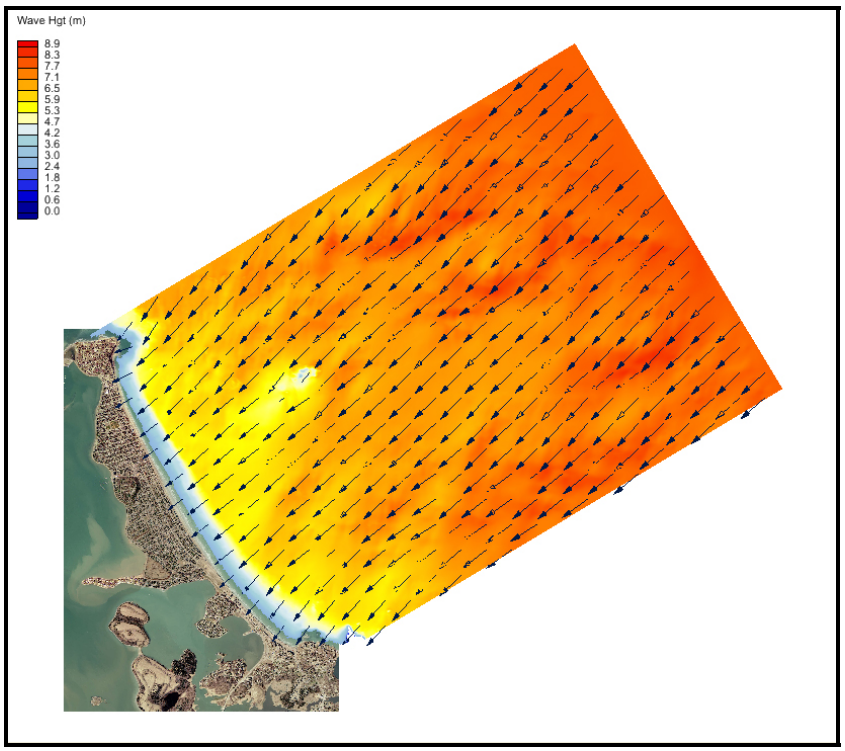

Figure 4-20. Spectral wave modeling results for a 50-year return period storm in the Nantasket Beach region. Wave height is presented in meters.

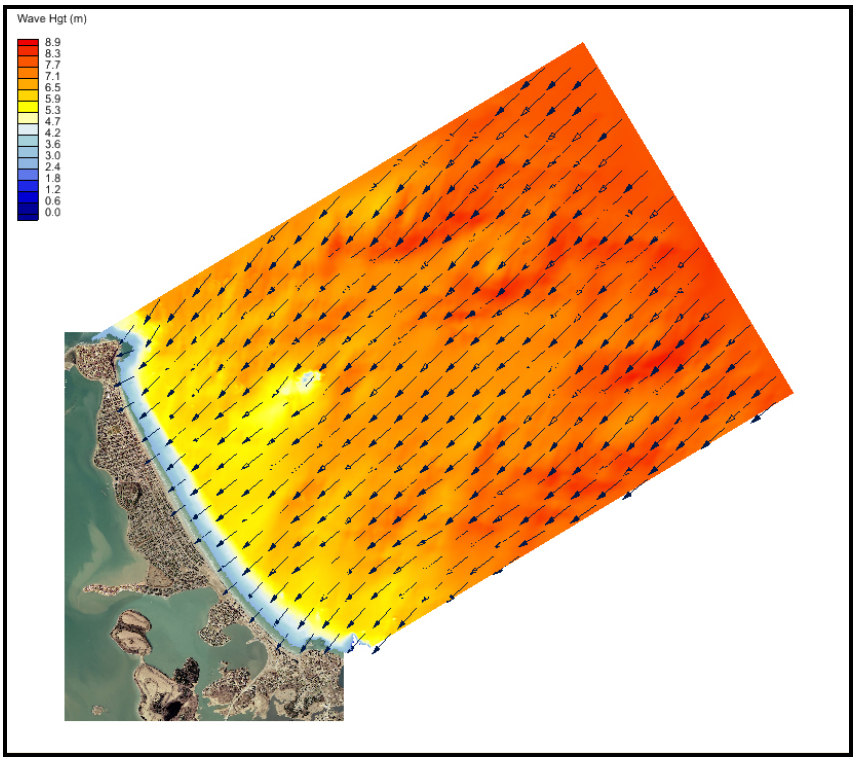

Figure 4-21. Spectral wave modeling results for a 100-year return period storm in the Nantasket Beach region. Wave height is presented in meters.

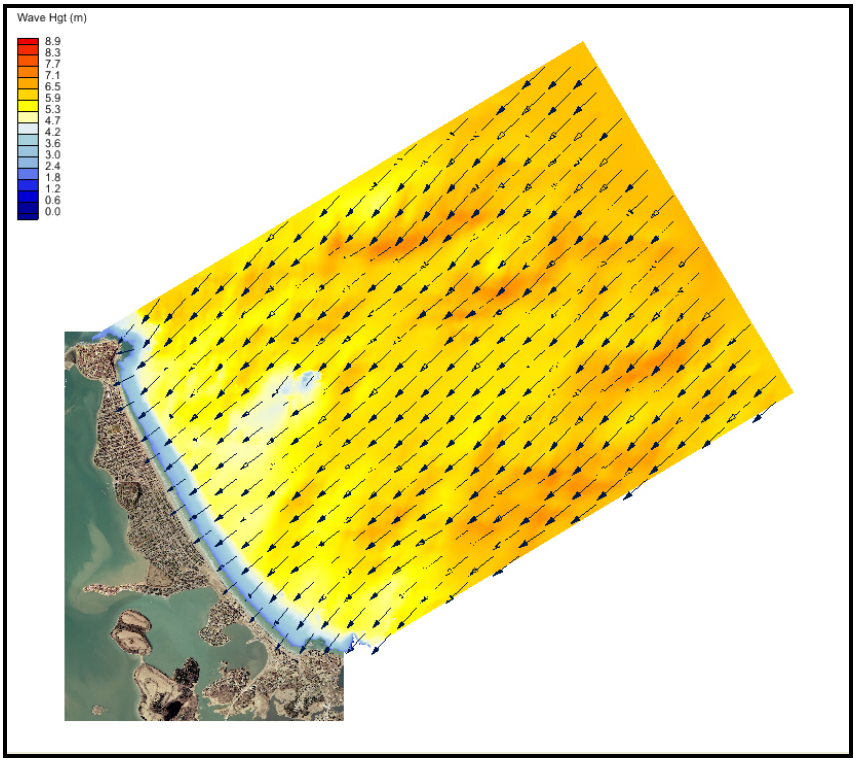

Figure 4-22. Spectral wave modeling results for the April Fools' Day Blizzard (April 1, 1997) in the Nantasket Beach region. Wave height is presented in meters.

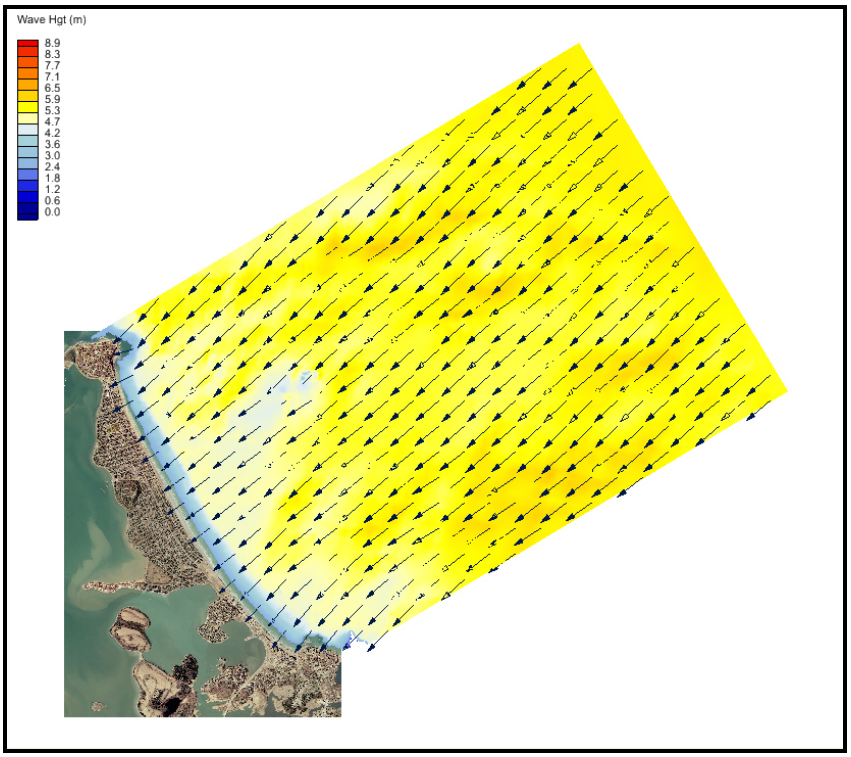

Figure 4-23. Spectral wave modeling results for the Perfect Storm (October 31, 1991) in the Nantasket Beach region. Wave height is presented in meters.

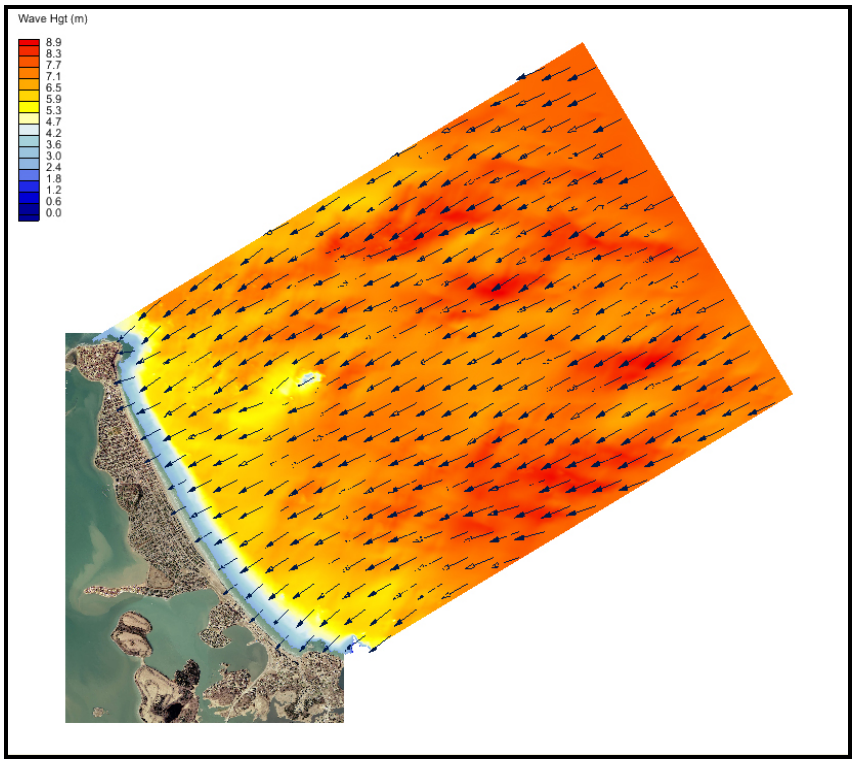

Figure 4-24. Spectral wave modeling results for the Nor'easter storm (Dec. 11-14, 1992) in the Nantasket Beach region. Wave height is presented in meters.

4.7 SEA LEVEL RISE

Another important consideration in the wave transformation simulations, as well as the long-term planning for Nantasket Beach, is potential sea-level rise. The potential impacts of sea-level rise present an additional natural hazard risk for developed areas within the coastal zone. The impacts are similar to those caused by shoreline erosion, and include increased flooding and wave activity in areas previously not affected, as the shoreline moves increasingly further inland.

Scientific research indicates that global (eustatic) sea level has risen approximately 6 to 8 inches (15 to 20 cm) over the last century (EPA, 2000). This eustatic rise in sea level has occurred in part due to glacial isostasy, warming of the world oceans, and melting of continental glaciers. Along most of the US coast, tide gage data show that local sea levels have been rising 2.5 to 3.0 mm/yr, or 10 to 12 inches over the past century. Because the tide gage stations measure sea level relative to the land, which includes changes in the elevations of both water levels and the land, tide gages measure relative sea level rise, and not the absolute change in sea level. Therefore, the rates of relative sea level rise have greater relevance to the evaluation of coastal hazards from sea level rise, than do changes in eustatic sea level.

While the topic of accelerated sea level rise is still heavily debated, the Intergovernmental Panel on Climate Change (IPCC) has undergone a considerable effort to analyze and review the current state of knowledge and provide an estimated range of predicted sea level rise into the next century. For Nantasket Beach, sea level rise estimates were evaluated from a number of sources, including NOAA (2008) and IPCC (2007) estimates. Model simulations were conducted for predicted sea level rise using the projected service life of the proposed alternative and a range of potential rates. The model simulations were relatively insensitive to the use of various rates of sea level rise (i.e., the results were not impacted by changing the rate of sea level rise). Therefore, sea levels based on historical rates of measured sea level rise (NOAA, 2008), which provide a reasonable median estimate of sea level rise predictions, were used in all model simulations.

Long-term tide gage data collected at the NOS (National Ocean Service) station in Boston Harbor, MA provide the closest measurements to Nantasket Beach (NOAA, 2008). Rates of rise computed from the Boston Harbor data set spanning the period from 1921 to 2006 indicate a relative rise in sea level of 2.63 mm/year, or 10.4 inches over the past century (Figure 4-25). This rate of sea level rise (2.63 mm/yr) was included in all model simulations, including assessment of the alternative(s) performance. These estimates help determine potential impacts of rising sea levels on future conditions at Nantasket Beach. Ultimately, the range of potential sea level rise scenarios do not have a significant impact on the model results over the expected service life of the various alternatives (both structural and beach nourishment).

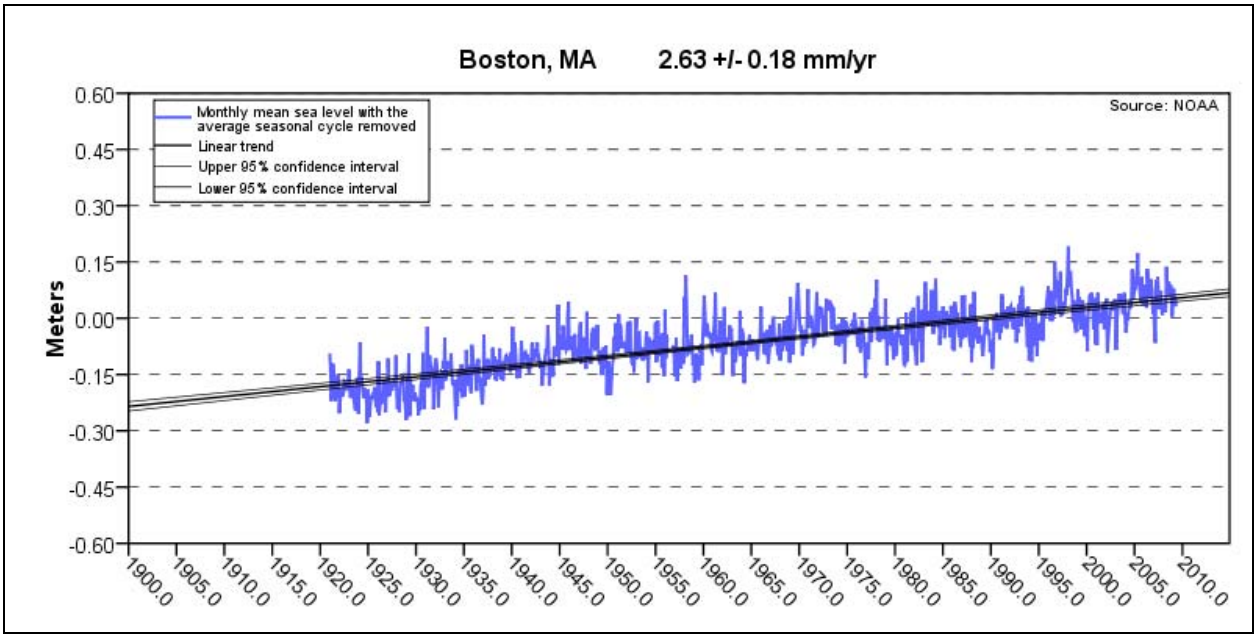

Figure 4-25. Long-term tide data from NOS gages at Boston Harbor showing relative rise in sea level (NOAA, 2008).

5.0 SEDIMENT TRANSPORT

Understanding the wave transformations is a critical step in the determination of shoreline processes and sediment transport in the nearshore region. In order to evaluate and assess any alternative that may be considered in the coastal region along Nantasket Beach, the sediment transport dynamics for the current conditions must be understood. This chapter obtained estimates of the alongshore sediment flux integrated across the surf zone, and subsequently estimated the regional sediment transport for Nantasket Beach. The sediment transport model was also used to determine the performance of various seawall alternatives for Nantasket Beach.

5.1 SEDIMENTS

The characterization of natural sediments at Nantasket Beach is an important first step in evaluating littoral processes and the movement of sediments along the shoreline. In addition, knowledge of the grain size of the beach sediments help to define the design grain size for any shore protection alternative involving beach nourishment.

The Nantasket Beach Characterization Study (USACE, 2006) was utilized to provide information on the type of sediments and grain sizes that exist along the beach and within the surf zone. The USACE obtained 64 vibracore and ponar samples along five cross-shore profiles. The samples were taken in the fall of 2005 (September 30 to October 8) along the cross-shore profiles numbered 1, 3, 5, 7, and 8 (Figure 4-3). The sample depths were to be four feet unless penetration was restricted, and the samples were then subdivided into upper and lower portions. The actual depth range for the upper samples was 0.7 to 2.2 feet (0.2 to 0.7 meters). Grain size analyses showed that the sediments were generally fine-grained (0.15 to 0.25 mm) with coarser sediments found on the landward portion of the profiles and offshore at the deeper sampling locations.

The study also quantified the cobble/gravel (>4.76 mm) and sand fractions (4.76 to 0.074 mm). In general, relatively less sand was found in the lower samples (2 to 4 feet below the surface) compared to cobble and/gravel. The average percentage of sand for all of the lower samples was 73%, while the average percentage of sand for the upper samples was 82% (Table 5-1). Profile #8 had the lowest percentages of sand at 56% and 62% for the upper and lower samples, respectively.

Table 5-1. Average cross-sectional profile sand fractions (USACE, 2006).

Profile Number	Lower Sample Average % Sand	Upper Sample Average % Sand
1	89.0	94.9
3	82.5	90.2
5	66.0	80.7
7	66.5	80.9
8	56.2	62.1

For the sediment transport modeling, a mixed grain size approach was utilized to incorporate the presence of the combined cobble/gravel/sand material found nearshore and on Nantasket Beach. This approach is further detailed in the sections to follow. For this modeling, it was necessary to determine a representative median grain size (D_{50}) for both the cobble/gravel and sand fractions. For the sand fraction, the median grain sizes determined in USACE (2006) for each of the upper samples were averaged to define a representative sand D_{50} equal to 0.25 mm. The median grain sizes of the cobble/gravel fraction for each of the upper samples were averaged to define a representative cobble/gravel D_{50} equal to 28 mm. The analysis was conducted on the upper samples in evaluating sediment transport, since this layer is subjected to the mobilization forces of waves and currents. The spatial distribution of the cobble/gravel and sand fractions was used in the sediment transport modeling presented in the chapter.

5.2 ANALYSIS APPROACH

Sediment movement in the coastal zone, as well as the effects of coastal structures on shoreline processes, can be estimated by using various types of sediment transport models. These models may differ in their detail, in their degree of representation of the physics of the problem, in their complexity, and in other manners. Process-based sediment transport models are those that directly address the fundamental physics of waves and sediment transport. These models which focus on those essential physics are able to encompass a variable wave field. Such sediment transport models may not represent all the details exactly, but they can be used to demonstrate regional sediment transport trends and the spatial influence of coastal structures on adjacent shorelines. The sediment transport model presented herein is a process-based model which determines regional sediment transport trends in the presence of time-variable (in direction and height) waves.

The goal of this model is to provide a physically-based representation of alongshore currents and sediment transport driven by breaking waves in the surf zone. The specific objective is to obtain estimates of the alongshore sediment flux integrated across the surf zone. To achieve this physically-based representation, it is important to understand what longshore processes may cause erosion or accretion of sediments. Typically, a section of shoreline can be represented with a cell, having a finite length along the shore. Sediment enters this cell from the updrift side (i.e., the side that alongshore currents are directed towards), and leaves the cell from the downdrift side. The net sediment balance will vary depending on the height, period, and direction of the nearshore waves.

A wave passing a cell may have the following effect on sediment:

(1) The same amount of sediment enters a cell as leaves the cell.

(2) More sediment enters a cell than leaves the cell.

(3) More sediment leaves a cell than enters the cell.

The first scenario leads to a stable cell shoreline. The shoreline neither erodes nor accretes. The second scenario leads to accumulation of sand in the cell, causing accretion (i.e., building out of the shoreline). This scenario is referred to as sediment convergence, as sediment converges in the cell. The final scenario leads to a net loss of sediment in the cell, causing erosion. This

possibility is referred to as sediment divergence, as sediment diverges from that cell. Thus, shoreline erosion or accretion can be thought of as a simple divergence or convergence of sediment moving alongshore. Of course, storms also can move sand offshore and other waves may move sand onshore; however, the focus of this chapter is on the alongshore movement of sand, which results in a majority of the net changes of the shoreline.

The regional sediment transport model requires the results of the wave field presented in Chapter 4. The sediment transport model consists of a hydrodynamic component to determine the wave-induced currents, and a sediment transport component to quantify the amount of sediment moved by those wave-induced currents. The hydrodynamic component is based on a standard set of equations that are widely accepted and generally used, more specifically known as the steady-state, depth-averaged mass and momentum equations for a fluid of constant density. These equations are standard in many surf zone applications (e.g., Mei, 1983) and provide a state-of-the-art representation of the alongshore current. The sediment transport component is based on a recent peer-reviewed and published formulation by Haas and Hanes (2004), which has been shown to be consistent with recent complex formulae for wave-driven sediment transport and with the Coastal Engineering Research Center (CERC) formula (USACE, 2002) for the total (laterally-integrated) alongshore sediment flux.

For Nantasket Beach, a high-resolution bathymetric grid was generated using the nearshore bathymetry/topography (Figure 5-1). The grid for the sediment transport model is the same high-resolution nested grid used for the STWAVE wave transformation model, with 10 m (32 ft) cells spanning 1,920 m (6,300 ft) in the cross-shore direction and 6,170 m (20,243 ft) in the alongshore direction. The wave transformation model was executed for the average annual conditions and the high-energy events on this high-resolution grid. The results from the STWAVE simulations are then applied as input into the sediment transport model.

Given the native geology of the New England area, many beaches consist of a mixture of sand, gravel and cobble. The analysis of sediment transport along Nantasket Beach includes this mixture of grain sizes. The sediment transport model includes an assessment of the potential mobilization of sediments of different grain sizes (i.e., the ability of the waves to initialize movement), as well as the amount of sediment available for transport. Specifically, simulations of sediment transport used the following two grain sizes based on USACE (2006): (1) a fine-to-medium grained sand having a d_{50}=0.25 mm, and (2) a coarse-grained pebble having a d_{50}=28 mm.

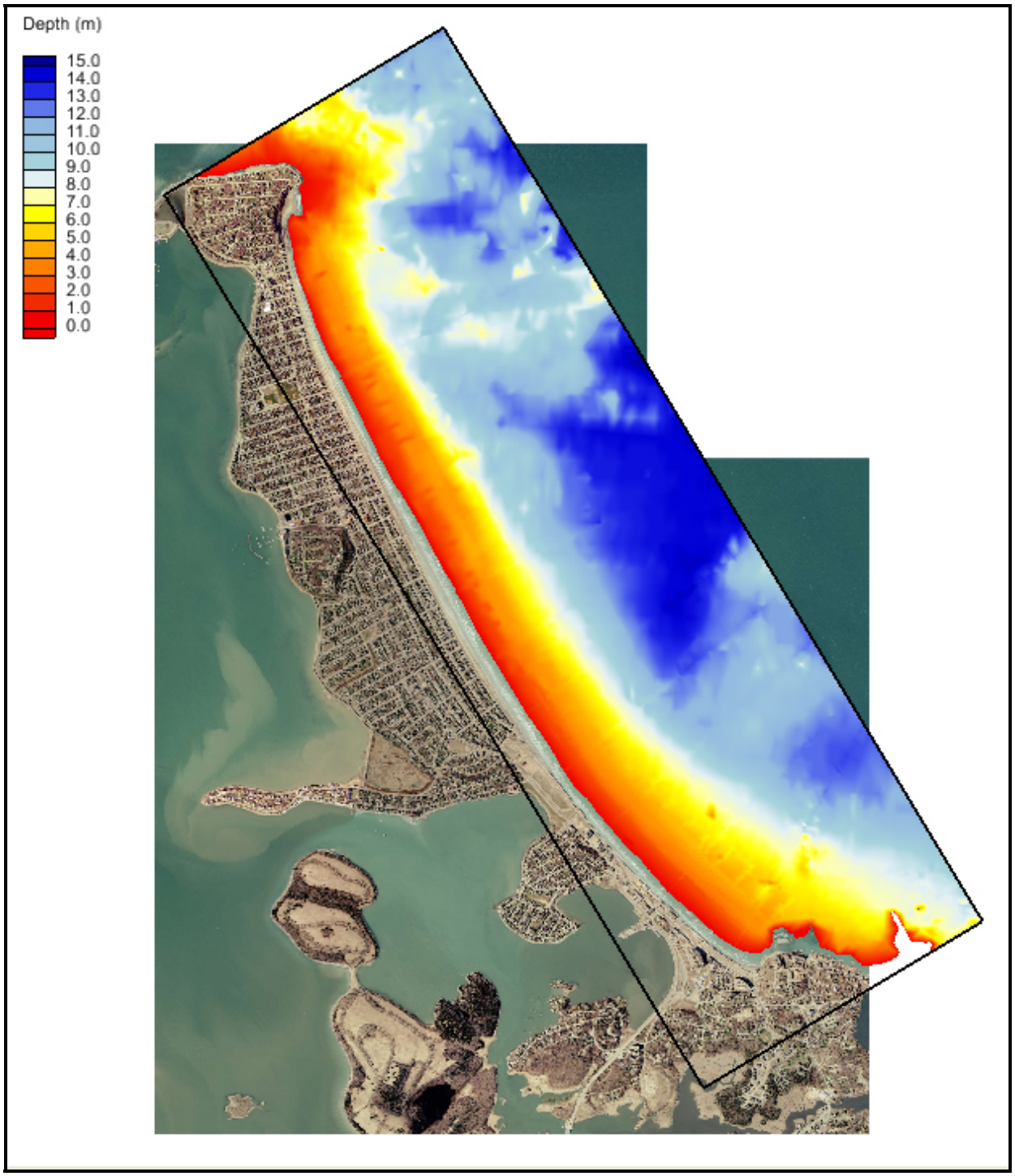

Figure 5-1. Nearshore, refined bathymetric grid for Nantasket Beach used in wave transformation and sediment transport models. Depth shown in meters relative to Mean Tide Level. Nopt for navigational purposes.

5.3 MODEL DESCRIPTION

As stated above, the sediment transport model used for the analysis of Nantasket Beach is a process-based model that uses standard steady-state, depth-averaged mass and momentum equations for the hydrodynamics, in conjunction with calculations of longshore sediment transport based on a methodology by Haas and Hanes (2004). The following subsections present in detail the model theory and formulation of the various model components, but it is not critical that the reader becomes familiar with the concepts presented below to understand the results of the modeling.

5.3.1 Hydrodynamic Component

Governing Equations

The wave-averaged, depth-integrated, mass-conservation equation for a constant-density fluid with a rigid lid is

$$\frac{\partial(Hu)}{\partial x}+\frac{\partial(Hv)}{\partial y}=0, \tag{5-1}$$

and the wave-averaged, depth-averaged momentum equations for a non-rotating system are

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial \eta}{\partial x}-\frac{ru}{H}+\frac{\tau_x}{(\rho H)} \tag{5-2}$$

and

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial \eta}{\partial y}-\frac{rv}{H}+\frac{\tau_y}{(\rho H)}. \tag{5-3}$$

Here x and y are the horizontal coordinates, t is time, u and v are the x and y components of the wave-averaged and depth-averaged horizontal velocity, g is the gravitational acceleration, η is the surface displacement, r is the bottom resistance coefficient, H is the water depth, ρ is the fluid density, and τ_x and τ_y are $-(1/H)\partial S_{xx}/\partial x - (1/H)\partial S_{xy}/\partial y$ and $-(1/H)\partial S_{xy}/\partial x - (1/H)\partial S_{yy}/\partial y$, respectively, where S_{xx}, S_{xy}, and S_{yy} are the components of the wave-induced radiation stress tensor (Mei, 1989).

A stream function (ψ), which defines the two-dimensional flow, can be defined by

$$(u,v)=H^{-1}\left(\frac{\partial \psi}{\partial y},-\frac{\partial \psi}{\partial x}\right), \tag{5-4}$$

which satisfies (5-1) identically, and an equation for the wave-averaged potential vorticity ξ, defined by

$$\xi = \frac{1}{H}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = -\frac{1}{H}\frac{\partial}{\partial x}\left(\frac{1}{H}\frac{\partial \psi}{\partial x}\right) - \frac{1}{H}\frac{\partial}{\partial y}\left(\frac{1}{H}\frac{\partial \psi}{\partial y}\right), \tag{5-5}$$

is obtained by taking the curl of (5-3) and (5-4) and dividing the result by H, which yields

$$\frac{\partial \xi}{\partial t} + u\frac{\partial \xi}{\partial x} + v\frac{\partial \xi}{\partial y} + \lambda\xi = \lambda\xi_0 + \frac{v_0 - v}{H}\frac{\partial \lambda}{\partial x} - \frac{u_0 - u}{H}\frac{\partial \lambda}{\partial y} \tag{5-6}$$

where $\lambda = r/H$, $u_0 = \tau_x/(\rho r)$, $v_0 = \tau_y/(\rho r)$, and $\xi_0 = H^{-1}(\partial v_0/\partial x - \partial u_0/\partial y)$.

In the present application, H is known, r is assumed to be given in the linear long wave approximation by $c_d[H_s/(4H)](gH)^{1/2}$ (e.g., Mei, 1983), and τ_x and τ_y are output from the wave transformation model. Here $c_d = 0.003$ is the drag coefficient for the surf zone under breaking waves (Feddersen et al., 1998) and H is the significant wave height, defined to be four times the standard deviation of the wave-induced oscillatory surface displacements, which is also given by the wave model. With this information, (5-4), (5-5) and (5-6) determine the coupled evolution of ξ, ψ, u and v.

<u>Boundary Conditions</u>

The coordinate system is defined so that x is positive onshore, $x = 0$ defines the offshore boundary of the computational domain, $y = 0$ and $y = L_y$ denote the alongshore boundaries of the computational domain, and the shoreline is a potentially irregular boundary in $x > 0$. In the present application, there can be only one shoreline, and H is restricted to be positive and nonzero everywhere in the domain. Boundary conditions are required for ψ on all boundaries and for ξ on inflow boundaries. The following boundary conditions are intended for applications in which the offshore boundary is well seaward of the surf zone and the shoreline at the alongshore boundaries is approximately straight and parallel to the y axis.

At the offshore boundary, the forcing and velocity fields are assumed to be weak, so that the alongshore velocity and potential vorticity are negligibly small and the offshore boundary conditions become

$$\frac{\partial \psi}{\partial x} = 0 \text{ and } \xi = 0 \text{ at } x = 0. \tag{5-7}$$

At the alongshore boundaries, the velocity field is assumed to be approximately confined to the y direction and approximately independent of y, so that the alongshore boundary conditions become

$$\frac{\partial \psi}{\partial y} = 0 \text{ and } \frac{\partial \xi}{\partial y} = 0 \text{ at } y = 0, L_y. \tag{5-8}$$

The shoreline is a streamline, so that ψ on the shoreline must be a constant, which may be set to zero, without loss of generality:

$$\psi = 0 \text{ on the shoreline.} \tag{5-9}$$

The shoreline is not an inflow boundary, so that the shoreline potential vorticity does not affect the solution.

<u>Numerical Solution</u>

Equations (5-4), (5-5) and (5-6) are solved by means of a standard numerical procedure described, for example, by Roache (1998). Spatial derivatives are represented using finite differences on a rectangular grid with equal spacing dx in the x and y directions. The representation of the spatial derivatives is second-order-accurate except that the advective terms in (5-6) are represented by a first-order upwind scheme. The time derivative in (5-6) is represented by an explicit first-order scheme with time step dt. The solution for each application begins from rest and advances in time until it reaches an asymptotic steady state. At each time step, the potential vorticity ξ is advanced according to (5-6), the elliptic equation (5-5) is then solved for the stream function ψ using Jacobi iteration (e.g., Lynch 2004), and finally the velocities u and v are calculated according to (5-4). Attainment of an approximate steady state requires that the solution advance until t is approximately equal to 3 times the maximum value of λ. Stability requires that the Courant number $(u^2+v^2)^{1/2}dt/dx$ based on the maximum flow speed be less than approximately unity.

5.3.2 Sediment Transport Component

Haas and Hanes (2004) proposed a simple formula for the alongshore sediment flux, which is, in the present notation,

$$q_s = \left(\frac{2c_1c_d}{g}\right) < |\boldsymbol{u}|^2 > u_s \tag{5-10}$$

where q_s is the alongshore component of the sediment flux, c_1 is an empirical constant approximately equal to 1.3, brackets denote an average over many wave periods, $\boldsymbol{u}$ is the instantaneous velocity vector (including both the wave-induced oscillatory velocity and the current), and u_s is the alongshore component of the current velocity.

In the present application, $\boldsymbol{u}$ is assumed to be dominated by wave-induced oscillatory velocities and to be related to wave-induced surface displacement by linear long wave theory, so that $<|\boldsymbol{u}|^2>$ approximates $[H_s/(4H)]^2gH$. In addition, a right-handed coordinate system (s,n,z) is defined so that s is locally alongshore, n is locally shore-normal, and z is vertical and positive upward. In this coordinate system, $Hu_s = \partial\psi/\partial n$. Equation (5-10) can therefore be written as:

$$q_s = 2c_1c_d\left[\frac{H_s}{4H}\right]^2\frac{\partial\psi}{\partial n} \tag{5-11}$$

In the surf zone, H_s/H is approximately constant ($H_s/H < 0.63$ is explicitly assumed by STWAVE), so that (5-11) can be integrated with respect to n across the surf zone to yield

$$Q = \frac{c_1 c_d}{8}\left[\frac{H_{sb}}{H_b}\right]^2 \psi_b \tag{5-12}$$

where Q is the alongshore sediment flux integrated across the surf zone and subscript b denotes evaluation at the break point, (i.e., at the seaward edge of the surf zone). In the present application, (5-12) is used to determine the sediment flux integrated across the surf zone after the stream function has been computed from the hydrodynamic component.

In determining sediment mobility, the threshold for mobility was established using the criterion parameter θ_{cr}, defined by Soulsby (1997) as:

$$\theta_{cr} = \frac{0.30}{1+1.2D_*} + 0.055\left[1-\exp\left(-0.02D_*\right)\right] \tag{5-13}$$

where D_* is the dimensionless grain size given by:

$$D_* = \left[\frac{g(s-1)}{\nu^2}\right]^{1/3} d_{50} \tag{5-14}$$

with g being the acceleration due to gravity, ν is the kinematic viscosity of water, d_{50} is the median grain size, and $s = \rho_s/\rho$.

The computation of the maximum bed shear stress due to the combined waves and currents, employed the algebraic expression by Soulsby (1997), which best fits the analytical model of Grant and Madsen (1979). The drag coefficient c_d of steady current in absence of waves and the wave friction factor f_w for waves in absence of current were determined as:

$$f_w = 1.39\left(\frac{A}{z_o}\right)^{-0.52} \tag{5-15}$$

$$c_d = \left[\frac{\kappa}{1+\ln\left(z_o/h\right)}\right]^2 \tag{5-16}$$

where $A=U_wT/2\pi$, the bed roughness length $z_o=d_{50}/12$, $\kappa=0.40$ is von Karman's constant, and h is the water depth.

5.4 SEDIMENT TRANSPORT RESULTS

5.4.1 Average Annual Directional Approaches

This section discusses the use of the regional wave model in determining the nearshore hydrodynamics, and subsequently the average annual sediment flux (i.e., the rate of sediment moving along the coast) along Nantasket Beach between Point Allerton and Atlantic Hill. The computed sediment transport rates are presented for the average annual wave conditions for the evaluated directional approaches.

The regional wave modeling results (Chapter 4) were used as input into the non-linear sediment transport model. Wave results from each of the average annual directional spectra bin simulations were used to develop the complete summary of sediment movement for various wave conditions. Simulations of sediment transport were conducted using a multi-grain size representation (d_{50}=0.25 mm and 28 mm) and the results were assessed to define the average annual sediment transport regime throughout the Nantasket region.

Model simulations were performed for the wave conditions represented by the directional bin spectra presented in Table 4-2. Figure 5-2 illustrates the sediment transport results for waves approaching from the northerly (351.5 to 14 degree) approach bin. Northwest (Point Allerton) is located towards the top of the plot; southeast (Atlantic Hill) is located to the bottom of the plot. Figure 5-2 presents the local bathymetry (left hand panel), the resultant wave height from the regional wave transformation model (center panel), and the associated sediment flux (right hand panel). The sediment flux represents the rate of sediment moving along the coast. Negative values indicate movement towards the northwest (from bottom to top of the figure); positive values indicate movement towards the southeast (from top to bottom of the figure). The rates are presented in units of 100,000 cubic yards per year (cy/yr) and can be used to quantify the annual sediment transport at Nantasket Beach. These calculations assume that sediment is available on the beach for transport (e.g., potential transport). If the shoreline is armored (e.g., revetment), or doesn't have a sediment source readily available, then the sediment transport rates may vary compared to the values presented herein.

As is expected for this northerly wave approach scenario, the sediment flux in Figure 5-2 shows sediment transport in a southeast direction along nearly the entire stretch of Nantasket Beach (i.e., a positive sediment flux corresponds to sediment transport from the top of the plot [Point Allerton] towards the bottom of the plot [Atlantic Hill]). The sediment transport rate is reduced relative to the rest of the beach just south of Point Allerton, due to the wave sheltering provided by the rocky formation. Advancing towards the southeast, the rate of gross transport increases, varying between 38,000 and 76,000 cy/yr, with the maximum reaching near 92,000 cy/yr.

As was presented in Table 4-2, this approach direction (351.5 to 14 degrees) contains a low amount of wave energy and has a small percentage of occurrences, and therefore produces smaller rates of sediment transport compared to other approach directions. This directional approach was shown to clearly indicate how the directionality of the transport correlates with the directionality of the waves. This represents only a single approach direction, and is only representative of times when waves are arriving from the north. All approach directions must be evaluated and aggregated to determine the net sediment transport movement at Nantasket Beach.

Figures 5-3 and 5-4 display the sediment transport model results from two additional wave approach directions, the northeast (36.5 to 59 degree bin) and east (81.5 to 104 degree bin), respectively. As in Figure 5-2, the local bathymetry is presented in the left hand panel, the resultant wave height is shown in the center panel, and the associated sediment flux is shown in the right hand panel. The results presented in Figures 5-3 and 5-4 correspond to the wave model results presented in Figures 4-18 and 4-20, respectively. Figure 5-3 illustrates model results for the wave directional bin having the most wave energy, as indicated by the larger wave heights. Sediment transport for this northeasterly wave direction is again primarily directed towards the southeast; however, the transport rates are much larger. The largest sediment transport rates exist just south of Harding Ledge (Figure 4-8) where the larger waves are also shown to exist. Moving in a southeasterly direction, although the net transport along the DCR reservation is to the southeast, there are areas along the DCR reservation where the transport is directed to the northwest. These changes in direction of transport point to areas where there is either the divergence (erosion) or convergence (accretion) of sediments. These abrupt changes in the directionality of sediment transport along the DCR reservation are an indication the shoreline in this area is dynamic with an active migration of sediments.

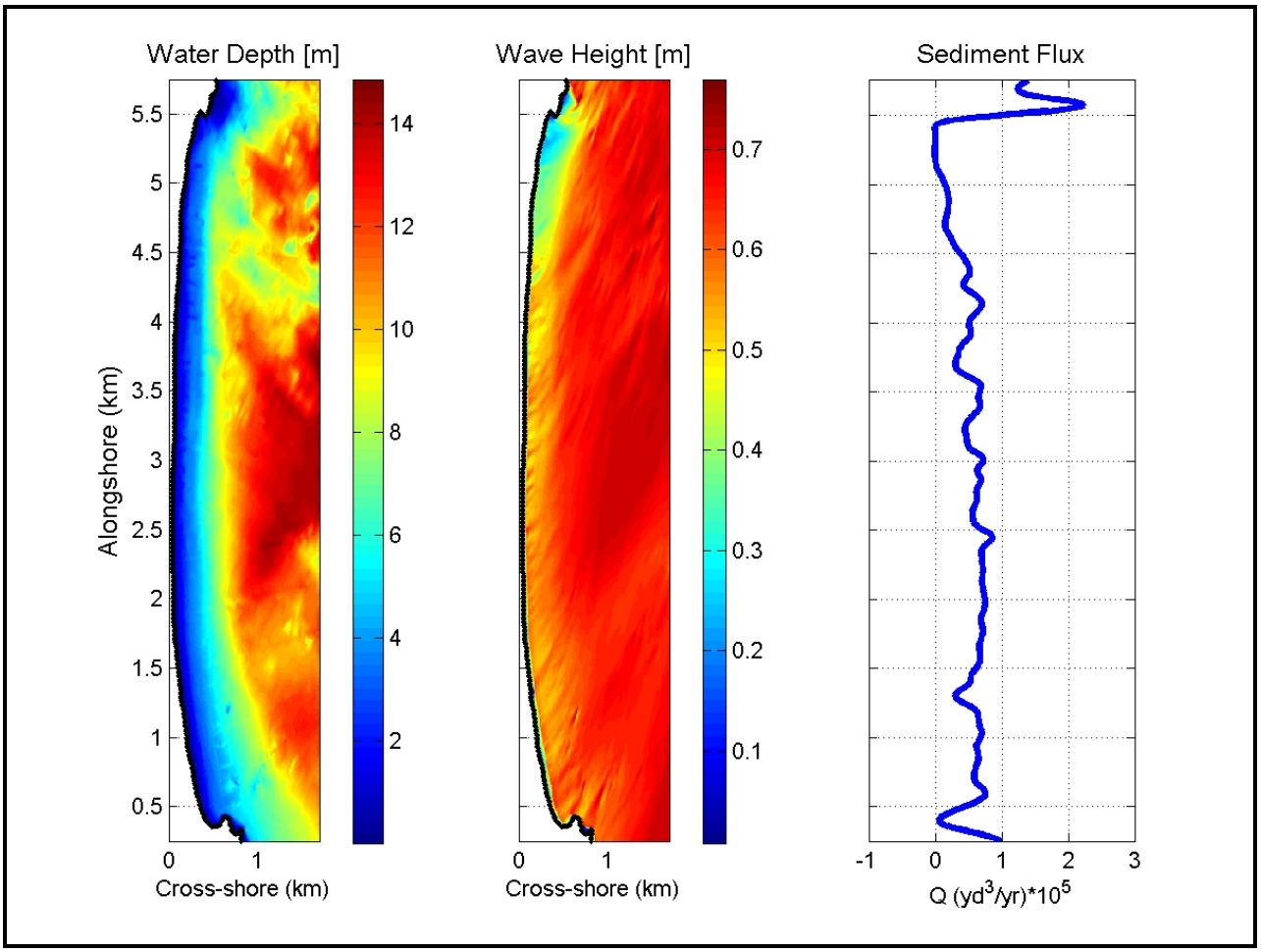

Figure 5-2. Sediment transport model results for a northerly wave approach (351.5 to 14 degrees). Water depth and wave height in meters.

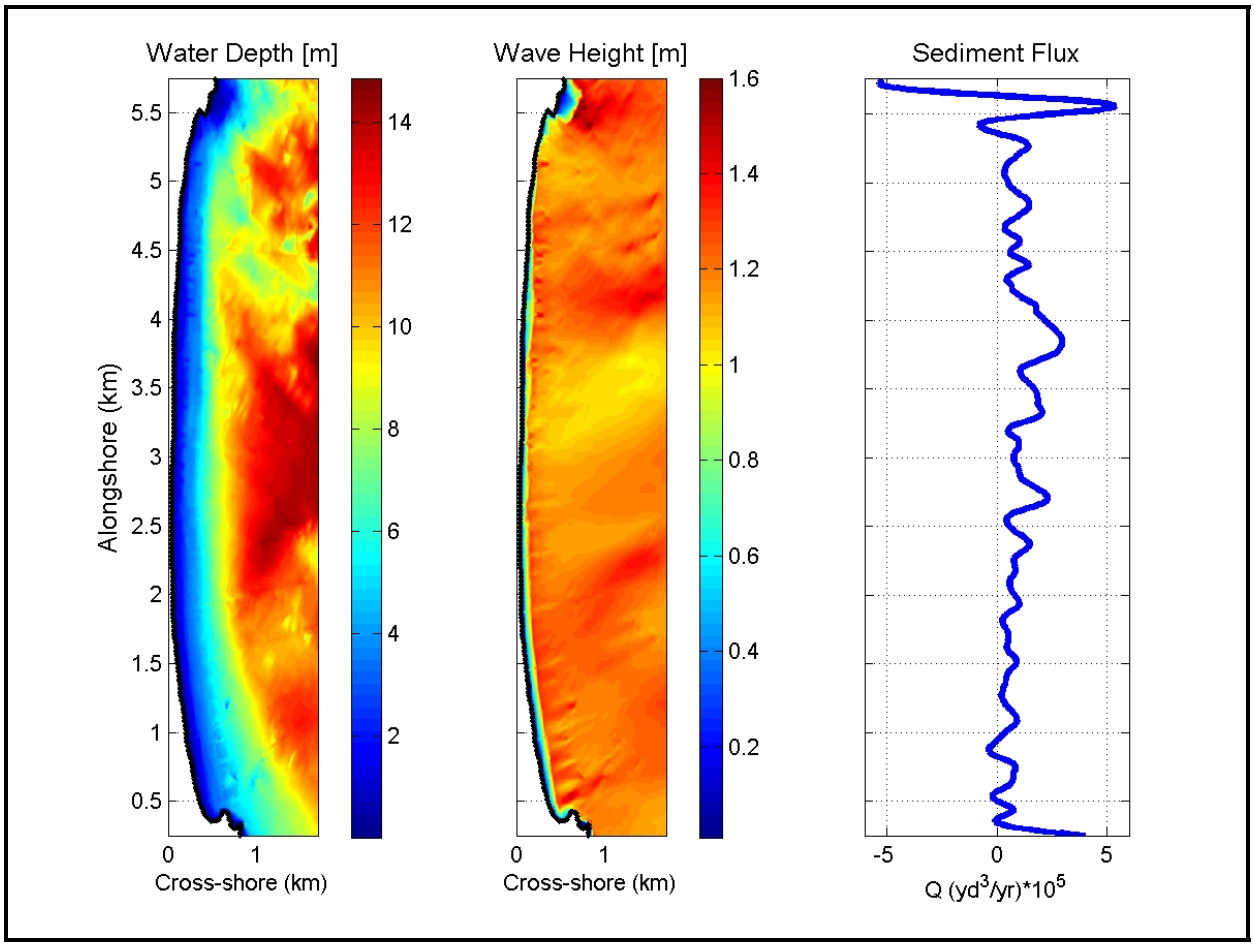

Figure 5-3. Sediment transport model results for a northeasterly wave approach (36.5 to 59 degrees). Water depth and wave height in meters.

Figure 5-4 represents a more easterly wave approach and the sediment transport rate is predominantly from the southeast to the northwest, as would be expected for this approach direction. This wave-directional bin (81.5 to 104 degrees) is the predominant wave direction for Nantasket Beach with the largest percentage of occurrence. In general, waves approaching from the east have an angle that is sufficient to drive the hydrodynamics necessary for sediment transport to the northwest.

Gross sediment transport rates vary significantly for the various average annual approach directions, and reach a maximum of 400,000 cy/yr. The magnitudes of the gross sediment transport rates provide an indicator of the wave energy associated within each wave approach direction.

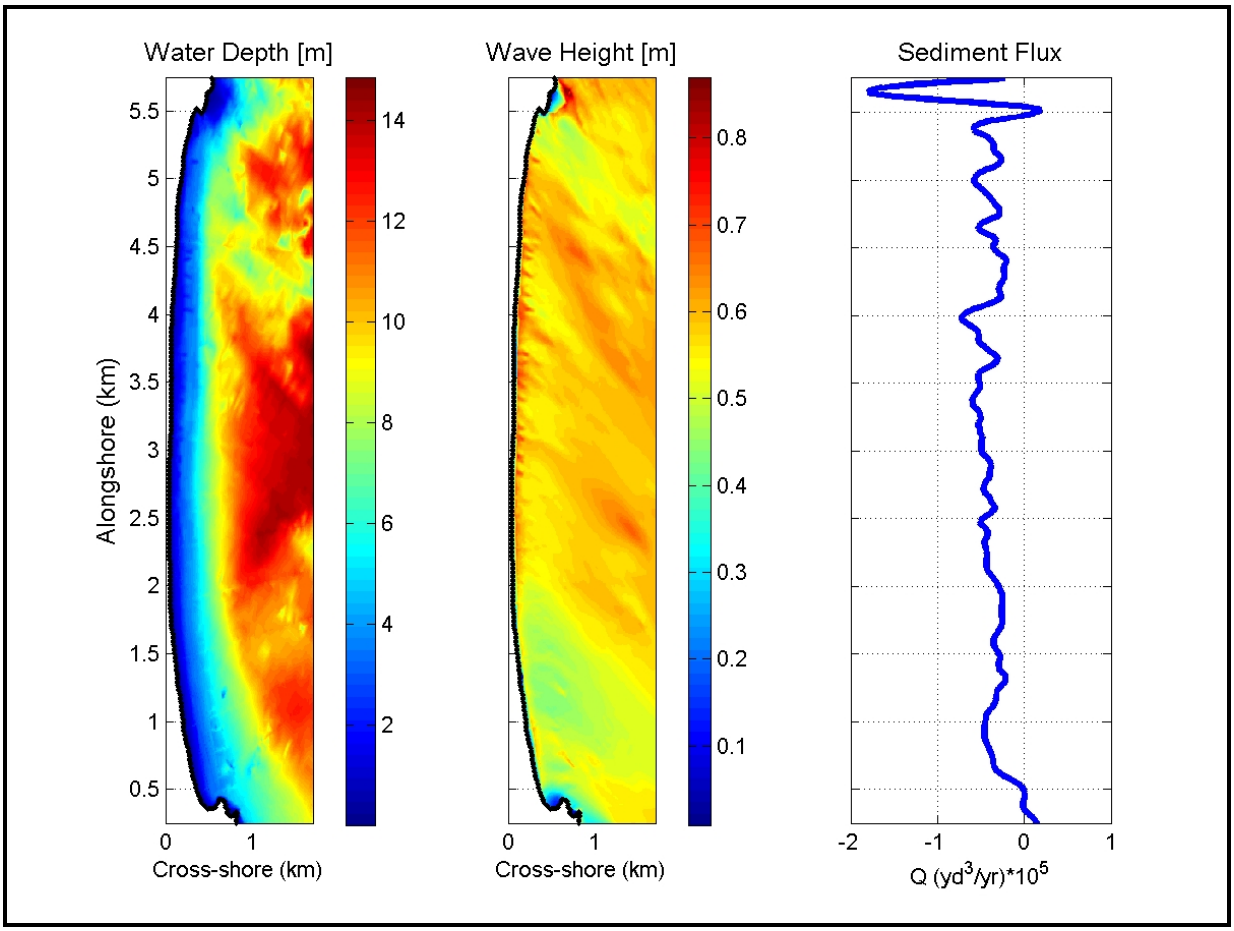

Figure 5-4. Sediment transport model results for an easterly wave approach (81.5 to 104 degrees). Water depth and wave height in meters.

The sediment transport results presented discussed so far focus on single spectral, directional distributions of wave energy. To accurately represent what occurs over an average year, the various wave scenarios need to be combined to represent an average year of wave climate. Using the percent occurrence of wave approach (Table 4-2), the average annual approach directions were normalized and combined to determine the net longshore transport rate. Figure 5-5 presents the average yearly sediment flux determined using the mixed grain size approach. The vertical axis represents distance alongshore. The DCR portion of Nantasket Beach is therefore located toward the bottom of the figure, while Allerton Hill is at the top of the figure. Figure 5-5 presents the local water depth (left panel) from the regional wave transformation model and the associated sediment flux (right panel). The sediment flux represents the rate of sediment moving along the coast; where negative values indicate movement toward the north/northwest (from bottom to top of the figure), and positive values indicate movement toward the south/southeast (from top to bottom of the figure). This rate is presented in units of m^3/yr and can be used to quantify the annual sediment transport in reaches along Nantasket Beach. The solid black line shown in the sediment flux figure is a fit of the flux results, indicating the general movement of sand along the coastline.

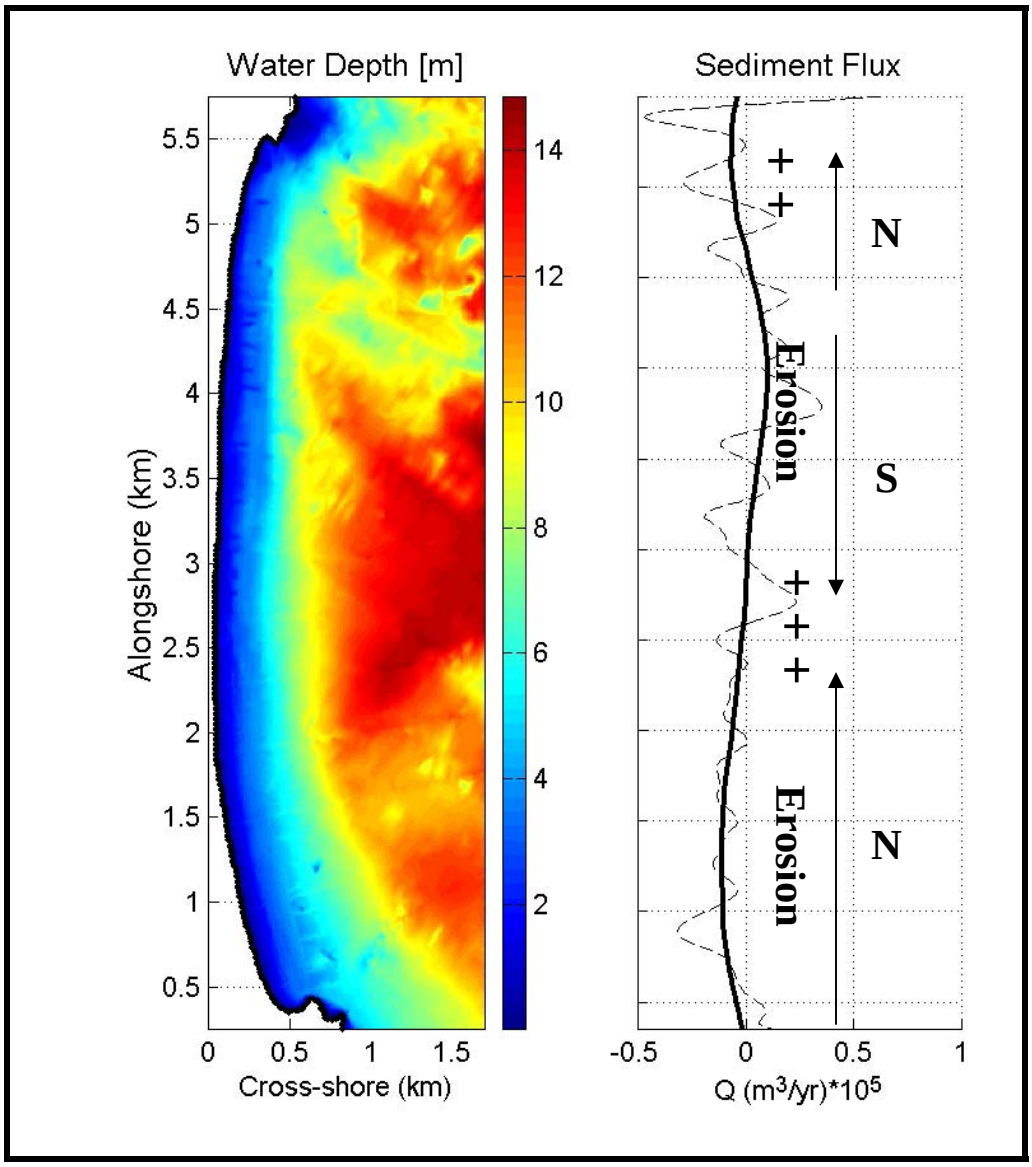

Figure 5-5. Sediment flux results for an average annual year at Nantasket Beach. Water depth in meters.

The sediment flux indicates that, along the southern portion of Nantasket Beach (0.5 to 3.0 km alongshore), the average annual longshore transport is directed to the northwest (negative flux value) at an average rate of approximately 4,060 cy/yr, with maximum rates ranging from 10,000 cy/yr to 50,000 cy/yr. The center portion of Nantasket Beach (3.0 to 4.5 km alongshore) experiences sediment transport to the southwest at an average annual rate of approximately 3,800 cy/yr, while the northernmost section of Nantasket Beach (4.5 to 5.5 km alongshore) indicates transport to the northwest at a minor mild rate. As such, net sediment transport along the Nantasket shoreline is relatively small and is directed towards the north/northwest. These relatively small transport rates, and reversals in transport direction along the shoreline, support the historically relatively stable nature of the Nantasket Beach shoreline, as presented in Chapter 3. For example, the northward sediment transport ranges from 10,000 to 50,000 cy/yr in the

DCR portion of Nantasket Beach (as shown in the dashed line). This is a relatively small flux of sediment, indicating that on an annual basis, not much sand is moved to either the north or the south.

The movement of sediment is further illustrated by the arrows expressing direction of sediment transport, as well as the subsequent convergence and divergence of the flux (creating areas of accretion and erosion, respectively). As shown, the sediment in the DCR portion of Nantasket Beach is transported to the north, and since there is no major source of sediment to the beach (due to the Atlantic Hill headland), an area of erosion is created. North of the DCR portion of the beach, there is an area of accretion (identified by '+++' on Figure 5-5) caused by a convergence of southward and northward moving sediment. The model also indicates a region of erosion north of the accretion near the center of Nantasket Beach, and an area of accretion at Allerton Hill (identified by '++' on Figure 5-5).

In general, the larger-sized cobble material is not mobilized during a majority of the average annual wave conditions. The more commonly occurring, but less energetic, wave approach directions arriving from the east and east-southeast (Table 4-2) are not capable of mobilizing the cobble material. During these conditions, only the sand portion of the beach is mobilized and transported to the north-northwest. The cobble component of the distribution is only mobilized during the more energetic wave conditions (e.g., northeast north-northeast). During these conditions, both the sand and cobble components are mobilized and transported to the southeast. In addition, during storm events, which also typically arrive from the northeast, both cobbles and sand are mobilized to the southeast. Therefore, in the alongshore direction at Nantasket Beach, cobbles are more consistently transported to the southeast, while the net movement of sand is more consistently to the northwest. This dissemination of the natural sediment distribution at Nantasket Beach is consistent with the observations of sediment types at the beach, where relatively more cobble based material is generally located in the southeast portion of Nantasket Beach, while the northwest portion of Nantasket Beach contains relatively more sand (USACE, 2006).

The sediment transport results were also compared to the historical shoreline change rates to determine the relative performance of the model. Figure 5-6 overlays the model sediment flux results against the historic rates of shoreline change. The red line indicates the sediment flux results, while the black line shows the historic rate of shoreline change (in terms of ft/yr). Negative values of sediment flux (red line) indicate movement of sand to the north, while positive values of sediment flux indicate movement of sand to the south. Negative values of shoreline change indicate erosion, while positive values indicate accretion. The areas of erosion and accretion shown in Figure 5-5 (caused by the convergence and divergence of the flux) match the observed shoreline change well. For example, sand moving from the southeast to the northwest in the DCR portion of Nantasket Beach would result in a loss of sediment in this region, therefore, the observed erosion that occurs in this region.

5.4.2 Representative Year Simulation

In addition to the average annual directional bin cases, a 1-year simulation of longshore sediment transport was conducted to provide additional insights into the wave–driven transport patterns in the vicinity of Nantasket Beach. Results from the representative yearlong STWAVE simulation

(see Section 4.4.2.2) were used as input conditions to the sediment transport model. Hourly results of sediment transport flux were compiled for the year long simulation and then summed to give an annual rate of transport for the representative year. Figure 5-7 shows the representative year (1987) sediment flux (red line in right hand panel), and results show similar trends to the average year simulations.

Figure 5-6. Sediment transport flux from modeling results (red line) compared to historic rates of shoreline change (ft/yr black line).

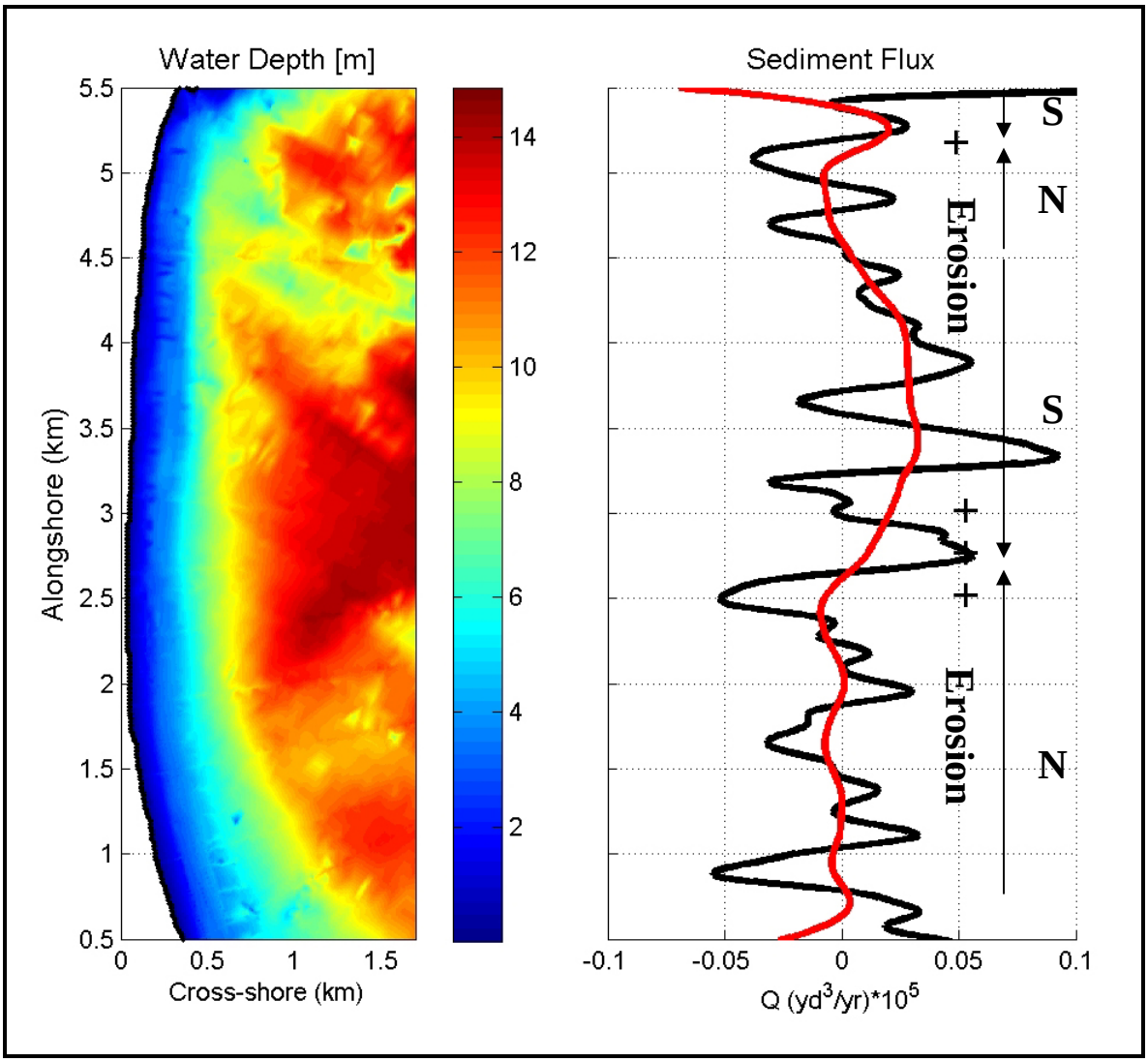

Figure 5-7. Representative year sediment flux for Nantasket Beach. Water depth in meters.

5.4.3 Sediment Transport during Storms

In order to put in context the amount of material that may be temporarily moved during a significant storm event, the sediment transport model was also used to evaluate the sand movement for significant storm events. For example, during a 10-year storm event, sediment transport rates average 60,000 cy/yr to the southeast, with maximum flux rates exceeding 200,000 cy/yr. This is significantly larger than the average annual conditions. Similarly, for the 50-year case, sediment transport flux rates average approximately 800,000 cy/yr, with maximums of over 2,000,000 cy/yr. Although these storms obviously don't last an entire year, and therefore move only a fraction of that amount, these high-energy storm events result in a significant amount of sediment movement at Nantasket Beach and play an important role in the overall consideration of alternatives for erosion mitigation. For example, a 1 day 50-year storm event could transport as much or more material as an entire average year (approximately 2,000 cy).

6.0 DEVELOPMENT OF ALTERNATIVES

Ocean waves, currents, tides, storm surges, and relative sea-level rise contribute to the erosion of sandy shorelines and the destruction of coastal property. Traditionally, attempts to combat these erosional pressures consisted of hard structures, such as groins, breakwaters, seawalls and revetments, and/or soft solutions such as artificial beach fills. Each of these established erosion mitigation measures has proven effective when used under favorable conditions; yet, none is suitable for every location, and implementation under the wrong conditions may have severe negative impacts on a coastal community.

During the past several years, new shoreline erosion mitigation measures have been developed; these measures are often referred to as alternative technologies. In the context of this analysis, the term alternative technology refers to any erosion control measure that has not been extensively used in the northeastern United States. Dozens of alternative technologies have been implemented throughout the United States during the past several years; however, only a few have proven to be effective. Many of these technologies are based on principles similar to more accepted engineering methods. Some alternative technologies are based on sound scientific principles, and for certain conditions will induce accretion along a beach face. However, care should be exercised in applying these methodologies since each stretch of shoreline is unique. In the following sections, the more promising of these methods of erosion control have been evaluated.

Decisions regarding management of shoreline erosion at Nantasket Beach can only be made after a thorough evaluation of available erosion mitigation alternatives. The following chapter describes a variety of established coastal engineering methods for erosion mitigation, as well as several less traditional approaches. The ideas upon which these methods were developed are explained, and their particular application at Nantasket Beach is discussed. Therefore, this chapter provides the preliminary alternatives analysis for Nantasket Beach by evaluating a range of commonly used coastal protection alternatives.

6.1 OVERVIEW

An alternatives analysis is the basis for determining the optimal solution and assessing potential impacts, both physical and environmental. A variety of factors are considered when evaluating the various alternatives (e.g., cost, feasibility, performance, environmental impacts, constructability, etc.), with the overall objective focused on selecting the optimal solution. As such, the goal of the assessment is to evaluate reasonable, practicable, and feasible alternatives that will achieve the goals and objectives of the project, while minimizing the short and long-term adverse effects, if any. The alternatives analysis procedure developed for Nantasket Beach, including a comprehensive list of the alternatives evaluated and the alternatives developed for more comprehensive evaluation, is presented in this chapter.

The studied alternatives were geared towards determining a long-term solution for creating and maintaining a functional recreational beach, improved storm damage protection for upland infrastructure, and fitting within the overall Master Plan for the DCR reservation property. Ultimately eight specific alternatives, including both structural (e.g., revetment, seawall, etc.)

and non-structural (e.g., retreat, beach nourishment, etc.) were determined jointly between the Department of Conservation and Recreation (DCR), the Town of Hull, the Citizens Advisory Committee (CAC) for Nantasket Beach, the Louis Berger Group, Inc. (Berger), and the Woods Hole Group (WHG). These alternatives are presented in Section 6.3 and were developed to work in concert with the existing coastal protection measures, while meeting the goals of the community for Nantasket Beach.

The alternatives were chosen at a meeting on January 31, 2007, during which all viable long-term solutions were discussed and considered, and an initial series of site-specific alternatives were selected for analysis that were developed as the most feasible solutions for the DCR portion of Nantasket Beach. Careful consideration was given to all factors associated with each alternative. For example, potential impacts on the neighboring shoreline, engineering feasibility, likelihood of success, cost, etc. were all considered in the final selection process. All members of the alternative development team (DCR, Berger, and WHG) agreed upon the final alternatives that were selected for consideration. The evaluation of these alternatives is presented in greater detail in Chapter 7.

6.2 TYPICAL COASTAL PROTECTION ALTERNATIVES

Prior to the development and selection of the final alternatives to be assessed in the detailed alternatives analysis, a range of traditional coastal protection alternatives were considered to determine potential solutions that may be feasible at Nantasket Beach. These alternatives, in addition to the no action alternative, were considered in the initial evaluation of potential solutions for Nantasket Beach. Types of alternatives that were considered included:

- No action
- Non-structural “soft” solutions (beach nourishment, dune reconstruction, nearshore berms)
- Structural “hard” solutions (revetments, groins, jetty modifications, breakwaters, and seawalls)
- Combinations of solutions (perched beach, beach nourishment with groins, etc.)
- Alternative technologies (beach dewatering, nearshore berms, submerged offshore reefs, and other alternative technologies)

Table 6-1 presents a list of the alternatives that were considered in the preliminary analysis. The table identifies if the alternatives were established shore protection methods (standard) or alternative technologies (non-standard), hard or soft solutions, and if they could be applicable at Nantasket Beach.

Table 6-1. Alternatives considered in the preliminary alternative analysis procedure.

Alternative	Method	Hard/Soft	Applicable for Nantasket
No action	N/A	N/A	No
Retreat/relocate	N/A	N/A	Maybe
Beach nourishment	Established	Soft	Yes
Perched beach	Alternative	Hard	No
Dune Reconstruction	Established	Soft	Yes
Revetments and seawalls	Established	Hard	Yes
Groins	Established	Hard	No
Breakwaters	Established	Hard	No
Beach dewatering	Alternative	Hard	No
Nearshore berms	Alternative	Soft	No
Offshore reefs	Alternative	Hard	No
Other alternative technologies	Alternative	Hard	No

6.2.1 Passive Alternatives

No Action

The no action alternative implies there would be no change to the present conditions at Nantasket Beach. This alternative is considered unacceptable by the project team as the existing seawall is currently at risk for failure in certain areas, the existing shorefront would continue to be eroded, a sustainable recreational beach would not exist, no protective action would be taken, and the upland infrastructure would face increased risk for potential damage or loss. The current water-dependant function of the Reservation would be compromised as the beach would not be maintained. Therefore, the "no action" alternative was not recommended; however, it is considered in the more detailed alternatives analysis (Chapter 7) as a baseline comparison for the other alternatives.

Retreat/Relocation

This alternative is similar to the no action alternative in that the beach is allowed to continue to erode; however, the seawall would either be removed or relocated further landward. This would directly impact current parking facilities, as well as some reservation infrastructure (MJM bathhouse) and local businesses. This retreat option may be combined with other coastal protection alternatives/techniques to create additional beach seaward of the removed or relocated seawall. Changes to the utilities and parking lot would also occur to account for the new structure location. Variations of this potential alternative were considered for further evaluation and details are presented in Section 6.3.

6.2.2 Established Shore Protection Alternatives

Beach Nourishment

One of the primary causes of coastal erosion is a deficit of sediment within the coastal littoral cell. To offset this deficit, nourishing the beach with compatible sediment placement is a logical means for improving the longevity of the shoreline where such a project is economically feasible. Beach nourishment does not stop erosion. Rather, the beach width is increased, recreational area is improved, and potential damage to upland infrastructure is postponed by extending the shoreline toward the ocean. As such, periodic renourishment must be anticipated. At a site like Nantasket Beach, the increased beach area also provides a major recreational and economic stimulus benefit.

Beach nourishment is typically the most non-intrusive technique for coastal protection and involves placing sand, from an offshore or upland source, in a designed template on an eroding beach. Figures 6-1 and 6-2 present examples of beach nourishment projects being constructed. Beach nourishment is intended to widen the beach, as well as provide added storm protection, increased recreational area, and in some cases, added habitat area. Although nourished sand is gradually displaced alongshore or transported offshore, the nourished sand that is eroded takes the place of the upland area that would normally have been lost or eroded during a storm event. Therefore, beach nourishment serves a significant role in storm protection. In addition, beach nourishment is the only alternative that introduces additional sand into the system. For coastlines with a dwindling sediment supply, such as Nantasket Beach, this is critical for long-term success. Solutions that do not involve beach nourishment typically involve rearranging the existing sand in a manner that will only benefit a portion of the beach or provide hardened protection that does not offer an improved beach area with no longevity.

Environmental concerns with beach nourishment projects include the potential for temporarily decreased water quality when sediments are dredged and deposited, and disturbing natural habitat when removing or depositing the dredged material. These concerns can be addressed by adhering to dredging time windows that avoid periods of shellfish, finfish, and shorebird activity. Grain size compatibility between the borrowed and native beach sediments should be maximized in order to avoid disturbance of nearshore resources such as shellfish and submerged aquatic vegetation, as well as to increase the lifespan of the nourished beach. For example, large differences in grain size between the native and borrow material may lead to changes in beach slope through natural adjustment of the new grain size introduced to the beach.

The many benefits of beach nourishment, and the ability to control environmental impacts with careful design and planning, make beach nourishment a viable alternative for the Nantasket Beach area. A beach fill project for this area would mitigate the on-going erosion, improve storm damage prevention and flood protection to infrastructure, and improve the recreational resource of both the DCR and neighboring beaches.

Figure 6-1. Beach nourishment project under construction.

Figure 6-2. Beach nourishment project under construction in Virginia Beach, VA (photo courtesy of Virginia Beach).

Beach nourishment was recommended for further evaluation, and a range of potential design layouts, including various lengths, beach widths, etc., are detailed further in Chapter 7. In addition, beach nourishment was also considered in concert with several other alternatives since nourishment meets a critical need for Nantasket Beach by providing a functional, useable beach during all stages of the tide.

Perched Beach

A perched beach is an alternative method of sand placement designed to reduce the amount of sand required, and to help retain the material for a longer time period. The nourishment volume is reduced by using a submerged sill to hold up or "perch" the beach above the natural bottom, significantly reducing the amount of sand required for beach construction and maintenance. The submerged sill is also designed to limit the loss of nourished sand seaward of its location. A perched beach is no longer solely a soft solution (e.g., beach nourishment only), since the sill is typically composed of rocks. Figure 6-3 presents a schematic drawing of a perched beach, while Figure 6-4 shows an example of a perched beach on Martha's Vineyard, MA decades after construction. The perched beach is not a common engineering solution implemented in the US and there is limited design information available. The USACE has recently indicated that model studies and calculations of life-cycle costs demonstrated that a perched beach was as expensive as repeated beach nourishments with no sill construction over a 30-40-year period (USACE, 2003). The perched beach alternative is not recommended for further evaluation at Nantasket Beach, since this would significantly change the beach usage. Although a perched beach can provide significant storm damage protection, it is not an ideal solution for a recreational beach setting. Swimming and water based activities become unsafe in such a setting, due the large rocks offshore that are hidden from view.

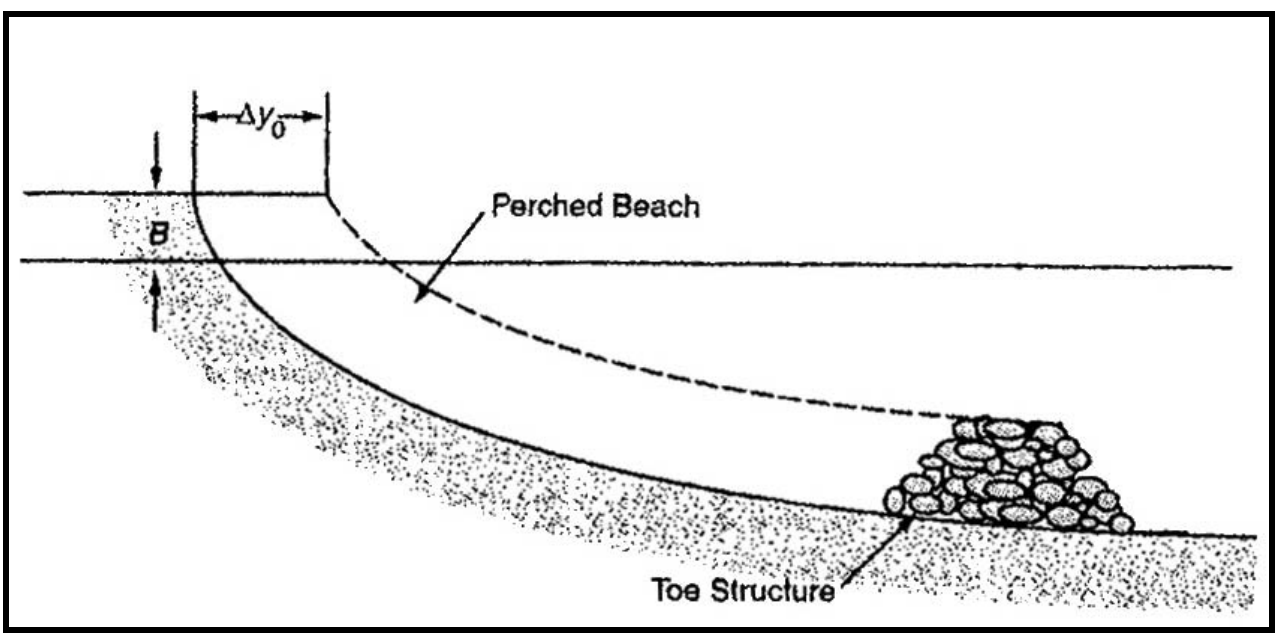

Figure 6-3. Schematic of a perched beach with a rubble mound sill. B is the berm height and Δy_0 is the increase in berm width (Dean and Dalrymple, 2002).

Figure 6-4. Example of a perched beach in Martha's Vineyard, MA. The perched beach has eroded behind the sill and is in need of replenishment.

Dune Reconstruction

Dune reconstruction is a rebuilding of the dunes landward of the beach. Protective dunes are useful when combined with nourishment distributed over the beach face. A coastal dune provides a vertical buffer that protects the landward property from storm waves. Additionally, the coastal dune provides a source of sediment for the beach as it slowly erodes during larger wave events. Figure 6-5 presents an example of a dune reconstruction project. Construction of a dune, which currently does not exist along the DCR portion of Nantasket Beach, is complicated due to the presence of the seawall and overall space restrictions. A dune could be placed in front of the existing seawall, or the seawall could be removed or relocated to allow for placement of a coastal dune similar to those located along the northern portions of Nantasket Beach. Dune reconstruction, by itself, is not recommended for DCR portion of Nantasket Beach; however it was combined with potential other alternatives in the overall alternatives assessment.

Figure 6-5. Example of a dune reconstruction project in Sandwich, MA (a) pre-construction, and (b) post-construction.

Revetments and Seawalls

Seawalls and revetments separate land from water, with the primary function of reducing wave energy and protecting the upland from the erosional forces of waves and currents. Seawalls are typically vertical structures (Figure 6-6), constructed with steel sheets or concrete. Revetments are sloping (Figure 6-7), constructed of concrete or quarry stones. Higher energy environments generally dictate the use of a seawall instead of a revetment or combination. These two types of structures interact with the nearshore littoral processes in a similar fashion. The DCR portion of Nantasket Beach currently has a seawall and/or revetment that span part of the beach.

Unlike groins and breakwaters, which may protect adjacent updrift beaches or improve the longevity of a beach fill, seawalls and revetments only protect the land directly behind them. If there is no beach fronting the structure, or if the beach is overtopped by storm flooding and wave action, a continual lowering of the profile in front of the structure will generally occur. This is due to the magnified erosional forces of the waves as they reflect from the structure, and to the loss of bank or dune sediments protected by the wall, that otherwise could help replenish the fronting beach. In addition, toe scour and flanking at the ends of the wall may threaten the structure itself as erosion continues. Additional forces threatening the structure may be induced if the structure is overtopped, as soil becomes saturated and soil pressure is increased behind the wall and reduced by scour in front of the wall.

Considering these complications, a seawall or revetment can benefit the natural coastal environment and the adjoining upland property if the elevation of the structure is sufficiently high to prevent regular wave overtopping and deep enough to resist scour and toppling. With a beach fronting a seawall or revetment to provide wave energy dissipation, the structure can provide protection from rare severe erosive forces. Installing a seawall often requires additional measures to build and maintain a beach in front of the structure. Typically, the combined costs of beach maintenance and seawall construction would be economically prohibitive. However, since the DCR reservation already has a significant seawall and/or revetment structures in place, the continued maintenance of the seawall and/or improvements to these existing structures is a reasonable alternative to consider. Also, given the highly developed nature of the area landward of the exiting seawall and the urban setting of Nantasket Beach, these structures offer much

needed storm damage protection that could not be achieved by a natural beach alone. Multiple seawall and revetment alternatives, and combinations with other alternatives, were considered in more detail for Nantasket Beach. These alternatives are presented in Section 6.3 and evaluated in Chapter 7.

Groins

Groins are typically constructed of rubble mound or wooden bulkhead, and are structures built perpendicular to the shoreline. In an environment with longshore sediment transport, a groin reduces erosion by trapping sand in the form of a fillet on the updrift side, although there is usually erosion on the downdrift side. This erosion/accretion trend is shown in Figure 6-8. Often, several of these structures are constructed consecutively along the shore to form a groin field. Since groins may inhibit longshore sediment transport, a groin field is most effective when the downdrift limit is a natural sediment sink, such as a tidal inlet or a naturally terminating headland. Otherwise, the construction of groins may result in severe erosion of the adjacent downdrift beach by denying the natural longshore sediment transport. Additionally, construction of groins typically results in some swapping of a footprint of nearshore habitat area from sandy beach to rocky intertidal in the locations where the groins are constructed.

Figure 6-6. The seawall along the DCR portion of Nantasket Beach.

Figure 6-7. Revetment located along the DCR portion of Nantasket Beach.

Figure 6-8. Existing groin showing updrift accretion fillet (left side of groin) and downdrift erosion zone (right side of groin). These shoreline conditions are typical in areas of groins.

Specific groin types that were considered at Nantasket Beach were groin fields (a series of groins along the shoreline), a terminal groin (a singular groin located at the downdrift end of a beach nourishment), and "T-head" groins. T-head groins are comprised of a standard shore perpendicular groin fitted with a shore-parallel T-head at their seaward end. The T-head is often built to interrupt the seaward flow of water and sand in rip currents that often develop along a groin's axis. The T-head may also act as a breakwater and shelter a sizeable stretch of beach behind it. This alternative would attempt to hold the beach nourishment in place by preventing losses in both the seaward and alongshore directions. In addition, the T-heads would afford additional wave protection by breaking wave energy.

When implemented under favorable natural processes, a properly designed groin or groin field can be effective in preventing beach erosion. However, natural conditions that are conducive for successful groin implementation, such as a sufficient sand source and dominant direction of longshore sediment transport, do not exist everywhere. Groins are not recommended for use at Nantasket Beach since they would significantly interfere with beach and water usage (e.g., surfing). Groins may also result in significant negative impact to the neighboring beaches to the north of the DCR reservation and would have high construction costs and environmental concerns. Therefore, groins are not a preferred alternative for Nantasket Beach.

Breakwaters

Breakwaters are designed to reduce wave action in the area leeward of the structure to retard beach erosion. Typically, this type of shore protection is provided from a single large offshore rubble mound (rock) structure, or a series of shorter segmented breakwaters oriented parallel to the shoreline (Figure 6-9). A segmented breakwater dissipates wave energy in its lee, and each breakwater allows for sediments to be deposited on the adjacent shoreline, forming a bulge in the beach defined as a salient. The wave climate and distance between the shoreline and the breakwater govern the salient growth. If the accreted sand makes contact with the breakwater, the formation is termed a tombolo.

The sources of the trapped sediment behind each breakwater are derived from the ambient littoral drift and the sediment transport induced by the diffraction pattern of the waves around the ends of the breakwater, which forces sediment toward the shadow zone. Trapping the natural littoral drift is a concern because erosion of the downdrift beaches may result. Artificially filling the salients to an equilibrium planform (adding extra sediment seaward of the shoreline and landward of the breakwater) may prevent downdrift erosion for some finite period of time (until more nourishment is required), and the longshore transport may continue, unaffected by the breakwater.

Determination of this equilibrium planform requires an accurate prediction of the salient growth behind a breakwater. A myriad of variables, spanning the natural littoral processes and wave conditions, as well as the properties of the structure, govern the shoreline response. For a single detached offshore breakwater, the reduction in sediment transport from the wave shadowing effect of the breakwater, the transport induced by the diffracted wave pattern, and the effects of wave energy transmitted through the structure must be weighed against the ambient sediment transport conditions to determine the shoreline response. A further consideration for a series of

segmented breakwaters is the design geometry. The interrelated effects of each structure's length, distance from shore, and the gap between each structure relative to the incident wavelength determine the post-construction shape of the shoreline.

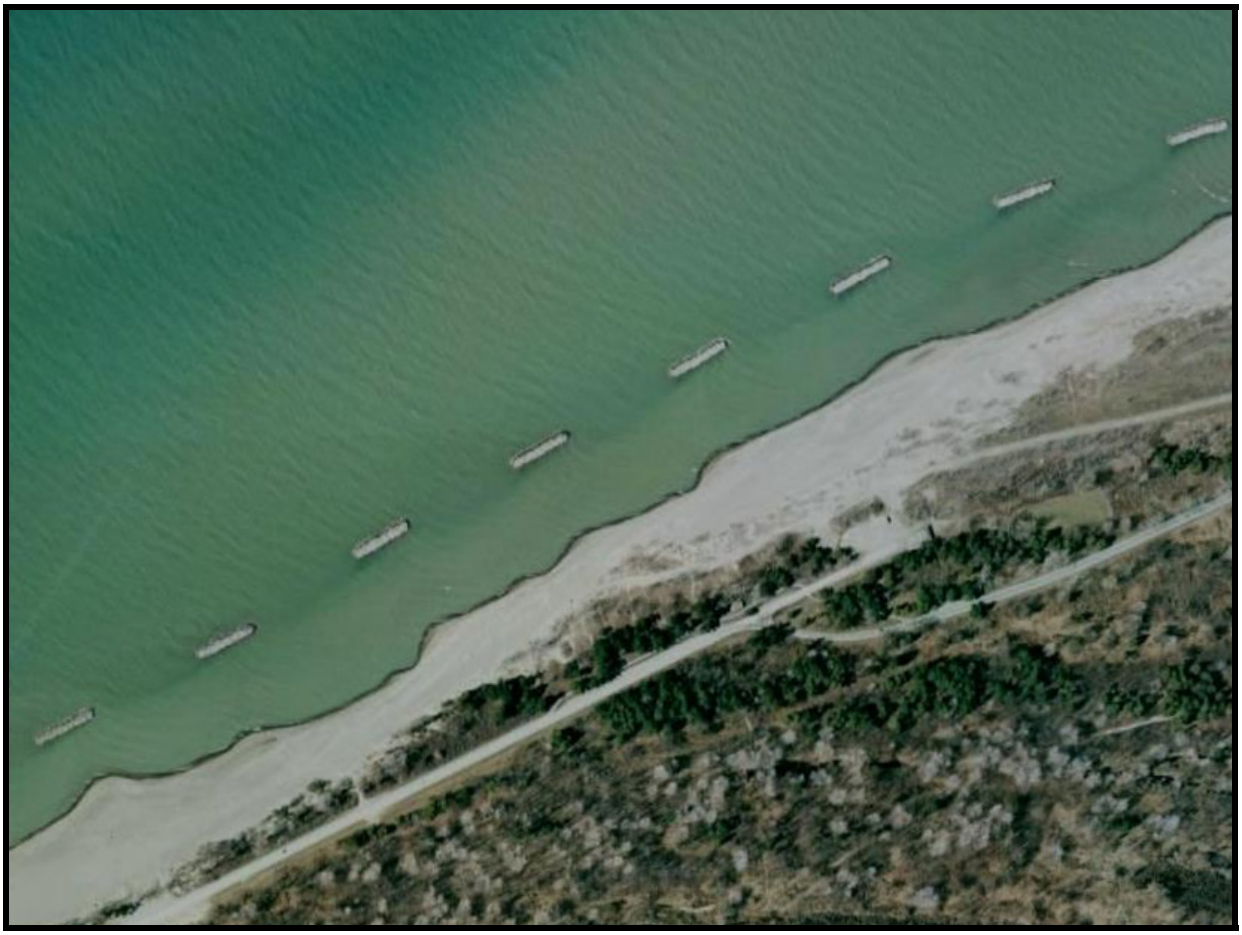

Figure 6-9. Detached breakwaters offshore of Presque Isle State Park, Erie, PA (Image from Google Earth).

As with groins, breakwaters are a viable means of stabilizing the shoreline; however, there are adverse effects. Physically, there is the potential for downdrift erosion, which may be aggravated by the formation of tombolos that cut off longshore sediment transport completely. Environmentally, alteration of bottom habitat and aesthetic beauty are also drawbacks. However, a properly designed system of breakwaters, where no tombolos form, will not inhibit longshore transport as much as groins.

By understanding the environmental drawbacks of detached offshore breakwaters and designing them to mitigate these concerns, they may be a viable option to control coastal erosion. Unfortunately, the cost of breakwater construction in an open coastal region can be expensive. To ensure that tombolos will not form, the offshore distance must be increased. It is also mandatory to construct the breakwaters far enough offshore to prevent impacts on the natural seasonal cross-shore transport of sand. This increase in offshore distance and water depth will directly affect the structure cost and environmental impact, since a breakwater constructed in

deeper water will require more material. For example, for a typical trapezoidal-shaped cross-section rock breakwater, the construction costs are tripled (or more) when the depth is doubled. In deeper water, the footprint of the breakwater increases (at least 50% increase in footprint with doubled depth), and potential adverse environmental impacts are also increased. At Nantasket Beach, the high construction costs, permitting, and interference with many recreational uses (e.g., surfing), outweigh the anticipated benefits, making detached offshore breakwaters infeasible. Therefore, although technically feasible, offshore breakwaters were not recommended for further assessment.

6.2.3 Alternative Technologies

Beach Dewatering

The primary goal of beach dewatering is to stabilize the shoreline by lowering the groundwater table. A beach dewatering system contains a series of pipes buried in the beach face through which water from the wave uprush is pumped from the beach. On a typical beach the water table is governed by tidal fluctuations, groundwater flow from land, and the uprush of water in the swash zone (the zone of wave action on the beach, which moves as water levels vary, extending from the limit of run-down to the limit of runup). Lowering the water table through beach dewatering at the shoreline theoretically may mitigate erosion problems in several ways. The process is analogous to the dewatering process used when excavating saturated soils, where the slopes are stabilized as a result of reducing the upward buoyancy force in the sand grains and through slight compaction as water percolates down through the soil. The decreased gradient between the lowered water table and sea level effectively decreases the outflow of water from the beach face, further stabilizing the berm and inhibiting offshore movement of sediment. Additionally, as sediment laden swash zone water is pumped into the beach face, erosion is prevented and small amounts of sediment may be accreted.

Beach dewatering projects using both gravity drainage and vacuum pumping systems have been designed and implemented at a number of sites. The most significant finding of these early cases is that dewatering systems may stabilize the beach, thereby providing an alternative for beach protection. However, the observed success of dewatering systems is limited to areas where an abundance of sediment is available. In the absence of a significant sediment supply, the effectiveness of beach dewatering is in question, and the technique cannot be expected to build a beach. The over-steepening of the beach due to the dewatering process indicates a change in the equilibrium profile shape meaning sand is captured on the upper portion of the profile. If the pumping process is discontinued, the beach profile can be expected to revert to its original equilibrium shape rather rapidly and transport this material offshore. Therefore, the beach that may have been built due to this temporary steepening of the profile, would be quickly lost during a readjustment of the profile. It is likely that this oversteepening may account for much of the accreted volume exhibited at the test sites.

In addition, the idea of beach dewatering raises a number of environmental concerns. First, the available literature does not adequately discuss the effects of dewatering systems on downdrift beaches. In a natural beach system, waves will tend to transport sand in the longshore direction depending on the offshore wave angle with respect to the shoreline. Since beach face dewatering systems accrete sand by interrupting a portion of the natural littoral drift, downdrift erosion

should be anticipated. Other concerns include high operational maintenance costs, and the potential for complete destruction of the system during major storm events.

A large beach dewatering project was initiated in the Siasconset area of Nantucket Island in 1994. This project has undergone at least one major redesign effort since its inception, and is still in the evaluation process. The construction and operation costs for this project have been significant, and to date the success of this technology at this site has been limited.

Due to the possible negative environmental impacts, the relatively high cost with respect to the potential benefits, and the unproven performance, this technology is considered experimental and is not recommended for Nantasket Beach. The overall sediment deficit within the Nantasket Beach area also argues against the use of beach dewatering.

Nearshore Berms

As an alternative to beach nourishment, sand may be deposited in the form of an offshore berm to act as a sediment source, or feeder berm for the beach. Although the best use of dredged material for shore protection is directly on the beach face in the form of nourishment, nearshore berms have been designed and implemented to make use of incompatible sediments that would normally have been transported to an offshore disposal site. Theoretically, the feeder berm serves as an offshore supply of sediment and a wave break that moves onshore during periods of low wave steepness, typically during the summer months. Depth of placement and grain size are important parameters for determining the behavior of the berm after placement. Wave forces cannot transport coarse material as readily as fine material. In addition, near-bottom velocities caused by waves are smaller in deeper water; therefore, the berm must be placed in depths where wave forces can transport the sediment.

The advantage of utilizing nearshore berms is their low construction cost. Dredged material can be easily dumped offshore to form a berm; however, the deposition of sediments must be within designed disposal area limits to assure shoreward transport. The deposition depth is also typically limited by the drafts of the fully loaded barges delivering the material.

At this time, monitoring data from nearshore berm projects show that they have little measurable effect on beach stability. In many cases, poor results have occurred due to placing the berm too far from shore to facilitate onshore movement. Although placement of sand in nearshore berms is a better use of incompatible sediments than deep-water disposal, littoral transport of this material does not appear to affect beach erosion rates. Typically, incompatible sediments are too fine, and placement in the nearshore may introduce environmental problems associated with water clarity. For example, water quality may be temporarily reduced, and benthic organisms may be covered as the sediments settle. In cases where the nearshore berm sediments are too coarse, the wave climate is not able to move the sediments into the littoral system. Instead, the berm sediments remain offshore and have little influence over the nearshore sediment transport.

For the Nantasket Beach area, nearshore berms most likely will not be beneficial. Whenever possible, available beach sediments should be placed within the littoral system as beneficial reuse, and directly on the beach for cases where increased beach width is required for

recreational purposes. The nearshore berms may also interfere with the recreational surfing activities that are conducted at Nantasket Beach.

Submerged Offshore Reefs

Submerged offshore reefs and breakwaters are a variation of the breakwaters discussed above. In these instances, breakwaters are submerged to eliminate perceived aesthetic impacts. Various types of submerged breakwaters, such as rock structures, artificial reefs, and beach cones, have been developed to reduce erosional forces on the beach and/or prevent the loss of sediment from the nearshore. The theory behind these structures is to reduce the height of incoming waves by reflecting and dissipating energy as the waves propagate over the submerged structure. For sediment trapping purposes, the breakwater acts as a physical barrier blocking sediments from moving offshore.

Submerged offshore breakwaters are often rubble mound rock structures oriented parallel to the shoreline. Other designs include concrete shapes such as the Beachsaver (Creter, 1994) or Prefabricated Erosion Prevention (PEP; Mitchell, 1994) reefs that have been implemented on the Atlantic coast of the United States. Both of these reefs are constructed of prefabricated concrete modules, which can be interlocked to protect large sections of a shoreline. Beachsaver modules have a triangular profile shape, a saw-toothed bottom, and rough "stepped" seaward and landward slopes. Beach cones have been developed for more localized protection in low wave energy environments (Davis and Law, 1994). They consist of concrete cones arranged in pyramidal clusters, interlocked with interstitial wave blocks and anchored to the sea floor with PVC pipes.

A great deal has been learned about submerged breakwaters through laboratory and field testing. Major deficiencies include excessive settlement of the structures and an inability to achieve expected wave height reductions. The latter problem is exacerbated in storms because surge levels increase the water depth above the structure, allowing for higher than normal waves to break on the exposed beach. During storms, as much as 95 percent of wave energy may be transmitted past a submerged breakwater. In addition, laboratory experiments have indicated significant longshore currents develop in the lee of the breakwaters (Browder, 1994). Although details of how this current might affect sediment transport are still being studied, initial indications show a net loss of sediment behind the structure with accretion at either end.

Submerged breakwaters can provide protection for beaches by dissipating wave energy during normal wave conditions, and combined with the advantage of their invisibility, these structures can potentially serve to mitigate beach erosion problems in a way that satisfies community interests. However, issues regarding environmental impacts remain unresolved. Locating "hard" submerged engineering structures within the nearshore zone disturbs bottom habitat, inhibits recreation swimming and water use, and creates a potential navigational hazard. This alternative is not recommended for Nantasket Beach.

Additional Alternative Technologies

Over the last few decades, numerous other devices have been patented to prevent beach erosion. The types of alternative technology devices span a wide range of ideas, including beach cones (Davis and Law, 1994), ultra-low profile geotextiles injected with concrete (Janis and Holmberg, 1994), various geotextile tubes and shapes, fishnets, stabilizers, and artificial seaweed (Stephen, 1994), and a host of additional innovative approaches. These alternative methods often employ nontraditional shapes or materials; however, they are positioned in traditional ways (e.g., to replicate a nearshore breakwater, revetment, or groin). Ultimately, their potential success depends on their ability to resist storm impacts and maintain durability over a design life.

Many of these devices claim to have solved the coastal erosion problem through creation of a beach or capturing sand. In cases, some of these devices can be effective in capturing sediment, and test cases utilizing these alternative technologies have shown beach growth. However, these test cases lack corresponding long-term data documenting the source of the deposited sand. In order for sand to be built up along one stretch of beach, it must have been taken from somewhere else in the system (if sand is not supplied via beach nourishment). Without adding sand to the system, these devices are simply impacting adjacent beaches or the offshore environment by rearranging the existing sand in the active sediment transport zone, similar to groins, jetties, and breakwaters.

In order to compare alternative technologies to standard coastal engineering solutions, the alternative technologies must be thoroughly assessed to ensure that their performance is adequate from a technical standpoint. Technical assessments should include, at a minimum:

- The alternative technology should be shown to maintain continued performance through the seasonal changes at a beach. For example, if a technology is put in place in the winter or spring, following the erosive storm season, the evaluation should consider the natural summer recovery of the beach. As the beach evolves to its summer profile, the build-up of the beach can create a temporary growth that may be misinterpreted as a success.

- Successful performance must be demonstrated with more than just before and after photographs. Long-term and large-scale measurement programs are required to validate the performance of the erosion control devices. This should include monitoring of not only the coastal site where the alternative technology is applied, but also of offshore and adjacent coastal regions to ensure negative impacts are not caused by the technology.

- The alternative technology must be able to withstand the forces of nature in open coastal environments. Engineering design and calculation should indicate that erosion control devices are able to withstand all the forces present during storms and the normal corrosion and fatigue associated with oscillatory wave action. In many cases, the erosion control devices are destroyed during storm events on the open coast.

In order to determine if an alternative technology is a reasonable approach for mitigating coastal erosion at a site, it must be carefully examined in order to ensure it is able to meet its promised function, minimize impact on the environment, survive for a predictable lifetime, and is cost

effective. To further the development of innovative technologies, Pope (1997) raised a number of questions that should be considered when evaluating an alternative technology. Most of the technologies developed do not satisfactorily answer these questions. For example, some of the questions Pope (1997) posed include:

- Is the alternative technology heavy enough, especially considering the forces of storm waves?
- If the technology does fail, could the structural components become an environmental or public safety hazard?
- How will the technology perform and will it perform the way it is expected to perform?
- Will the technology be tolerant of erosion and scour effects?
- Will the technology be stable enough and anchored such that it doesn't fall apart?
- Does the technology perform as promised, and are there any adverse impacts to adjacent areas? Has this been documented and shown using long-term data?
- What is the technologies effective life?
- How much will constructing and maintaining the nontraditional or innovative system cost compare to more traditional methods?
- What are the design criteria?
- Is the material that is being constructed from survivable in a high-energy wave environment?
- What will it cost to remove the system (if necessary)?
- Has long-term monitoring of the performance of the alternative technology been conducted both at the site, as well as offshore and at adjacent beaches?

Nontraditional and innovative technologies need to be subject to the same design cost and performance criteria and constraints as the more established traditional methods. Additionally, the alternative technology has the extra burden of overcoming previous shortcomings and proof that they function effectively. These alternative technologies are not recommended for use at Nantasket Beach. Adequate information is not available to support their use at a site of high wave energy such as Nantasket Beach. Additionally, the scale, potential impacts to significant infrastructure if the technology does not perform as expected, and overall value of Nantasket Beach is not conducive to implementation of these alternative technologies. However, certain technologies, specifically the Advanced Coastal Technologies (ACT) ProTecTube™, were considered in concert with other alternative approaches (Section 6.3.8) to supplement traditional methods and to assess a scenario developed by the members of the Citizens Advisory Committee (CAC).

6.3 NANTASKET BEACH ALTERNATIVES SELECTED FOR CONSIDERATION

The previous section presented the traditional alternatives considered to mitigate erosion at a coastal location. Most of the alternatives considered provide the ability to protect the shoreline and upland infrastructure. However, Nantasket Beach, which is a significantly used recreational beach, must be serviceable for a wide range of functions, and the alternative cannot be a protective measure only. The beach must provide area for recreational usage (e.g., sunbathing, swimming, walking, surfing, etc.), while also providing protection. Therefore, most of the alternatives that were determined to be most technically feasible include the addition of new sand to the system through beach nourishment. This is not surprising, since the southern portion of Nantasket Beach has a deficit of sand and a dwindling sediment supply. The development of the upland has eliminated a natural source of sediment from the shoreline, and there is an insignificant amount of sediment supplied from the updrift (to the southeast) region. Chapter 7 will evaluate the most feasible alternatives to a greater extent, and specifically evaluate the performance of the beach for each alternative. The final alternatives selected for evaluation, as developed jointly between the DCR, the Town of Hull, the CAC, Berger, and the WHG on January 31, 2007, were:

- **Alternative 1: *No Action.*** This alternative would consist of taking no action at Nantasket Beach and making no changes to the existing seawall or fronting beach.

- **Alternative 2: *Seawall Toe Protection.*** This alternative would add stone toe protection in front of the existing seawall in areas where no current toe protection exists (i.e., mid-section of the seawall). Toe protection is similar to a small revetment that would be placed seaward of the existing seawall. This alternative has been implemented along the southern section of the Nantasket Beach seawall (Figure 6-10).

- **Alternative 3: *Seawall with Revetment.*** This alternative would place a revetment in front of the existing seawall, providing added protection not only for the existing seawall and upland infrastructure, but also providing an improved wave dissipation structure when compared to a vertical concrete seawall. An example of the revetment proposed along the DCR reservation is presented in Figure 6-7, which consists of the revetment installed along the northern section of the Nantasket Beach seawall.

- **Alternative 4: *Beach Nourishment.*** This alternative would consist of adding beach nourishment directly seaward of the existing seawall with no modifications or changes to the seawall itself. Figure 6-11 shows an example of the proposed nourishment alternative, including the new location of the Mean High Water line on the beach.

- **Alternative 5: *Seawall Toe Protection and Beach Nourishment.*** This alternative is a combination of Alternatives 2 and 4, where toe protection would be placed in front of the mid-section of the seawall (which is currently unprotected); then the beach nourishment would be placed on top of the toe protection and extending seaward by approximately 180 to 200 feet. The nourishment would initially cover the toe protection completely.

Figure 6-10. Seawall toe protection along the southern section of the Nantasket Beach Seawall.

- **Alternative 6: *Seawall with Revetment and Beach Nourishment.*** This alternative is a combination of Alternatives 3 and 4, where a revetment would be placed in front of the mid-section of the seawall (which is currently unprotected) and then the beach nourishment would be placed in front of the revetment, partially covering the revetment) and extend seaward by approximately 180 to 200 feet. The nourishment would cover a significant portion of the revetment; however the crest of the revetment armor units would remain exposed.

- **Alternative 7: *Retreat and Construct New Seawall, Revetment, and Dune***. This alternative would remove and demolish the existing seawall, retreat approximately 30 feet landward, construct a new seawall, fronting revetment, and place a dune-like feature in front of the new seawall. Existing parking areas and infrastructure (e.g., MJM bathhouse) would need to be demolished or moved as part of this alternative. The fronting revetment would be similar to the toe protection that currently exists along the southern portion of the current seawall. As such, rock armor units would extend approximately 35 feet seaward from the base of the new seawall. The actual increase in beach width would be minimal (relative to the current beach width). Subsequently, sand would be brought in to cover some of the fronting toe protection material and provide some temporary dune and beach area. This material would be placed at a much steeper slope than the proposed beach nourishment alternatives (4, 5, 6, and 8). This dune-like

feature consists of a smaller volume of material and would not extend the beach width by more than approximately 40-45 feet from the toe of the revetment. This alternative would extend along the entire length of the Conservation and replace all existing structures (seawall, STP, and revetment).

- **Alternative 8: *Remove Seawall and Beach Nourishment.*** This alternative would remove and demolish the existing seawall and replace the seawall with a natural dune and fronting beach nourishment. The dune would also utilize ACT ProTecTubes™ as a core of the dune. A significant amount of landward area would be required to create a stable dune system, and this would require removal of nearly all of the current parking areas, roadways, a significant number of public reservation buildings, as well as some business properties and buildings.

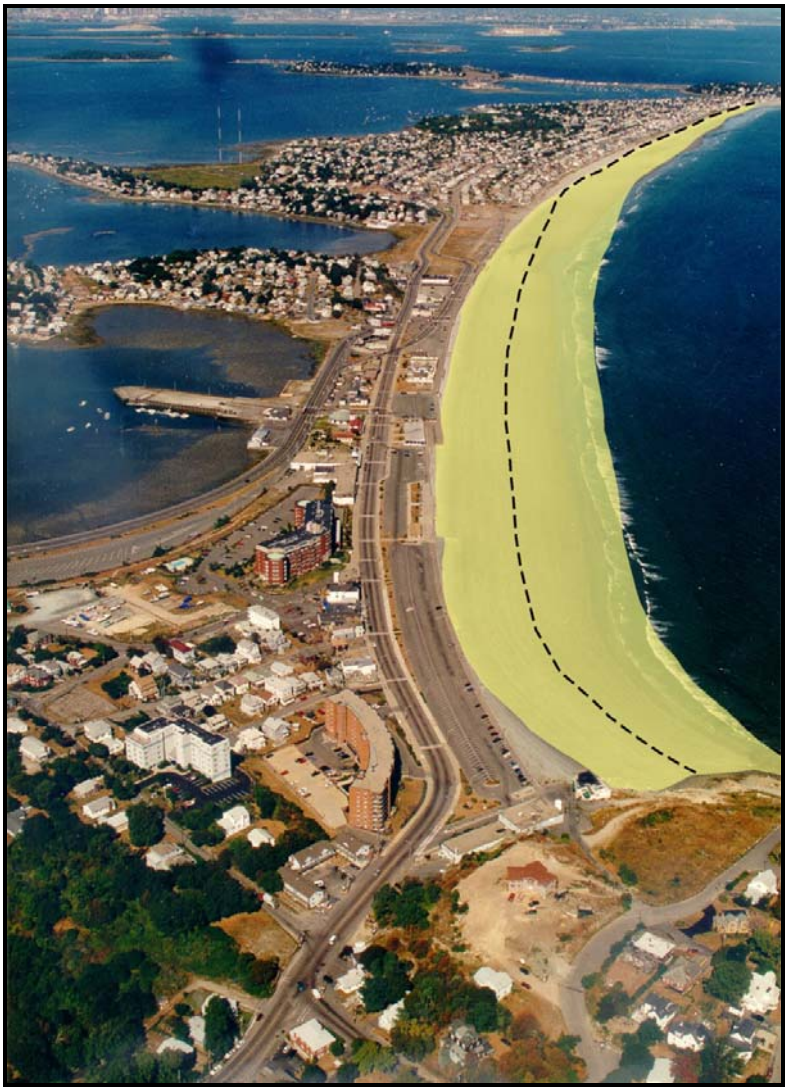

Figure 6-11. Example of proposed beach nourishment (conceptual design, not exact proposed design) at Nantasket Beach, the dashed line shows the new location of Mean High Water on the beach.

7.0 COASTAL PROTECTION ALTERNATIVES ANALYSIS

In addition to the development and selection of the alternatives for more detailed analysis, a comprehensive list of evaluation criteria was also developed during the January 31, 2007 meeting. These evaluation criteria were divided into specific subcategories and used to compare the selected alternatives. The evaluation criteria included:

- *Storm Protection and Impacts:* Includes evaluation of the upland flooding potential, the ability of the alternative to provide storm protection for upland infrastructure, and the direct loss of infrastructure due to the construction of the alternative.

- *Service Life:* Performance of the alternatives, including the lifetime of the beach nourishment, as well as the lifetime of the overall shoreline protection system (e.g., including structural lifetime).

- *Socio-Economics:* Includes potential economic benefits or disadvantages to the community, aesthetics, and recreational benefits.

- *Permitting and Construction:* Includes the relative complexity of the environmental permitting, the length required for permitting, and the construction length for each of the alternatives.

- *Costs:* Incurred over the life cycle of the alternative – this includes the initial capital cost, operation and maintenance costs, and upland damage costs and/or savings during a storm event.

In this chapter, each of the eight selected alternatives is analyzed from a coastal processes and performance perspective (which addresses the evaluation criteria of storm protection and impacts), alternatives performance/service life, socio-economic aspects, permitting, and costs.

7.1 STORM PROTECTION AND IMPACTS

In order to assess potential upland flooding and the level of storm damage protection provided to the buildings and upland infrastructure at Nantasket Beach, the impacts of a 100-year return period storm at Nantasket Beach were evaluated for each alternative. The wave run-up and overtopping occurring during a 100-year storm event, using the model results presented in Chapter 4, were determined for each alternative. The rate of overtopping for each alternative provided a quantitative measure of the amount of water that may flood the Nantasket Beach Reservation from ocean storm waves. These values were used to assess the variations in potential flooding associated with each alternative. In addition, the influence on the Federal Emergency Management Agency (FEMA) flood zones was assessed in a qualitative manner to determine if the alternative may impact the location of flood zone lines. Finally, the direct loss of existing infrastructure that would occur due to the construction of the alternative was determined based on a conceptual design for each alternative.

7.1.1 Wave runup and overtopping

Wave runup and overtopping of the potential alternative were determined in order to compare the relative coastal flooding protection afforded by each alternative. Essentially, wave runup is the measure of how high the water propagates up the structure or beach, while wave overtopping is an estimate of how much water gets behind a structure during a given storm.

Wave runup is defined as the maximum water surface elevation (measured vertically) from the still water level. Figure 7-1 illustrates the concept of runup and rundown on a simple smooth slope. The runup depends on the height and steepness of the incoming wave, the slope angle, the surface roughness, and the permeability and porosity of the slope. An increase in the permeability of a slope or the roughness of the slope will decrease the level of runup, as water is allowed to inflow into the structure or greater energy is dissipated, respectively. Figure 7-2 provides an example of the reduction in runup caused by a greater level of permeability.

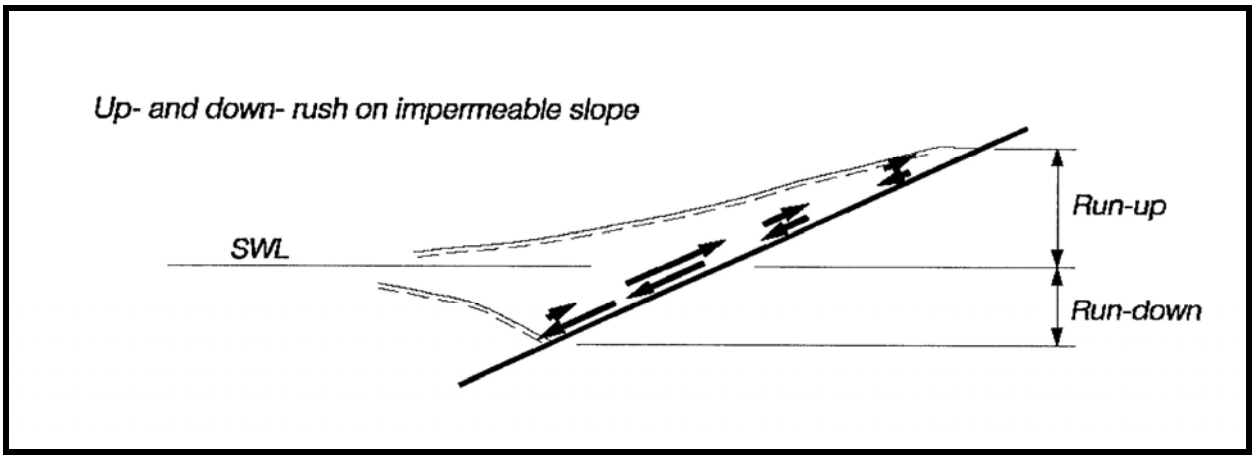

Figure 7-1. Illustration of runup and rundown on a smooth impermeable slope (USACE, 2002).

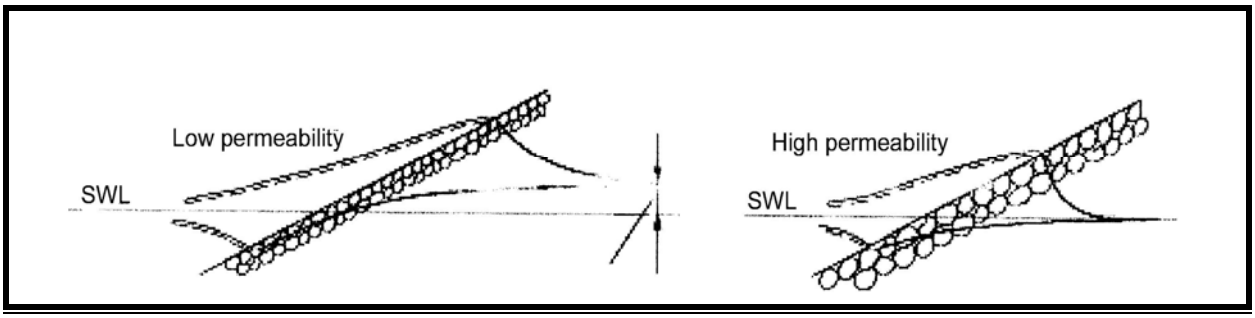

Figure 7-2. Effect of structures permeability on the level of runup. The left hand panel shows a low permeability structure resulting in increased runup, while the right hand panel shows a high permeability structure with decreased runup (USACE, 2002).

Engineering analysis of the wave runup was conducted using standard engineering methodology for both coastal seawalls/bulkheads and revetments. For the vertical seawall alternatives, the methodology was developed by Saville (1955, 1956) as presented in the Shore Protection Manual (USACE, 1984). For the proposed rubble sloping alternatives (e.g., revetment), wave runup was calculated using the method of van der Meer and Stam (1992) as:

$$\frac{R_{u2\%}}{H} = 0.835\xi_{op} \qquad for\ 1.15 < \xi_{op} \leq 1.72 \tag{7-1}$$

$$\frac{R_{u2\%}}{H} = 1.1\xi_{op}^{0.46} \qquad for\ 1.72 < \xi_{op} \tag{7-2}$$

where

$$\xi_{op} = \frac{\tan\alpha}{\sqrt{H/L}} \tag{7-3}$$

with the variables defined as:

$R_{i2\%}$	is the runup level exceeded by 2 percent of the incident waves,
H	is the significant wave height,
α	is the slope of the structure
L	is the wavelength.

Wave overtopping occurs when the highest runup levels exceed the crest of the structure, thereby allowing water to flow over and behind the structure, conceptually shown in Figure 7-3. Wave overtopping can result in significant structural and human safety concerns, as shown in Figure 7-4. Overtopping is presented as a time averaged volume of water that is discharged over the crest of the structure (liters/second for every meter [l/s-m]). The amount of allowable overtopping depends primarily on the type and function of the particular structure. Wave overtopping is unevenly distributed in time and space and a major portion of the overtopping discharge during a storm is due to a small fraction of the waves. Most estimates of overtopping are based on empirical formula developed in field and laboratory studies. Wave overtopping can result in significant upland flooding or erosion landward of the coastal structure. The ability of a structure or beach to reduce wave runup and overtopping is a key component of the overall shoreline protection. Therefore, a key component of the relative effectiveness of each of the proposed alternatives is the relative levels of overtopping allowed.

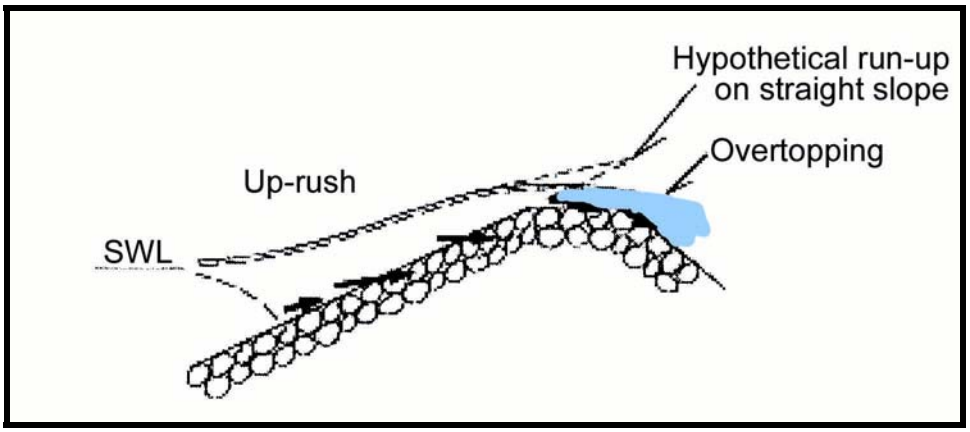

Figure 7-3. Illustration of wave overtopping of a sloped structure. Overtopping occurs when the runup exceeds the crest of the structure (USACE, 2006).

Figure 7-4. Examples of wave overtopping at seawall structures.

For the proposed seawall alternatives, both the methodology of Saville (1958) and the methodology of Franco and Franco (1999) were utilized to predict the overtopping (Q) in order to provide a range of potential overtopping rates. Saville (1958) predicted overtopping rate as:

$$Q = (gQ_0^* H^3)^{1/2} e^{-\left[\frac{0.217}{\alpha}\tanh^{-1}\left(\frac{h-d_s}{R}\right)\right]} \tag{7-4}$$

while Franco and Franco (1999) predicted the overtopping rate as:

$$Q = (gH^3)^{1/2} * 0.082 e^{\left(-3.0\frac{R_c}{H_s}\frac{1}{\gamma\beta\gamma_s}\right)} \tag{7-5}$$

where

H	is the significant wave height at the structure
R_c	is the freeboard (distance between the structure crest and still water elevation)
D_s	is the depth of the structure toe
Q_0 and α	are empirically determined coefficients based on incident wave characteristics and structure types
γ_s *and* γ_B	are geometry and wave crest factors

For the sloped revetment, the methodology of van der Meer and Janssen (1995) was applied.

$$Q = \sqrt{gH^3}\,0.2\exp\left[-2.6\frac{R_c}{H}\frac{1}{\gamma_b\gamma_r\gamma_h\gamma_\beta}\right] \tag{7-6}$$

where

H	is the significant wave height at the structure
R_c	is the freeboard (distance between the structure crest and still water elevation)
$\gamma_r, \gamma_b, \gamma_h$ *and* γ_β	are various factors such as the surface roughness, etc.

7.1.2 FEMA Flood Zones

In addition to wave runup and overtopping, which quantify the potential ocean-based flooding that can occur during a storm event, the FEMA flood zones for the Nantasket Beach region were also evaluated to ascertain if potential changes to the delineation of the zones could occur due to each alternative. Figure 7-5 presents the current flood zone delineation at Nantasket Beach. The letters in the different zones represent various levels of flooding that are expected during a 100-year return period storm event. These are defined as follows:

- V zone – Areas of coastal flooding with waves
- AO zone – Areas with flooding with depths between 1 and 3 feet
- A zone – Areas with flooding
- C zone – Areas of minimal flooding

For the alternatives that keep the seawall in place (Alternatives 1 to 6), the flood zones would remain the same. However, for those alternatives that include structural improvements to the seawall or add beach nourishment (Alternative 2 to 6), the flood zones could potentially improve (move seaward). For the cases where the seawall is modified or removed (Alternatives 7 and 8), these flood zones would be expected to move landward and would impact the ability to construct and/or modify buildings and increase insurance rates. For example, Figure 7-6 shows the expected flood zones for Alternative 8. The potential change in FEMA flood zone delineation is summarized in Table 7-1.

Figure 7-5. Existing FEMA flood zone delineation at Nantasket Beach (see previous page for explanation of symbols).

Figure 7-6. Expected location of new FEMA flood zone delineation at Nantasket Beach after the implementation of Alternative 8 (see previous page for explanation of symbols).

7.1.3 Direct Loss of Infrastructure

Construction of some of the alternatives would result in direct loss of existing upland infrastructure. If the seawall remains in its current location (Alternatives 1 to 6), the current infrastructure would not be impacted. However, modifications and/or removal of the seawall would have direct impacts on some of the Nantasket Beach infrastructure. Figure 7-7 shows the impact of Alternative 7 (i.e., moving the seawall 30 feet landward) on the MJM bathhouse. Although some parking area would also be lost, the MJM bathhouse would be the only building impacted in Alternative 7. Alternative 8 would have a much greater impact on the Nantasket Beach infrastructure, since removing the seawall and replacing it with a more gently sloping natural dune would require significantly more cross-sectional space. Figure 7-8 shows the potential impact of Alternative 8 on the same area as shown in Figure 7-7. The direct loss of infrastructure for all alternatives is summarized in Table 7-1. Figures 7-7 and 7-8 are conceptual drawings only.

7.1.4 Summary

Table 7-1 presents a summary of storm damage impacts for each of the eight final alternatives. Specifically, the table provides the wave overtopping results, the potential damage to infrastructure, the expected impact on the FEMA flood zones, and the direct loss of infrastructure. The Shore Protection Manual (USACE, 1984) provides the level of damage to infrastructure associated with the quantity of wave overtopping. Overtopping rates represent the amount of water that is expected to overtop the alternative (seawall, revetment, etc.) during a 100-year storm event with the tide level ranging from mid to high tide. Limiting the amount of overtopping that occurs during the storm event provides some protection benefit. Wave overtopping is typically reduced for a sloping rubble structure or when a beach is fronting the structure since the wave energy is more easily dissipated on the face of the sloping structure or due to the beach.

The rate of overtopping for Alternative 8, which does not include any type of hard coastal structure, could not be directly quantified, since the proposed dune is a dynamic feature that will begin to erode, transport sediment offshore, and overwash (movement of the dune landward) during the storm event. Therefore, the dune evolution during the 100-year storm was simulated using a cross-shore sediment transport model (SBEACH) to determine the potential impact on the dune alternative (Alternative 8). Additionally, Table 7-1 presents the reduction or increase in upland flooding potential (when compared to the no action alternative) and the potential shift in FEMA Flood Zones. Finally, the table also presents the infrastructure that will be directly lost during the construction of each alternative.

Table 7-1. Wave overtopping and upland flooding potential for the final alternatives.

Alternative	Upland Flooding Potential	Impact to Mapped Flood Zones	Overtopping Rate	Expected Impacts due to Large Storm	Direct Loss of Existing Infrastructure
1. No Action	Significant upland flooding	FEMA Flood Zones remain the same	**1-51 l/s-m*** overtopping.	Seawall failure, Significant damage to buildings, Very dangerous to pedestrians, Unsafe vehicular traffic at any speed	No impact unless wall fails
2. Toe Protection	**Small** reduction	FEMA Flood Zones remain the same	**0-34 l/s-m*** overtopping.	Damage to structure, Damage to buildings, Very dangerous to pedestrians, Unsafe vehicular traffic at any speed	None
3. Revetment	**Medium** reduction		**0-20 l/s-m*** overtopping.		
4. Beach Nourishment	**Large** reduction, while nourished beach in place	FEMA Flood Zones remain the same	**0-3 l/s-m*** overtopping.	No damage to seawall, Minor damage to signs, posts, etc., Dangerous to pedestrians on wall, Unsafe vehicular traffic at high speed	None
5. Toe Protection with Beach Nourishment					
6. Revetment with Beach Nourishment					
7. Move Sewall back, revetment and dune	**Medium** reduction	FEMA Flood Zones would shift landward 30 feet.	**0-16 l/s-m*** overtopping.	Damage to structure crest, Damage to infrastructure, Very dangerous to pedestrians, Unsafe vehicular traffic at any speed	MJM Bath house
8. Remove seawall and build dune	**Large** reduction, while nourished beach in place	FEMA Flood Zones will shift landward significantly	Dune migrates approximately **50-75 feet (15.2-22.9 m)** landward	Dune migration into roads & buildings, Damage to buildings, Very dangerous to pedestrians, Unsafe road traffic at any speed	Nantasket Ave. northbound; Tivoli Bathhouse; Bernie King Pav.; MJM Bathhouse; private property; parking areas

l/s-m = liters per second for every meter along the beach

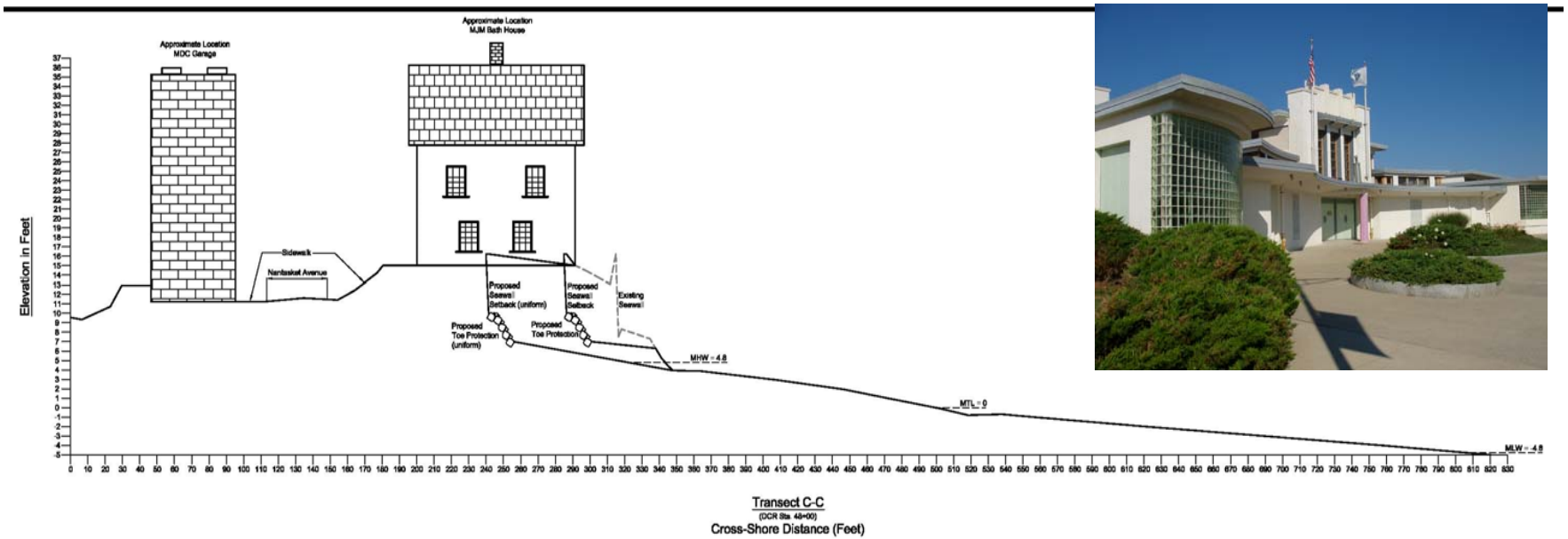

Figure 7-7. Conceptual layout of the new seawall and impact on the MJM bathhouse for Alternative 7 (conceptual layout only, not to scale).

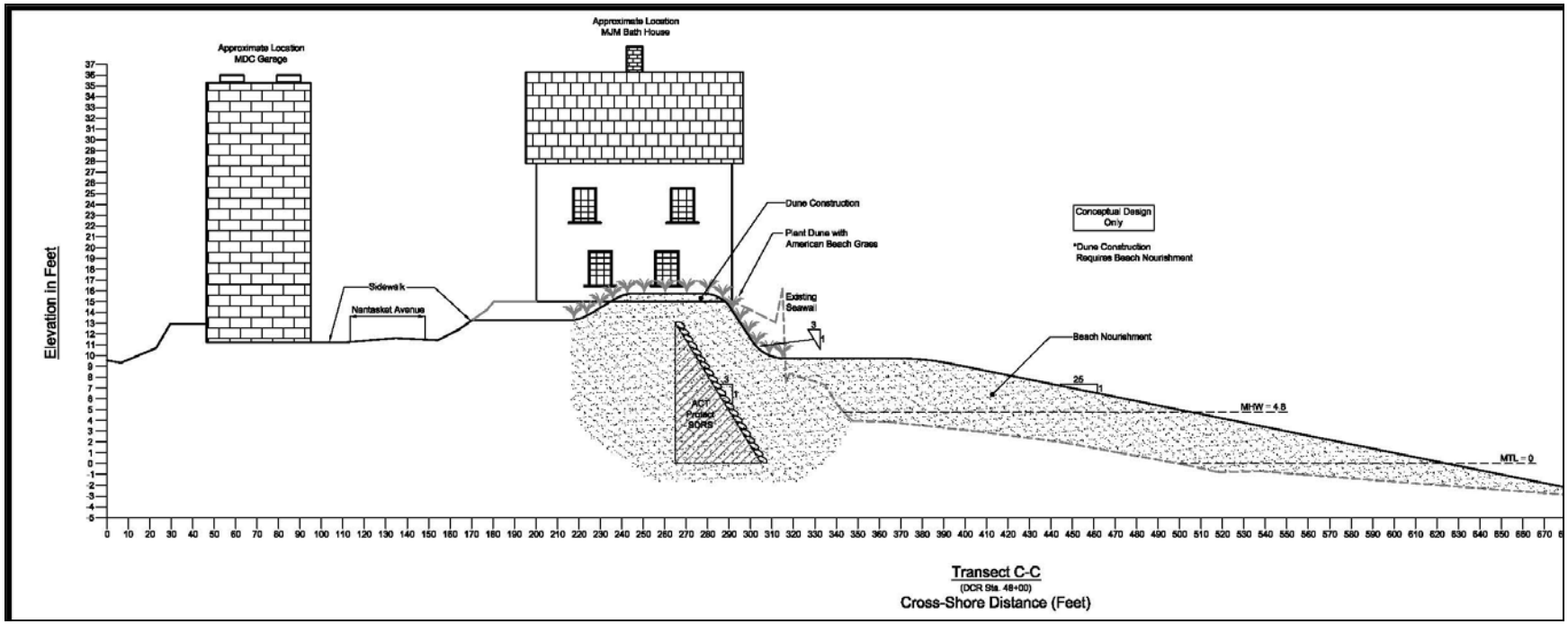

Figure 7-8. Conceptual layout of Alternative 8 and impact on the MJM bathhouse (conceptual layout only, not to scale).

7.2 ALTERNATIVE SERVICE LIFE

Another important criterion in the evaluation of the alternatives is the performance or service life of each alternative. For the long-term solution at Nantasket Beach, this consists of two components:

- *Performance of the beach:* The time long does the beach last before the recreational value returns to the current condition of no high tide beach.
- *Performance of the shoreline protection system as a whole*: How long is protection afforded by the combination of any structure and how does the beach last.

For example, for the no action alternative, there is currently no beach available at high tide, and the existing seawall has a limited lifetime remaining before failure is expected. The U.S. Army Corps of Engineers performed a stability analysis for the seawall, as described in Winkelman and Jones (2005). Calculations were performed in accordance with the USACE's *Engineering Manuals, Retaining and Flood Walls* (EM 1110-2-2502) and *Stability Analysis of Concrete Structures* (EC 1110-2-6058). The analysis evaluated the structure for stability in overturning, sliding, and bearing capacity for the no-storm and 100-year storm conditions. The USACE determined that the seawall requires the following elevations of sand in front of it for stability:

- No-storm conditions: Elevation of +7 feet NGVD
- 100-year storm: Elevation of +9 feet NGVD

Recent beach survey data (September, 2008) show that the elevation in front of the mid-section of the seawall (i.e., the section without rock protection) does not meet the required elevations to withstand a 100-year storm. Further, based on the current elevation of the beach fronting the seawall, as well as the observed rate of erosion from recent surveys (Louis Berger, 2006), the seawall is currently unstable and likely in danger of collapse in less than 10 years for normal conditions, and less than 6 years for storm conditions.

7.2.1 Beach Nourishment Performance

Beach Nourishment Design

If beach nourishment is the preferred alternative, or a component of the preferred alternative, the beach nourishment template should be optimized. A successful beach nourishment project is engineered and consists of more than simply placing sediment on a beach. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area. As such, beach nourishment designs must identify the coastal

processes at the site. Typically, computer models (Chapters 4 and 5) are used to help design the nourishment template.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A higher and wider beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 7-9 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic renourishment intervals are also usually a part of the nourishment design. If renourishment is required in less than 5 years, then the nourishment is probably not cost-effective. If renourishment isn't required until after 10 years, then a nourishment project is likely cost-effective. The renourishment interval will vary based on the initial design, wave climate, sand used, number and types of storms, and project age. In addition, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic renourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms from year to year. This section presents the various beach nourishment designs evaluated for Nantasket Beach. Initially, over 36 different nourishment scenarios were developed and evaluated.

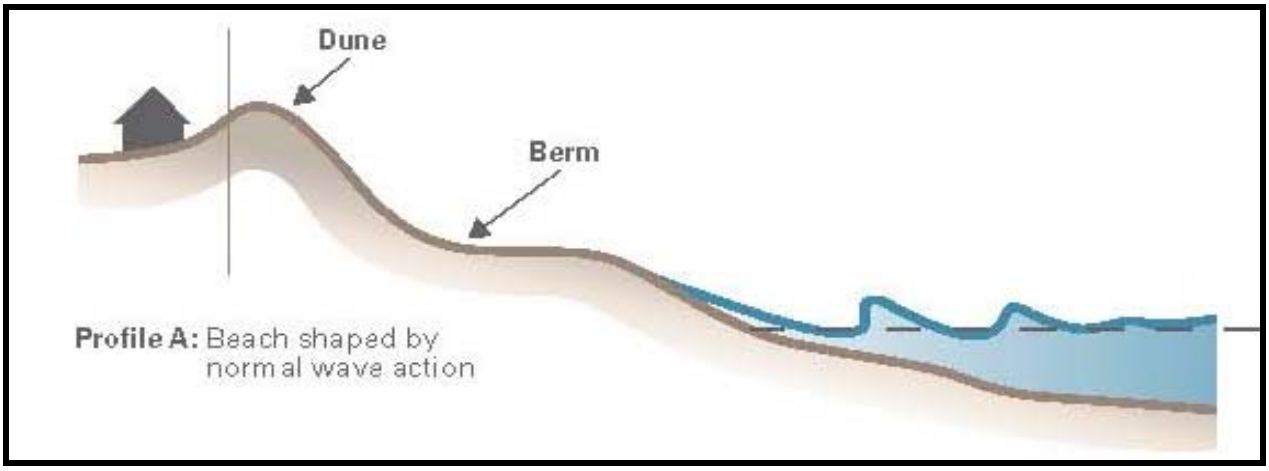

Figure 7-9. Typical beach profile and features (USACE, 2002).

Nourishment design parameters for Nantasket Beach included the following:

- *Nourishment Length:* The goal project length (extending alongshore) is 6,800 feet, spanning the entire DCR portion of Nantasket Beach.

- *Berm Width:* Berm widths of 25, 50, 75, and 100 feet were evaluated. The berm width relates directly to the increase in overall beach width. In the initial simulations, it was discovered that berm widths of 25 and 50 feet did not maintain adequate performance and were eliminated. Therefore, initial berm widths of 75-100 feet (varies alongshore) were

used. These berm widths resulted in the placement of approximately 100 cubic yards per linear foot of beach.

- *Berm Height:* Berm elevations of both 10 and 12 feet NGVD were evaluated in the alternatives assessment.

- *Offshore Slope:* For all berm templates, offshore slopes of both 1:18 and 1:25 (vertical to horizontal) were evaluated.

- *Nourishment Volume:* Nourishment volumes were determined for all scenarios based on the design beach nourishment template. In the alternatives assessment, the volume templates ranged from 610,000 to 789,000 cy of material.

- *Grain Size/Source:* Three specific grain size combinations were evaluated. These included: (1) a grain size of 0.25 mm that matches the native beach sand portion, (2) a grain size of 0.45 mm, as slightly coarser grain size than native, and (3) a mixed grain size of cobbles and sand that currently resides on Nantasket Beach.

Beach Nourishment Performance Methodology

The evaluation of proposed nourishment alternatives combines the conservation of sediment equation with the linearized transport equation. This formulation, called the Pelnard-Considére (1956) equation (Equation 7-7), is used in obtaining theoretical results to establish design and performance standards for nourishments. A more detailed description of the derivation of the equations and their applications can be found in Dean (2002).

$$M(t) = \frac{2\sqrt{Gt}}{l\sqrt{\pi}}\left(e^{-\left(\frac{l}{2\sqrt{Gt}}\right)^2 - 1}\right) + erf\left(\frac{l}{2\sqrt{Gt}}\right) \qquad (7\text{-}7)$$

where *M(t)* is the proportion of sand remaining in the placed location, *G* is the alongshore diffusivity parameter, *t* is time, and *l* is the project (nourishment) length. The alongshore diffusivity is presented by Pelnard-Considére (1956) as:

$$G = \frac{KH_b^{5/2}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)} \qquad (7\text{-}8)$$

where K is the sediment transport coefficient (a function of sediment size), B is the berm elevation, H_b is the breaking wave height, h_* is the depth of closure, p is the *in-situ* sediment porosity (approximately 0.35 to 0.40), s is the sediment specific gravity (approximately 2.65), and κ is the ratio of wave height to water depth within the surf zone (approximately 0.78).

The Pelnard-Considére equation can be applied to determine the performance of a beach nourishment project. For example, Figure 7-10 presents the spreading of an idealized,

rectangular nourishment. Although simplified, this example illustrates the planform view of nourishment dispersion. Figure 7-10 contains a series of lines depicting the temporal planform evolution of a rectangular nourishment. The resulting planform is symmetrical about the centerline of the nourishment. Therefore, only one-half of the resulting planform is shown in Figure 7-10. The solid black line indicates the initial fill template, and subsequent lines indicate the temporal progression of the nourishment. The vertical axis indicates the nourishment width (or distance seaward from the original shoreline), while the horizontal axis indicates the alongshore distance from the center of the nourishment. Within 1-year of placement of the nourishment, the shoreline excursion at the center of the project has already retreated over 100 ft, as sand has been transported in both directions due to the perturbation that is created on the shoreline. However, as shown by the lines corresponding to temporal changes in fill, the material diffuses onto the adjacent properties and is not lost from the local system immediately.

The Pelnard-Considére equation can be applied to many different scenarios by adjusting the boundary conditions. Dean (2002) has adapted the equations to evaluate sand movement in regions with inlets and/or structural influences. In addition, since the wave environment at Nantasket Beach can be complex, calculation of the alongshore diffusivity was completed based on the wave distribution for each average annual directional approach bin, as described in Chapter 4. Values of alongshore diffusivity were then computed for each directional bin and used in the modeling of beach nourishment performance.

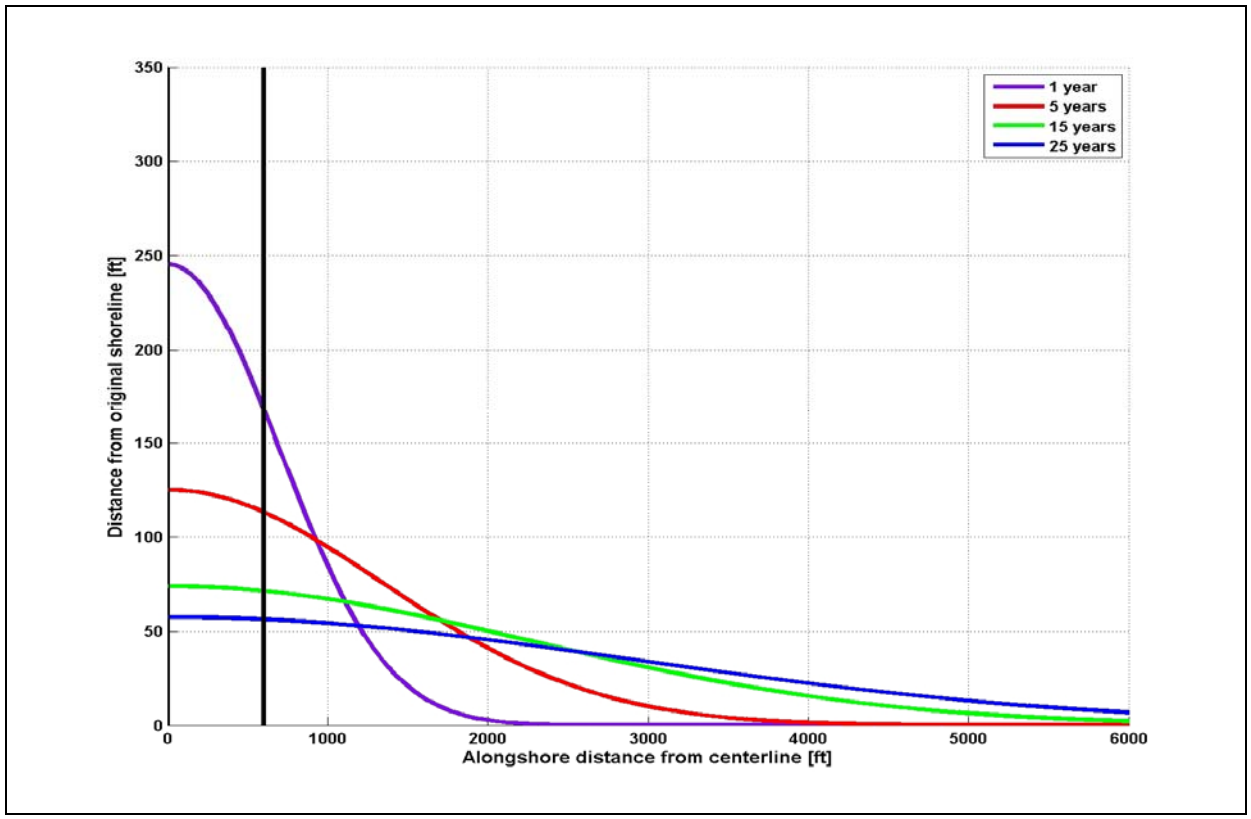

Figure 7-10. Temporal evolution of an example nourishment. Since the nourishment spreading is symmetrical in this simple case, only half the fill distance is presented.

Beach Nourishment Performance

Beach Longevity

Since the material diffuses (spreads) over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material (by percent) left in the project area. Subsequently, alternatives can be compared to one another based on their ability to maintain a beach. The service life of the beach nourishment is based upon the percent of the initial beach nourishment left within the boundary of the initial fill. The percentage remaining will decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment may have been transported offshore or along the beach. Therefore, although the sediment no longer falls within the initial nourishment template, it has not disappeared from the system as a whole. The lifetime is calculated using the wave model results and the sediment transport results for average annual conditions. This includes typical storm events that occur over the course of an average year; however, this does not include larger storm events that may disperse a significant amount of material during a single event. Since the infrequent, larger storms are unpredictable, they are not directly included in the analysis. Therefore, the performance evaluation provides a reasonable estimate of the lifetime of the beach for each alternative given typical conditions that can be expected. If an infrequent, larger storm does occur during the project lifetime, the expected longevity would be reduced.

Figure 7-11 presents the performance of the range of beach nourishment scenarios (between the upper and lower solid lines) at Nantasket Beach. The black line represents the best performing beach nourishment scenario, while the blue line represents the lowest recommended performance beach nourishment scenario. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time. All results include a background erosion rate corresponding to 1.0 ft/yr. That is, in addition to the dispersion that is occurring, an additional 1.0 ft/yr is eroded due to the natural erosion of the beach (the highest average rate of erosion from the historical shoreline change evaluation for the DCR portion of Nantasket Beach). The percent of initial material remaining is presented along the left hand axis, while the time (in years) is presented along the bottom axis. For example, after 5 years, approximately 26-40% of the initial fill volume is remaining depending on the exact amount of material, type of material, and berm width used. Additionally, Figure 7-11 shows that 50% of the nourishment remains in the initial template region after approximately 2 to 4 years. This does not indicate that 50% of the initial fill volume has disappeared, but rather is no longer in the initial template area. Curves similar to those presented in Figure 7-11 were used to determine the relative performance impacts of various berm widths and heights, offshore slopes and grain sizes. For example, Figure 7-12 shows the performance of various grain size nourishment material at Nantasket Beach. The solid black line shows the performance of a mixed sand (0.25 mm) and cobble nourishment, the red line show the performance of a 0.45 mm mean grain size sand nourishment, and the blue line shows the performance of a 0.25 mm mean grain size sand nourishment. As expected, performance is slightly increased for the larger grain size fill material. These types of performance curves can be used to select the best performing nourishment design template considering all potential variables.

In order to verify that the performance modeling for Nantasket Beach was reasonable, the performance curves were compared to the measured performance of monitored beach nourishment projects in Massachusetts, as well as some in Florida. Figure 7-13 presents a comparison of the mean modeled performance with monitored nourishment performances for Gulf Shores, Sanibel Island, and Bonita Beach, Florida, as well as Dead Neck and Long Beach, Massachusetts. The modeled nourishment performance for Nantasket Beach (red line) appears reasonable, and perhaps somewhat conservative, when compared to actual nourishment performance. The range of modeled performance curves for Nantasket Beach compare well to those nourishments in the northeast, where a similar wave climate would be expected.

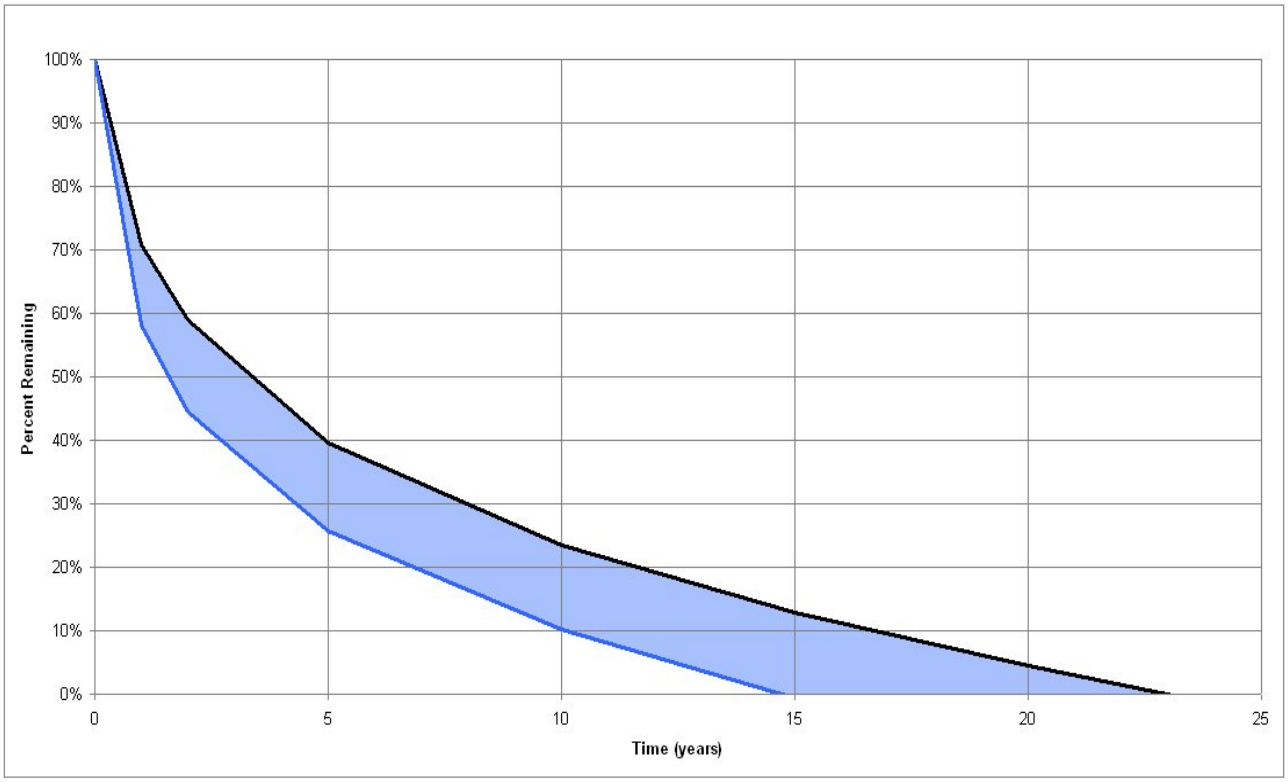

Figure 7-11. Beach nourishment performance for nourishment scenarios simulated at Nantasket Beach. The vertical axis represents the percent of fill remaining in the initial template area, while the horizontal axis represents time in years.

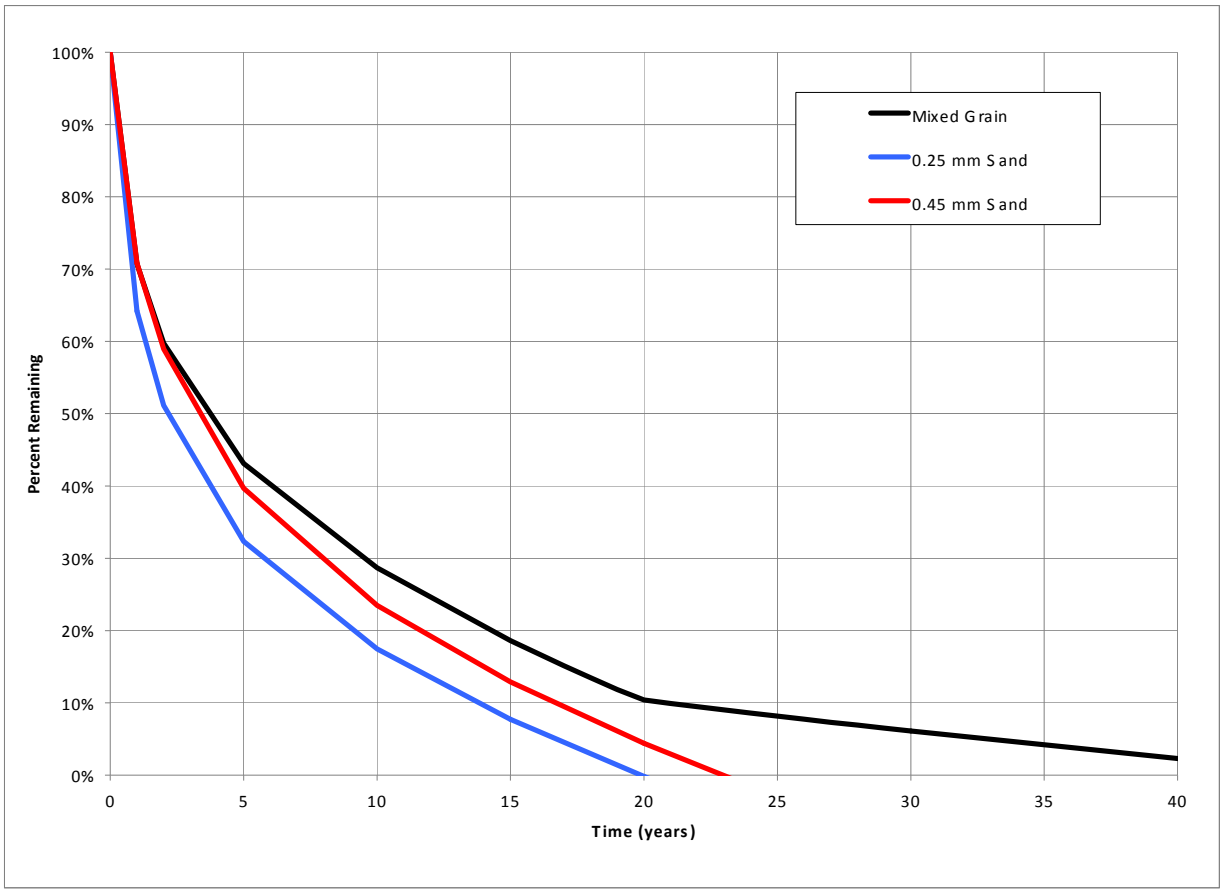

Figure 7-12. Beach nourishment performance for nourishment scenarios with a mixed cobble and sand grain nourishment (black line), a 0.25 mm sand nourishment (blue line), and a 0.45 mm sand nourishment (red line).

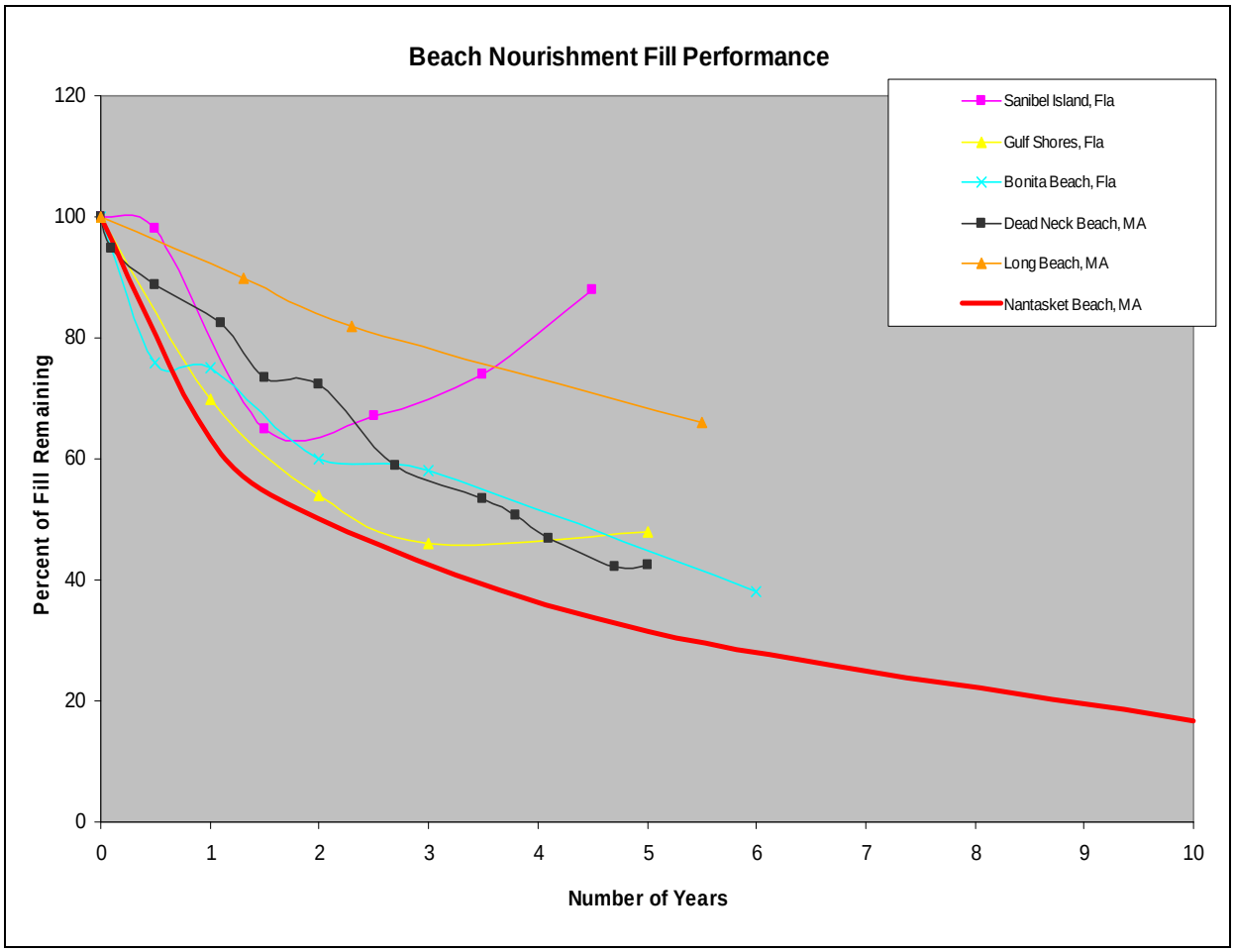

Figure 7-13. Comparison of the average projected Nantasket Beach nourishment performance to monitored beach nourishment performance.

For Alternative 7, the existing seawall would be demolished and a new seawall and fronting revetment would be constructed 30 feet landward. The fronting revetment would be similar to the toe protection that currently exists along the southern portion of the current seawall. As such, rock armor units would extend approximately 35 feet seaward from the base of the new seawall. Therefore, the actual increase in beach width would be minimal (relative to the current beach width). Subsequently, sand would be brought in to cover some of the fronting toe protection material and provide some temporary dune and beach area. This material would be much smaller in quantity and placed at a much steeper slope than the proposed beach nourishment alternatives (4, 5, 6, and 8). This dune-like feature would consist of a smaller volume of material and would not extend the beach width by more than approximately 40-45 feet from the toe of the revetment (compared to the 180-200 feet associated with the beach nourishment alternatives). This partial sand dune like feature would cover the revetment (35 feet seaward from the seawall) and extend the beach approximately 5-10 feet seaward of the toe of the revetment, and does not represent a significant gain in overall beach width. For Alternative 7, it is assumed that the gained beach width (approximately 5-10 feet from the base of the revetment) would continue to erode at the historical erosion rate of approximately 1.0 ft/yr. Although the overall gained beach

width for Alternative 7 is significantly less than the gained beach for the full beach nourishment alternatives, the rate of erosion would be slower. The minimal amount of gained beach for this alternative would erode at a slower rate than sand pushed much further seaward into the active littoral zone, where dispersion of the sediment would be increased With the historic rate of erosion (1.0 ft/yr) the gained beach would erode back to the base of the revetment over approximately 5-10 years.

Critical Width

Beach nourishment projects are designed to optimize storm damage reduction benefits relative to costs. Designing a project to protect against any and all storms is not economically feasible. Extreme conditions and severe storms could exceed the capacity of a beach nourishment project to protect property. Therefore, a reasonable storm damage protection goal is typically established, defined here as the critical width. For Nantasket Beach, the critical width was defined as the minimum beach width remaining after nourishment before which a 10-year storm event would jeopardize upland infrastructure or the coastal structure (seawall, revetment). It assumes that once the beach width reaches the critical width, maintenance nourishment would be required to provide protection against a 10-year storm event, even though some amount of the existing nourishment may still be remaining. To assess critical width, a cross-shore profile adjustment model (SBEACH) was used to evaluate the storm protection provided by the design nourishment templates. Once the beach reaches this critical width, there is a reasonable chance that damage may occur during a moderate to large storm event. This signifies when a renourishment project should be planned. The critical width varies for various alternatives. For example, for the alternatives where a coastal structure (e.g., seawall, revetment) is used to provide a second line of defense for the beach nourishment, the beach could be allowed to erode back to its current condition and the coastal structure would still provide protection from a 10-year storm event (until the service life of the seawall is reached). However, for the alternative that removes the seawall, the beach nourishment could not be allowed to erode completely since some of the beach/dune system would be needed to provide protection against a 10-year return period storm. These differences in critical width define the overall system service life before maintenance would be required (Section 7.2.2).

The computer model chosen to perform the beach cross-shore evolution was SBEACH (Larson and Kraus, 1989). SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and further developed and verified based on field measurements (Larson and Kraus, 1989; Larson, Kraus, and Byrnes, 1990). The model predicts the time-dependent evolution of existing or design beach and dune profiles for specified water levels and wave conditions. In addition to the proposed nourishment template, the model requires a time-series of wave heights, wave periods and water levels as forcing inputs. The specific storm information required by SBEACH is a time history of total water level (tide plus surge) and wind wave height and period. For evaluation of the proposed beach nourishment templates, SBEACH was used to simulate erosion of the beach profile during storms of record using the wave information developed in Chapter 4.

Figure 7-14 shows the results of the cross-shore profile adjustment caused by a 10-year storm event at Nantasket Beach for Alternative 8. The initial profile (black line) shows a 15-foot beach

berm at elevation 12 feet NAVD 88 and dune fronting a representative transect at the DCR portion of Nantasket Beach. The large structure behind the dune structure represents a building. The red line shows the beach profile following the 10-year storm event. The initial profile is eroded significantly and the dune has been exposed to wave action and overtopping and the start of significant flooding is expected. Therefore, once the initial nourishment has decayed to width of approximately 15 feet, a 10-year storm event could cause significant upland damage. For example, if Alternative 8 was constructed, after 9 to 17 years the beach would have a width of 15-feet (Figure 7-11) and renourishment would need to be considered.

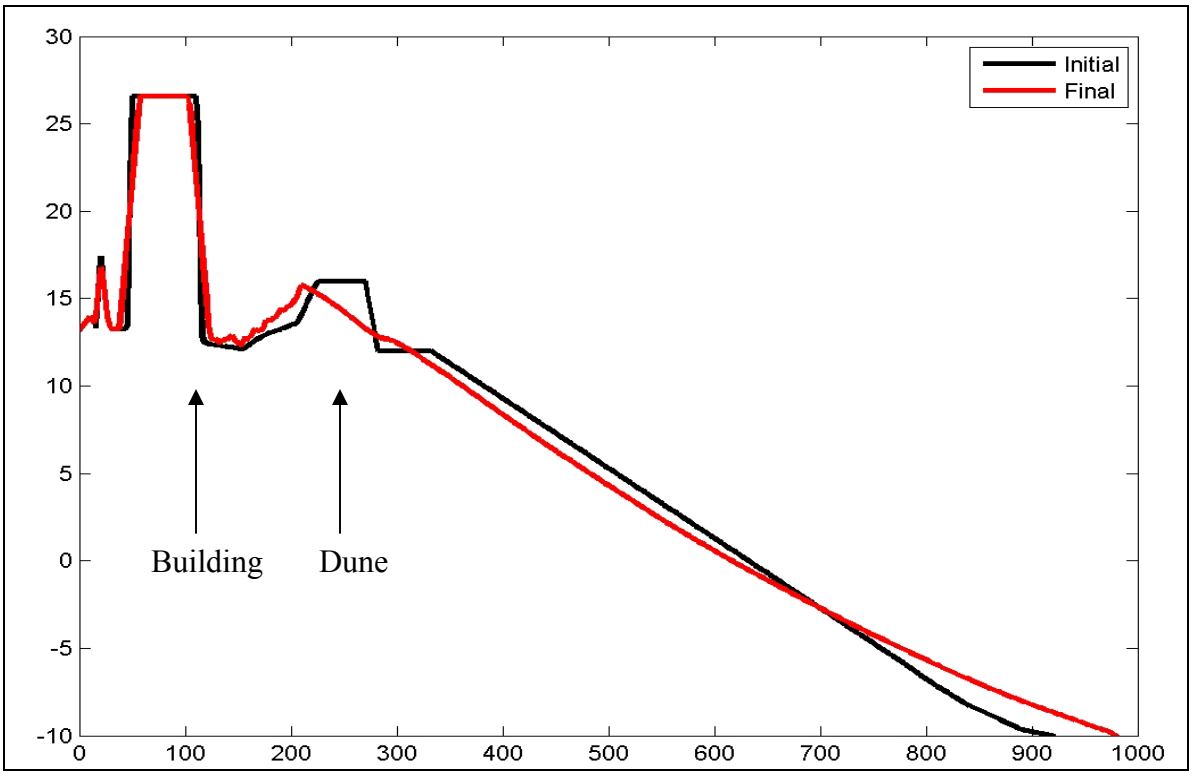

Figure 7-14. Pre and post storm profiles of a 15-foot wide beach berm at 12 feet NAVD 88 for Alternative 8. Elevation in feet NAVD 88 is presented on the vertical axis, and cross-shore distance (feet) is presented on the horizontal axis.

7.2.2 Structure Service Life and Overall System Service Life

In order to determine the overall system service life of each alternative, the service life of any proposed structures must be considered in addition to the beach lifetime. The overall service life is then the combination of the performance of the beach nourishment (if included) and the service life of the structure (if any).

- **Alternative 1:** The existing service life of the seawall structure with no protection is 0 to 6 years, as discussed above, based on beach erosion calculations and can vary depending on storm frequency and intensity.

- **Alternative 2:** Service life of the seawall is directly linked to the service life of the toe protection. The typically life of toe protection, which is sometimes considered a "temporary" measure, has an expected life span without maintenance of 15 to 25 years.

- **Alternative 3:** This alternative would construct a revetment structure in front of the existing seawall designed to be a more permanent storm damage control and scour countermeasure. The revetment is designed to have a 50 year lifespan without significant maintenance requirements.

- **Alternative 4:** This service life is based on the life span of the beach nourishment (15-23 years) plus the expected life of the wall with no protection (0-6 years). Therefore, the overall service life is 15 to 29 years.

- **Alternative 5:** Service life of the seawall is directly linked to the service life of the toe protection and beach nourishment. The typically life of toe protection, which is sometimes considered a "temporary" measure, has an expected life span with no maintenance of 15 to 25 years, beginning from a point which beach nourishment has eroded to the critical width (15 to 23 years). Therefore, the overall system service life would be approximately 30 to 48 years.

- **Alternative 6:** Service life of the seawall is directly linked to the service life of the revetment and beach nourishment. The revetment was designed to have a 50 year lifespan without significant maintenance requirements, beginning from a point which beach nourishment has eroded to the critical width (15 to 23 years). Therefore, the overall system service life would be approximately 65 to 73 years.

- **Alternative 7:** The construction of a new seawall and revetment is expected to have a design life of approximately 65 to 75 years. This alternative does not include the full beach nourishment of alternatives 4, 5, 6, and 8, and only includes a partial sand dune that is intended to cover the new revetment.

- **Alternative 8:** There is no proposed coastal structure in this alternative, and the beach will require renourishment after approximately 9 to 17 years, when the beach will reach a critical width. Although the beach itself will last 15 to 23 years, without any second line of defense, the beach would need to be renourished in order to maintain protection for upland infrastructure against a 10-year return period storm when the nourished beach width is reduced to 15 feet.

Table 7-2 presents a summary of the beach and overall system service life for each of the alternatives as detailed in this section. As discussed, the beach service life is provided as a range based on the grain size distribution, beach berm width, and berm height selected for final design. Table 7-2 also presents the increase in the high tide beach width initially after placement of the proposed alternative.

Table 7-2. Beach and overall system service life for the final alternatives.

Alternative	Initial High Tide Beach Width	Useable Beach Service Life	Overall Shore Protection System Service Life
1. No Action	Current Conditions	N/A	0-6 years
2. Toe Protection	N/A	No high tide beach	15-25 years
3. Revetment	N/A		50+ years
4. Beach Nourishment	185-200 feet	15-23 years	15-29 years
5. Toe Protection with Beach Nourishment	185-200 feet		30-48 years
6. Revetment with Beach Nourishment	185-200 feet		65-73+ years
7. Move Seawall back, revetment and dune	5-10 feet	5-10 years*	65-75+ years
8. Remove seawall and build dune	185-200 feet	15-23 years	9-17 years

* 20-30 years to reach the base of the seawall without a revetment/toe protection

7.3 SOCIO-ECONOMIC IMPACTS

The primary socio-economic considerations of any alternative consist of the following:

- Aesthetic and recreational benefits
- Economic benefits

This analysis focuses on the shoreline protection aspect of the project. Impacts from improvements of the upland portion of the Nantasket Beach Reservation are considered in the Master Plan.

7.3.1 Aesthetic and Recreational Benefits

As stated, Nantasket Beach is one of the primary recreational beaches of the area, drawing visitors from the Town of Hull and surrounding communities in the summer. Recreational activities along the beach and the seawall include the following (Figures 7-15 to 7-21):

- Sunbathing
- Swimming
- Surfing
- Kite-surfing
- Canoeing
- Socializing
- Walking along the promenade or along the beach at low tide
- Activities at the Bernie King Pavilion (such as senior citizen dances; youth events)
- Entertainment activities within the Nantasket Beach Reservation (carousel, mini-golf, arcades)
- Special events held at the Nantasket Beach Reservation (e.g., Nantasket Beach Car Show; Hull Youth Football Carnival).

Naturally, the primary season for recreation is the summer due to warm air temperatures and water temperatures that are acceptable for bathing. However, recreation occurs throughout the year at varying degrees of intensity.

Aesthetic and recreational benefits cannot easily be quantified as they are largely a personal experience. However, general assumptions can be made based on common perceptions:

- **Beach Width:** A large expanse of sand is considered preferable over a narrow strip of sand for the following reasons:
    - It allows recreation on the beach at all tidal levels (including high tide).
    - It increases the capacity of the beach for beachgoers, which means that beachgoers can spread out more unless the total number of beachgoers goes up proportionately.
    - It is visually more pleasant.
- **Grain Size:** A pure sand beach is preferable over a cobble beach, or mixed sand/cobble beach.
- **Beach Access**: Obstructed beach access (stairs, ADA accessible ramps) is not desirable (Figure 7-22).
- **Rocks:** Rocks along the seawall are not visually pleasant in combination with a narrow beach. The wider the beach, the less are rocks perceived to be a concern.

- **Seawall damage:** A seawall damaged during a storm, and resulting safety measures are not desirable.

Considering these assumptions, the following would pertain to the evaluated alternative with regards to aesthetic and recreational values (Table 7-3).

- **Alternative 1:** There would be little change under the no-action alternative. However, should the mid-section of the seawall fail during a storm, the aesthetic and recreational impacts would be considerable, as experienced during the collapse and repair period for the northern section of the seawall (Figure 7-23). The damaged section would be roped off, interrupting the walk along the promenade. Parts of the seawall may lie on the beach. Repairs would be slow given the needed design and permitting requirements. Depending on the location of the seawall failure, facilities such as the MJM bathhouse may become unavailable.

Figure 7-15. Beach in mid-section of the seawall during high tide (July 2005).

Figure 7-16. Beach in mid-section of the seawall during low tide (July 2007).

Figure 7-17. Beach in southern section of the seawall with existing toe protection during high tide (July 2005).

Figure 7-18. Beach in southern section of the seawall with existing toe protection during low tide (July 2007).

Figure 7-19. Beach promenade at MJM Bathhouse during high tide (July 2005).

Figure 7-20. Senior citizen dance at the Bernie King Pavilion (July 2005).

Figure 7-21. Socializing along the Nantasket seawall (July 2007).

Figure 7-22. Access to the beach via granite stairs constructed in 2007.

Figure 7-23. Damaged beach section along the northern section of the seawall. The seawall failed in 1991; it was repaired by 2006.

Table 7-3. Socio-economic benefits of the shore protection alternatives.

Alternative	Aesthetics and Recreational Benefits	Economic Benefits
1. No Action	No change short-term	No change short-term
2. Toe Protection	Less attractive	Minor benefit
3. Revetment		Minor benefit
4. Beach Nourishment	More attractive	Benefit
5. Toe Protection with Beach Nourishment		
6. Revetment with Beach Nourishment		
7. Move Seawall back, revetment and dune	Mixed	Minor Benefit
8. Remove seawall and build dune	Mixed	Uncertain

- **Alternatives 2 and 3:** The placement of rocks along the 2,100-foot-long mid-section of the seawall would reduce the width of the beach. The placement of toe protection (Alternative 2), similar to the toe protection along the southern part of the seawall, would typically narrow the beach over a width of approximately 20-25 feet, depending on the elevation of sand in front of the toe protection. The placement of a revetment (Alternative 3), similar to the revetment in the northern section of the seawall, would narrow the beach also by approximately 20-25 feet. Both alternatives would is essence eliminate most of the remaining high-tide beach in the mid-section of the seawall (Figure 7-15). The revetment would be more massive than the toe protection, thus would likely be perceived as a greater aesthetic impact. Either alternative would reduce the recreational benefits during high tide. On the other hand, both alternatives would prevent failure of the seawall thus avoid the resulting recreational and aesthetic impacts in the long term.

- **Alternatives 4 to 6:** Placing sand on the beach would be attractive for the aesthetic and recreational reasons outlined above. It is assumed that the wider the nourished beach, the less relevant are the aesthetic and recreational impacts of a hard structure placed in front of the seawall in addition to the beach nourishment (i.e., toe protection under Alternative 5; revetment under Alternative 6). Relative to Alternative 4 (no hard structure), a hard structure as part of Alternatives 5 and 6 would reduce the risk of seawall failure if a severe storm was to erode most of the beach nourishment.

- **Alternative 7:** Moving the seawall back by 30 feet increases the width of the high tide beach, although part of the gain would be taken up by the revetment. In addition, a partial sand dune would initially result in a widening of the beach after placement, as the

sand dune would spread out. The width of the high tide beach for this alternative would depend to a large extent on the design of the partial sand dune. A wider footprint and a larger volume of sand placed into the dune would result in a wider high tide beach. The specific design of the sand dune would also have an effect on the aesthetic and recreational value. On the other hand, a landward shift of the seawall by 30 feet would have adverse impacts from the loss of the MJM Bathhouse, and the reduced functionality of the Bernie King Pavilion.

- **Alternative 8**: The aesthetic experience would be considerably different from the existing experience. In place of an easily accessible beach, there would be a sand dune and natural beach. Parking would be further offsite, as the current parking areas adjacent to the seawall would be largely taken up by the natural beach. The setting of Alternative 8 is considered aesthetically more attractive than the current seawall. Recreational impacts are mixed, however. On one hand, the experience of beachgoers would be improved due to the natural setting and wider beach. On the other hand, less people would have access to the beach. In addition, the loss of existing infrastructure such the Bernie King Pavilion, MJM Bathhouse, playground, restaurants, adjacent parking, and the Clarion Hotel are considered a considerable adverse impact. Furthermore, aesthetics and recreational benefits could be severely impacted after a storm if reservation and private buildings are damaged or destroyed.

7.3.2 Economic Benefits

Current economic activities on the reservation include the following:

- **Hotel:** The three-story Clarion Hotel is located along Hull Shore Drive, to the south of Water Street (Figure 7-24). The hotel has 105 guest rooms and is open year-round.

- **Residential properties**: There are several condominium buildings along the southern end of the beach:
  - Ocean Place Condominiums (Figure 7-25)
  - Horizons Condominium
  - Atlantic Hill Condominium (Figure 7-26)
  - Oceania Residences, constructed in 2007 on the hillside to the south of Nantasket Beach (Figure 7-26).
  - Condominiums are also planned along the northern section of the seawall on a parcel owned by the Hull Redevelopment Authority.

  Property values of these condominium buildings are expected to be affected by the recreational and aesthetic benefits of the Nantasket Beach.

- **Food establishments**: There are several restaurants, small coffee shops, ice-cream store within or just outside of the Reservation (Figures 7-27 to 7-28). Some of these establishments are open year-round, while others are only open during the summer.

- **Carousel**: Open from May through September (Figure 7-29).
- **Gift and craft shops, Arcades**: These establishments are only open during the summer.
- **Nantasket Landing Miniature Golf:** Open from early May to October, depending on the weather.
- **Bank:** The Rockland Trust Bank adjacent to the Red Parrot Restaurant is largely unaffected by beachgoers.
- **Parking:** Parking fees of the DCR lots are set by DCR. There are also some private lots, including the lot by the Hull Redevelopment Authority.
- **Summer camp along the beach:** Day camp groups for children spend the day on the beach during the summer (Figure 7-30).
- **Equipment rentals along the beach:** Currently, there are no commercial activities along Nantasket beach such as kayak or beach chair rentals.
- **Master Plan** *(in progress):* Planned improvements as part of the Master Plan, such as vendor stands along the promenade.

Figure 7-24. Clarion Hotel.

Figure 7-25. Ocean Place Condominiums.

Figure 7-26. Condominium buildings on Atlantic Hill (Oceania Residences on the right and Atlantic Hill Condominium on the left).

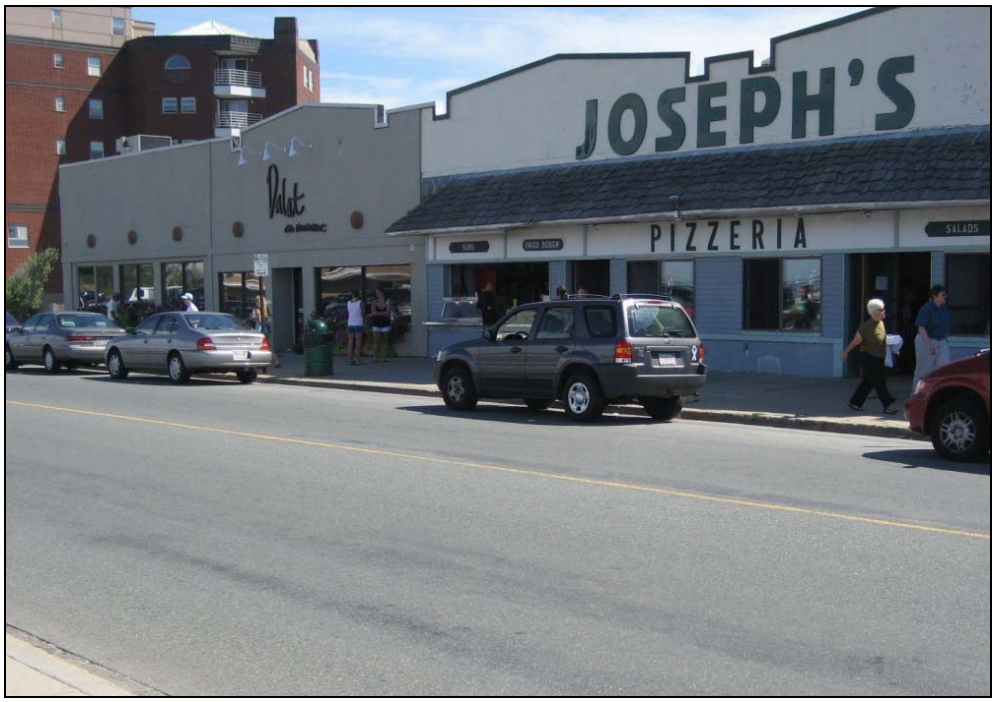

Figure 7-27. Restaurants along Nantasket Avenue.

Figure 7-28. Ice cream shop along Nantasket Avenue in the summer.

Figure 7-29. Friends of the Paragon Carousel.

Figure 7-30. Members of a summer day camp recreating at Nantasket Beach.

Variables related to the shore protection alternatives assessment for economic benefits include the following:

- **Number of beachgoers:** A greater number of beachgoers would result in a greater number of economic activities.
- **High tide beach conditions**: A beach that is unavailable during high tide results in people spending less time at the Reservation, resulting in less economic activity. While some beachgoers may move to the beach along the northern part of the Reservation, or go out for lunch, an increase in the length of the period during which the beach is inundated during high tide likely results in a decrease in beachgoers.
- **Seasonal vs. year-round activities**: Most economic activities at the site currently occur in the summer. A greater degree of activities during other seasons would depend on the attractiveness of the reservation as a day destination for primarily recreation, or evening destination for activities such as eating out.

Considering these factors, the following economic impacts are anticipated for the various shore protection alternatives (Table 7-3). It is noted that revenues from parking were not considered in this analysis, as parking would shift to other nearby locations, and as parking fees are currently set at a comparatively low rate.

- **Alternative 1:** There would be little change under the no-action alternative. However, should the mid-section seawall fail during a storm, the economic benefit would be reduced slightly as less people would be attracted to visit Nantasket Beach.

- **Alternatives 2 and 3:** In the short term, the placement of a rock structure (toe protection or revetment) in the mid-section of the seawall would have a minor adverse economic impact as the existing high tide beach in this section would be reduced. However, over the long term, the reduction in risk of seawall failure would result in minor economic benefits relative to current conditions.

- **Alternatives 4 to 6:** Placing sand on the beach would have economic benefits as a greater number of beachgoers would be attracted to the beach. In addition, beachgoers would stay longer, as there would be a beach during high tide. Additional benefits would occur as a result of improvements proposed as part of the Master Plan (in progress). There would also be an increase in value of private and DCR-owned properties and buildings (including condominiums).

- **Alternative 7:** Moving the seawall back by 30 feet increases the width of the high tide beach, although part of the gain would be taken up by the revetment. In addition, the partial sand dune would add additional beach width. As a result, beachgoers would stay longer on the beach, presumably frequenting businesses more often, thus resulting in a minor economic benefit.

- **Alternative 8**: The economic benefits are more speculative for this alternative. Less beachgoers would be expected on the beach due to more difficult access to the beach. On the other hand, the beach may be considered aesthetically more attractive, bringing in more visitors during other seasons or in the evening. However, an economic factor that would need to be considered as well would be the loss or damage of private and DCR-owned property during a large storm. The risk of such damage would affect property values and insurance rates. In addition, the loss of business along Hull Shore Drive (e.g., Red Parrot Restaurant, Clarion Hotel) would have adverse economic impacts. Also, there would be less space available for new amenities considered under the Master Plan.

7.4 PERMITTING AND CONSTRUCTION

7.4.1 Permitting

All of the proposed Nantasket Beach shore protection alternatives would trigger a number of state and federal regulatory programs. With the exception of Alternative 1, all the alternatives involve substantial fortification (toe protection or revetment; Alternatives 2, 3, 5, 6) of the existing seawall, or involve demolition and replacement with a new seawall (Alternative 7) or sand dunes (Alternative 8). The level of permitting complexity for the various alternatives varies (Table 7-4).

All alternatives, except Alternative 1, require the following filings:

- Massachusetts Environmental Policy Act (MEPA) Environmental Impact Report
- Massachusetts Wetlands Protection (WPA) Order of Conditions
- Section 401 Water Quality Certification
- Chapter 91 Waterways License
- Section 404 U.S. Army Corps of Engineers authorization
- Coastal Zone Management (CZM) Federal Consistency Concurrence.

Alternatives with a beach nourishment or dune construction component (Alternatives 4 to 8) introduce substantially greater permitting complexity and cost due to potential environmental impacts associated with the sediment source, transport and placement. Based upon preliminary estimates of required sand volumes, upland sources for sand and trucking to the site would be considerably more expensive than a marine source. However, recent efforts to seek regulatory approvals for offshore sediment sources for beach nourishment have stalled. Permitting with sand from an offshore sand source would be more stringent than with sand from an upland sand source and would also require approvals from the National Marine Fisheries Service (NMFS) regarding impacts to Essential Fish Habitat.

Impacts to landside infrastructure associated with Alternative 8 (and to a lesser extent with Alternative 7) add another layer of regulatory considerations with additional cost. These alternatives may require relocation of roadways and underground utilities, displacement of residents and businesses, impacts to open space protected under Article 97, impacts to historic buildings protected under Section 106, hazardous materials concerns with building demolition and FEMA approvals for alternation of flood zones.

Table 7-4. Environmental permitting and construction period estimates of the shore protection alternatives.

Alternative	Environmental Permitting		Construction Period
	Complexity	**Permitting Period**	
1. No Action	None	n/a	n/a
2. Toe Protection	Comparatively simple *(5)*	**0.75 years**	**1 year**
3. Revetment	Standard	**1.5 years**	**1 year**
4. Beach Nourishment	Complex	**3 years (offshore source)** *(1)* **1.5 years (upland source)**	**Rock Structure (Alt. 5 & 6)** *1 year* **Beach Nourishment (Alt. 4 - 6)** *1 year - Offshore source: (1)* *9-14 years (upland source) (2)* **Totals**: Alt. 4: 1-14 years Alt. 5: 2-15 years Alt. 6: 2-15 years
5. Toe Protection with Beach Nourishment		**3 years (offshore source)** *(1)* *Rock structures:* 1.5 year *Beach Nourishment:* 3 year **1.5 years (upland source)** *Rock structures:* 1 year *Beach Nourishment:* 1.5 years	
6. Revetment with Beach Nourishment			
7. Move Seawall back, revetment and dune	Complex	**3 years** (offshore source) *(1)* or (upland source)	**4 years (offshore source)** *(1)* *Wall / Rock structure:* 3 years *Partial sand dune:* 1 year **6+ years (upland source)** *Wall / Rock structure:* 3 years *Partial sand dune: 3+* years *(3)*
8. Remove seawall and build dune	Very complex	**3-5 years** (Offshore sand source) *(4)*	**4 years** (offshore sand source) *(4)*

(1) This assumes that an offshore sand source can be utilized which is currently not possible.

(2) Based on a nourishment rate of 75,000 and 50,000 cy/year, respectively.

(3) Rough estimate only, as the length for construction depends significantly on the specific design and volume of sand to be placed in a partial sand dune.

(4) This alternative is not considered feasible using an upland sand source.

(5) Permit applications are largely prepared as part of the former Seawall Toe Protection (STP) application in 2006.

Estimates of the permitting period are included in Table 7-4. The shortest permitting is required for Alternative 2 (i.e., nine months), for which some of the permit applications already partially exist as a result of permitting efforts in 2006 for the placement of seawall toe protection (STP) in response to an accelerated shore protection schedule proposed by then DCR Commissioner Golledge. Permitting for Alternatives 3 would require approximately 1.5 years. Permitting for the remaining alternatives would be considerably longer and are fundamentally affected by the following two factors:

- **Offshore Sand Source:** An offshore sand source is currently unavailable and will likely not be available for several years. The extent of permitting requirements, if and when an offshore source is available, is currently not known. Estimates listed in Table 7-4 are provided for the time that a source *is* available.

- **Upland Sand Source:** The Town of Hull has stated that it is concerned about the environmental impact from the required truck traffic due to noise, traffic congestions, and structural impacts to roads.

7.4.2 Construction Period

The length of construction varies considerably between different alternatives (Table 7-4):

- **Alternatives 2 and 3:** Rock structures in the mid-section of the seawall will require approximately one year to be placed.

- **Alternatives 4 to 6:** Construction of the rock structures for Alternatives 5 and 6 would require one year; these structure should be placed prior to placing beach nourishment. Beach nourishment from an offshore source (if available) can be completed within one year. Beach nourishment from an upland source would require considerably more time and can be done over several years, depending on the agreed nourishment rate using trucks. However, the rate of nourishment from upland sources needs to be greater than the rate of erosion to be effective. The recommended rate for nourishment is 50,000 to 75,000 cy/year (see Section 8).

- **Alternative 7:** Demolition of the existing seawall and construction of the new wall and affected infrastructure is estimated to require 3 years. Demolition of the old wall and construction of the new wall would need to be carried out in a manner that does not endanger coastal properties during the demolition of the existing structures. Placing the sand for the partial sand dune requires approximately one year using an offshore source (if available). As for Alternatives 4 to 6, the duration needed for placing the dune from an upland sand source is dependent on the agreed frequency of truck traffic, and thus may last several years.

- **Alternative 8:** Demolition of the existing wall and construction of the sand dune and affected infrastructure is estimated to require 4 years. Demolition of the old wall and construction of the dune would need to be carried out in a manner that does not endanger coastal properties during the demolition of the existing structures. An offshore source is

more critical for this alternative for two reasons: (1) A gradual placement of the sand is not practical and would make the beach unattractive for as long as it takes to provide the needed sand for the dune, as the existing seawall would need to stay (at least partially) to provide shore protection in the interim. (2) A significant sand source should be readily available in case a major storm erodes part of the dune to a point where it no longer provides effective shore protection (assuming that the extent of the storm damage is contained and still allows for reconstruction of the dune).

7.5 COST ESTIMATES

Cost estimates were developed for the shoreline protection alternatives consisting of the following components:

- Initial capital costs
- Operation and maintenance costs
- Right-of-Way costs
- Upland damage costs

Costs do not include loss of business costs which are most relevant for Alternative 8.

7.5.1 Initial Capital Costs

Capital costs pertain to the construction of the infrastructure required for each shoreline protection alternative. These costs include the following components, as applicable:

- Final Design and Permitting
- Demolition and Removal
- Construction of rock structures, seawall, dunes, roads, utilities
- Placement of beach nourishment

Costs are based on estimated quantities and items of the conceptual design on a per-foot basis. Unit costs were obtained from a variety of standard sources including the following:

- Previous projects completed at Nantasket Beach
- Other beach restoration projects
- Other marine infrastructure projects
- Massachusetts Highway Department projects
- Other New England Department of Transportation projects
- U.S. Army Corps of Engineers cost estimates
- Engineering judgment based on complexity

7.5.2 Operation and Maintenance Costs

Operation and maintenance (O&M) consisted on the following key components:

- **Renourishment costs of the beach:** This applies to alternatives with a beach nourishment component. For Alternatives 4 to 6, the beach is estimated to require

renourishment on average every 20 years. For Alternative 8, the beach is estimated to require renourishment on average every 12 years at a cost of approximately $16 million at current dollars (i.e., unadjusted for inflation).

- **Routine repairs to existing and proposed structures, and a 10-year cycle**: This would include repairs of the seawall, resetting of the revetment, adjustments to the dunes, and repairs of building from storm damage. It is assumed that the return period of a storm causing damage is 10 to 25 years.

The total operation and maintenance costs calculated for each alternative was closely linked to the service life of each respective structure.

7.5.3 Right-of-Way Costs

These costs are based on research conducted by U.S. Army Corps of Engineers (New England District) that were updated in 2007. These costs only include private parcels at this time.

7.5.4 Upland Damage Costs

Upland damage costs pertain to damage of public and private buildings and infrastructure from storms. These estimates were developed by the U.S. Army Corps of Engineers on February 8, 2006 and provided to us for this project. Baseline values for upland damage costs that were applied consist of the following:

- Alternative 1: $0.53 million/year
- Alternatives 2 and 3: $0.395 million/year
-
- Alternative 4: $0.05 million/year year (assuming the beach is maintained)
- Alternatives 5 and 6: $0.05 million/year (first 20 years), and
  $0.395 million/year during the last 30 years (unless beach is renourished)
- Alternative 7: $0.05 million/year for the first 30 years, and
  $0.395 million/year for the last 20 years (unless beach is renourished)
- Alternative 8: $0.05 million/year (assuming the beach is maintained)

7.5.5 Costs for each Alternative

Costs for the eight shoreline protection alternatives are summarized in Table 7-5 and Figure 7-31. These costs are based on current value dollars (i.e., are not adjusted for inflation).

- **Alternative 1:** Capital costs pertain largely to concrete spall and seawall joint repairs along 4,500 linear feet of the seawall (mid-section and southern section of the seawall). Q&M costs would consist of routine repairs to the seawall, resetting of the toe protection, and emergency repairs to the wall and other infrastructure after major storm events. Upland damage costs ($26.5 million) are the highest of all alternatives as a result of the risks from seawall failure during a storm. The total life cycle costs for Alternative 1 are estimated to be $42 million to $67 million. The wide spread is a function of damage from seawall failure as a result of a major storm.

- **Alternative 2:** Capital costs pertain to concrete spall and seawall joint repairs along 4,500 linear feet of the seawall (mid-section and southern section of the seawall; $0.6 million), as well as the placement of the toe protection in the mid-section of the seawall ($3.6 million). The upland damage costs are still high ($19.8 million) as risks to structures during major storms remain. Q&M costs would consist of routine repairs to the seawall and resetting of the toe protection. The total costs for Alternative 2 are estimated to be $26 million.

- **Alternative 3:** Capital costs pertain to concrete spall and seawall joint repairs along 4,500 linear feet of the seawall (mid-section and southern section of the seawall; $0.6 million), the removal of the toe protection in the southern section of the seawall ($1.4 million), as well as the placement of the revetment in the mid-section and southern section of the seawall ($11 million). Q&M costs would consist of routine repairs to the seawall and revetment. Upland damage costs are similar to the costs for the revetment using the USACE approach ($19.8 million). The total costs for Alternative 3 are estimated to be $35 million.

- **Alternative 4:** Capital costs pertain to concrete spall and seawall joint repairs along 4,500 linear feet of the seawall (mid-section and southern section of the seawall; 0.6 million), as well as placement of beach nourishment across the full length of the beach (6,000 linear feet; $16 million). Q&M costs would consist mostly of renourishment costs every 20 years, as well as repairs to the seawall which would increase within each renourishment cycle as the sand is gradually eroded. Upland damage costs are sharply reduced to $2.5 million due to the much wider beach. The total costs for Alternative 4 are estimated to be $67 million.

- **Alternatives 5 and 6:** Capital costs for these alternatives would be the sum of the capital costs for Alternatives 2 and 3, respectively, and the costs for beach nourishment. Q&M costs would consist of repairs to the seawall and rock structures. The largest O&M line item would pertain to renourishing the beach at 20 year intervals ($16 million per renourishment). Upland damage costs are lower with renourishment than without renourishment. The total costs for Alternatives 5 and 6 are estimated to range from $35

million to $78 million, depending on the chosen rock structure and on renourishment plans.

- **Alternative 7:** Capital costs pertain to the removal of the existing toe protection, seawall and parking ($8 million); MJM bathhouse modifications or removal ($2 million); construction of a new seawall ($17 million); construction of a revetment ($12 million), and placement of a partial sand dune ($9 million). O&M activities would consist of routine repairs to the seawall and revetment, and optional beach nourishment. As for Alternatives 5 and 6, upland damage costs would vary depending on renourishment plans. The total costs for Alternative 7 are estimated with $59 million or $96 million, depending on renourishment plans.

- **Alternative 8:** Capital costs pertain to the demolition of the seawall, rock structures, MJM bathhouse, Bernie King Pavilion, and Tivoli bathhouse; excavation of parking lots and roadways; and roadway and utility reconstruction. An additional $12 million would be required for Right-of-Way costs as a result of buildings that need to be taken along Hull Shore Drive along the mid-section of the seawall (i.e., buildings from the Parrot Restaurant through the Clarion Hotel); these costs do not include lost revenue by these businesses. O&M activities would consist of beach renourishment every 12 years to maintain the critical beach width ($67 million over 50 years), as well as repair or replacement of the ProTec tubes which would form the central core of the dunes ($7 million in 50 years). Upland damage costs would be low, assuming the critical beach width is maintained to be able to withstand a major storm at all times. The total costs for Alternative 8 are estimated with $133 million to $145 million; the higher value includes the Right-of-Way costs.

Table 7-5. Life cycle cost estimates of the shore protection alternatives.

Alternative	**Initial Capital Costs**	**Operation and Maintenance Costs** *50-year Horizon* (Present Value Cost)	**Upland Damage Costs** *(6)* (USACE, NAE District Estimates)	**Total Costs 50-year Horizon** (Present Value Cost)
1. No Action	$0.6 million	$15 - $40 million *(1)*	$26.5 Million	**$42 - $67 million**
2. Toe Protection	$4 million	$2.5 million *(2)*	$26.5 million	**$26 million**
3. Revetment	$13 million			**$35 million**
4. Beach Nourishment	$17 million	$47.5 million *(2,3)*	$2.5 million	**$67 million**
5. Toe Protection with Beach Nourishment	$20 million	$2 million *(2)* *(without renourishment)* $47 million *(2,4)* *(with renourishment)*	$12.9 million *(without renourishment)* $2.5 million *(with renourishment)*	**$35 million** *(without renourishment)* **$70 million** *(with renourishment)*
6. Revetment with Beach Nourishment	$29 million			**$44 million** *(without renourishment)* **$78 million** *(with renourishment)*
7. Move Seawall back, revetment and dune	$48 million	$2 million (2) *(without renourishment)* $ 46 million *(2,5)* *(with renourishment)*	$9.4 million *(without renourishment)* $ 2.5 million *(with renourishment)*	**$59 million** *(without renourishment)* **$96 million** *(with renourishment)*
8. Remove seawall and build dune	$56 million *(without Right-of-way)* $68 million *(includes Right-of-way) (6)*	$74 million *(7)*	$2.5 million	**$133 million** (without Right-of-way) **$146 million** (includes Right-of-way) *(6)*

(1) Highly variable. Possible range $3 million to $8 million every 10 years.

(2) Rock structure maintenance (reset/replace) as well as seawall maintenance every 10 years.

(3) Beach requires renourishment approximately every 20 years ($16 million).

(4) Beach can be renourished every 20 years ($16 million for Alt. 4-6; $8.8 million for Alt.7), but not required.

(5) Beach can be renourished after 10-15 years, but not required.

(6) Capital costs do not include the value of long-term, or shorter-term, revenues lost by businesses.

(7) Beach/dune requires renourishment approximately every 12 years ($16 million), as it must be maintained once the beach reaches critical width (10-15 feet). Also, replacement of ProTec tubes after significant storm events.

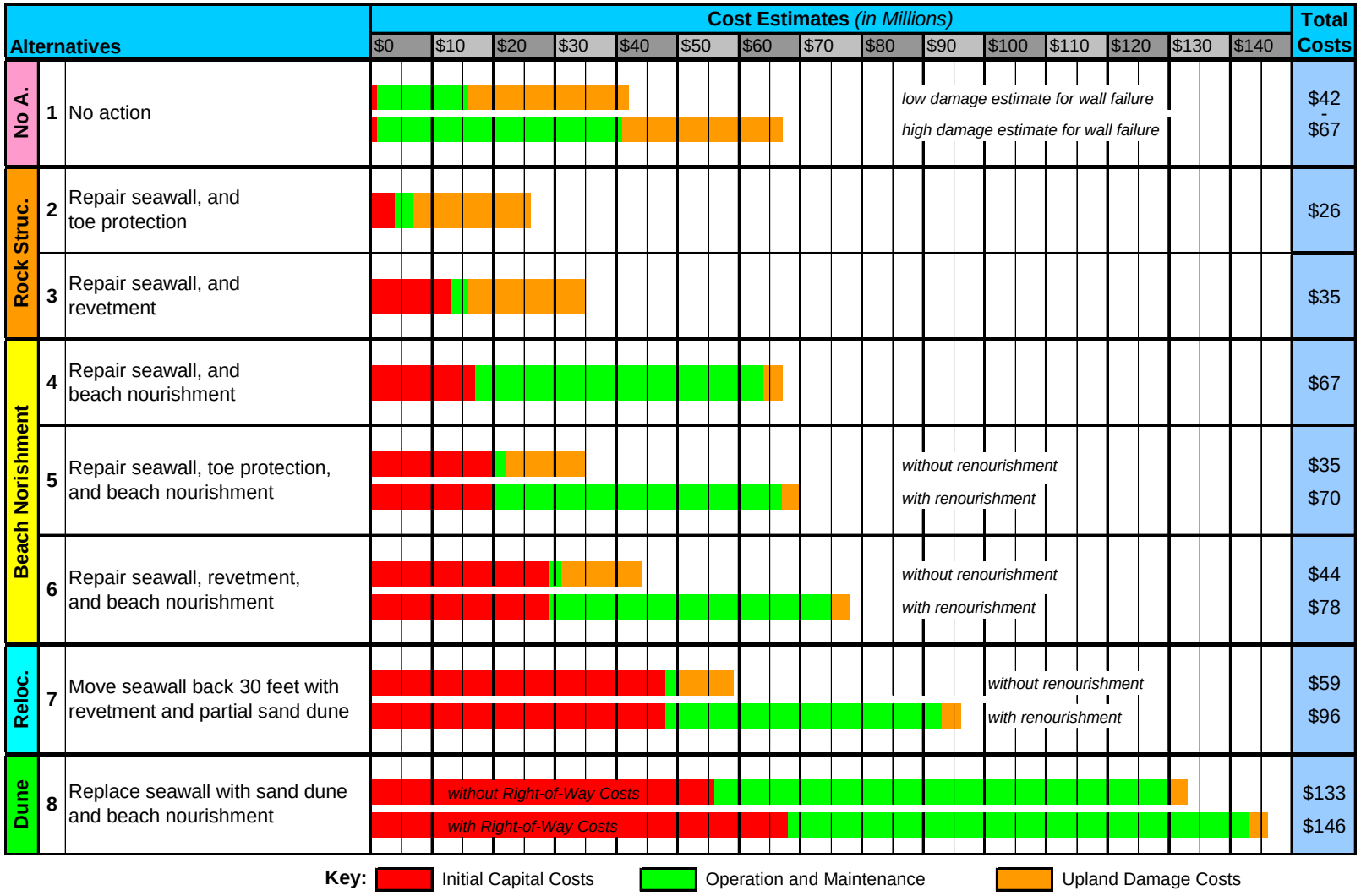

Figure 7-31. Estimates of Total Costs (based on 50-Year Horizon in Present Value Dollars).

8.0 SAND SOURCE INVESTIGATION

Since beach nourishment may likely be a key component of the preferred alternative, borrow sediment would be required to supply beach nourishment material to Nantasket Beach. A key component of a nourishment project is identifying a suitable sand source(s) that meet the engineering design criteria, is affordable, and is acceptable from an environmental standpoint. A sufficient quantity and quality of sand must be identified, preferably from a location in close proximity to the beach, and from a location where removal of sand will not result in undesirable environmental impacts.

Although identification and assessment of a specific source of sediment to nourish Nantasket Beach was not included as part of the current scope of the study, an initial investigation was conducted to identify potential feasible source options for beach nourishment alternatives. This investigation represents a preliminary evaluation on potential upland and offshore sources, including a feasibility assessment of using upland material in the construction of a large nourishment project. Upland sources may be significantly more expensive due to transportation costs. Locating a new offshore borrow site can be challenging since locations need to have a significant quantity of compatible material and limit environmental impacts to the dredge location. Additional studies, field data collection, environmental assessments, compatibility evaluation, and permitting is required prior to final selection, approval, and utilization of a borrow location.

Sand grain size is typically a governing design factor. The ideal sand source provides a grain size that is at least as coarse as the native beach material. Sand that is finer than the native beach sand often is eroded more rapidly from the beach by waves and currents. The result of using sand that is finer than the native beach sand is added expense, reduced storm protection, and reduced beach nourishment design life. Consequently, adequate testing of the native beach and the alternative sand source(s) is crucial to ensure the sand source provides clean, beach-compatible material that satisfies the engineering design criteria.

As part of this study, both upland and offshore sources were considered as to their potential for beach nourishment operations at Nantasket Beach, at a preliminary level. The location of the sand source dictates the method(s) by which the sand can be transferred to the beach, and the cost of construction. Sand from upland sources is typically trucked to the beach, which can be expensive depending upon the proximity of the source to the beach and the prevailing cost of trucking and fuel. Trucking operations also limit the volume of sand that can be delivered to the beach, and can cause traffic and community conflicts. For large nourishment projects like Nantasket Beach, use of upland sand sources would require the nourishment to take place over multiple years in order to get the total amount of sand required to the beach. A closer look at upland and offshore sand sources, as they pertain to Nantasket Beach, is included in the subsections to follow.

8.1 UPLAND SAND SOURCES

Based on the current regulatory climate and recent history in permitting offshore sand sources for beach nourishment in Massachusetts, an upland-based source may be the most feasible option for Nantasket Beach from a regulatory standpoint, at least for the foreseeable future. If another offshore sand source is considered in the future, it will likely not be available for mining for 3 to 5 years, at a minimum. Therefore, an assessment of the feasibility, logistics, and performance of using a land-based sand source for beach nourishment was conducted. Specifically, the potential feasibility of using an upland-based sand source to nourish Nantasket Beach, requiring construction over multiple seasons to complete the full nourishment project was evaluated in this section.

8.1.1 Potential Upland Sources and Vendors

Although a number of vendors were contacted for information regarding their sand resources and availability to provide material for this project, only vendors that stated they could provide the entire targeted nourishment volume of at least 25,000 cubic yards (cy) per year are presented in this report. All sand supply contractors have stated that the information (e.g., sand unit prices, grain sizes, and source locations) provided to the Woods Hole Group for this report is not guaranteed and is subject to change. The costs presented in this section are based on cost in 2008, and do not include potential impacts of economic fluctuations or inflation. Competitive bidding at the time of construction will determine the actual costs.

- *Kingstown Corporation, Plymouth, MA:* The Kingstown Corporation of Plymouth, MA has stated that it can supply up to 700,000 cy of beach compatible sand over the duration of the project. The unit cost for the sand is $16.50/cy, which includes delivery from the Plymouth quarry to Hull. The grain size D_{50} of the material is 0.38 mm. Kingstown has stated that it can deliver approximately 2,000 cy/day using dump trailers with a capacity of 34 tons, or roughly 26 cy.

- *P.A. Landers, Plymouth, MA:* The P.A. Landers, Inc. company of Plymouth, MA stated that it could supply up to 700,000 cy of beach compatible sand over the duration of the project. The unit cost for the sand was not provided at this time, but the cost would include delivery from their multiple quarry locations in Plymouth to Hull. A grain size was not provided for the material, although it was assured that the material would have a D_{50} of approximately 0.3 to 0.6 mm. P.A. Landers has a large fleet of trucks with 26 cy capacity trailers and has the ability to deliver up to 3,000 cy per day to the project site.

- *Cape Cod Aggregates, Bourne, MA:* The Cape Cod Aggregates company of Hyannis, MA stated that it could supply up to 700,000 cy of beach compatible sand over the duration of the project. The unit cost for the sand was $20.50 – $22.50/cy, which includes delivery from either of their source quarries in Bourne or Sandwich, to Hull. The distance from Bourne to Nantasket is 47 miles one way, and 52 miles from Sandwich to Nantasket. The grain size D_{50} of the Bourne and Sandwich material is 0.41 mm and 0.53 mm, respectively. Cape Cod Aggregates stated that it could deliver approximately 30 to 40 truck loads, or 800 to 1,100 cy/day using dump trailers with a capacity of roughly 26 cy.

- *G. Lopes Construction, Taunton, MA:* The G. Lopes Construction company of Taunton, MA stated that it could supply up to 700,000 cy of beach compatible sand over the duration of the project. As of late August 2008, G. Lopes had over 100,000 cy available for immediate delivery. The unit cost for the sand was $19.25/cy, which includes delivery from their source quarry, 46 miles to Hull. The grain size D_{50} of the material is approximately 0.3 to 0.45 mm. G. Lopes stated that it could deliver approximately 2,240 to 2,800 cy/day using dump trailers with a capacity of roughly 28 cy.

- *Plympton Sand and Gravel, Plympton, MA:* The Plympton Sand and Gravel Company of Plympton, MA stated that it could supply up to 60,000 cy/year of beach compatible sand over the duration of the project. The unit cost for the washed sand was $23.75/cy, which includes delivery from their Plympton, MA source quarry to Hull. The washed sand product was proposed by Plympton S&G because it contains only trace amounts of fine grained sediments. The grain size D_{50} of the material is 0.65 mm. The company has stated that it could deliver approximately 2,000 to 3,000 cy/day using dump trailers with a capacity of roughly 26 cy.

- *A.A Will Materials Corporation, Stoughton, MA:* The A.A. Will Materials Corporation of Stoughton, MA stated that it could supply up to 700,000 cy of beach compatible sand over the duration of the project. The unit cost for the sand was $28.50/cy, which includes delivery from their Sandwich, MA source quarry to Hull. The grain size D_{50} of the material is 0.36 mm. A.A. Will stated that it could deliver approximately 230 to 310 cy/day using dump trailers with a capacity of roughly 26 cy.

- *A.D. Makepeace, Wareham, MA:* The A.D. Makepeace Company of Wareham, MA stated that it could supply up to 700,000 cy of beach compatible sand over the duration of the project. The unit cost for the sand was $20.00/cy, which includes delivery from their Wareham and Carver, MA source locations to Hull. The grain size D_{50} of the material is 0.61 mm. A.D. Makepeace stated that it could deliver approximately 2,000 to 3,000 cy/day using dump trailers with a capacity of roughly 26 cy.

8.1.2 Compatibility Comparison of Sources

A compatibility comparison is presented in this section for each of the identified upland sources and suppliers. This comparison is intended to assist in a potential decision of which upland source may be most appropriate for use as nourishment material of Nantasket Beach. The comparison is based on the physical properties of the sand, delivery logistics, and cost.

The options for a Nantasket Beach nourishment source require careful consideration in order to choose the most appropriate and efficient means to complete the project and minimize impact to the environment and community. Consideration of the upland sources and vendors described in the previous section was performed by evaluating certain common parameters in a comparative cost-benefit analysis. These parameters assess beach compatibility and rate and cost of delivery. Table 8-1 tabulates the parameters evaluated in this analysis: material grain size, delivery method, delivery distance, rate of delivery, and unit cost. It is important to note that the information contained in Table 8-1 was provided by the sand supply contractors for feasibility

guidance only, and that information is subject to change based upon source availability, source location, and fuel costs at the time of the nourishment construction.

Although the evaluation parameters may be self-explanatory in nature, they are nonetheless defined here to ensure the relevance to the compatibility comparison and Table 8-1.

- *Material Quantity:* Defines the volume of sediment available for nourishment usage for each year. For example, A.D. Makepeace Company of Wareham, MA stated that it could supply up to 700,000 cy/year, while the Plympton Sand and Gravel Company of Plympton, MA stated that it could supply up to 60,000 cy/year. However, the amount of sediment supplied each season is limited by the available days for transport and number of trucks available. Therefore, the value presented in the table presents the maximum amount of material available for each nourishment season. This value can be compared to the scenarios presented in the technical analysis section (8.1.4).

- *Material Grain Size:* Defined as the median grain size (D_{50}) of a source sample. This was the primary parameter used to evaluate the compatibility of the upland source material with the native Nantasket Beach material, and quantify the resistance of the nourishment material to erosional forces. In addition, other physical parameters (such as source sorting and color) were also considered when speaking with the vendors and reviewing the grain size distributions. However, the exact grain size, sorting, color and/or upland source location is not selected as part of the current analysis. The focus of this analysis is solely the technical feasibility of using an upland source for a nourishment project of this scale.

- *Delivery Method:* Describes the process and equipment used to transport nourishment material to Nantasket Beach.

- *Delivery Distance:* Quantifies the road distance in miles that a truck must travel to transport the nourishment material from the source to the project site.

- *Rate of Delivery:* Defines the rate at which a volume (cy) of material can be transported to Nantasket Beach in a single workday.

- *Unit Cost:* Monetary value ($) associated with a volume (cy) of nourishment material. This includes all costs (mobilization/demobilization, transport, fuel, etc.) unless specifically indicated.

Table 8-1. Nantasket Beach Nourishment: Matrix of Upland Sources.

Vendor	Source Location	Material Quantity (cy/year)	Material Grain Size (D_{50} mm)	Delivery Method	Delivery Distance (miles)	Rate of Delivery (cy/ workday)+	Unit Cost ($/cy)	Notes
Kingstown Corporation	Plymouth, MA	100,000	0.38	26 cy Dump Trailer	30	2,000 – 3,000	$16.50	
P.A. Landers, Inc.	Plymouth, MA	100,000	0.3 – 0.6	26 cy Dump Trailer	30	3,000	TBD*	
Cape Cod Aggregates	Bourne and Sandwich, MA	100,000	0.41 – 0.53	26 cy Dump Trailer	47 – 52	800 – 1,100	$22.50	
G. Lopes Construction	Taunton, MA	100,000	0.3 – 0.45	28 cy Dump Trailer	46	2,100 – 2,600	$19.25	100,000 cy avail. as of 8/29/08
Plympton Sand and Gravel	Plympton, MA	60,000	0.65	26 cy Dump Trailer	35	2,000 – 3,000	$23.75	Washed Sand, Limit of 60,000 cy/year
A.A. Will Materials Corporation	Sandwich, MA	100,000	0.36	26 cy Dump Trailer	50	~300	$28.50	Masonry Sand, Truck Limited
A.D. Makepeace	Wareham and Carver, MA	100,000	0.61	26 cy Dump Trailer	45	2,100	$20.00	

* PA Landers did not provide a cost/cubic yard of material.
+ Assumes an 8 hour workday

For this analysis, all sources will be transported to Hull from RT 3 via RT 228, Summer St. (or RT 3A), Rockland St., and George Washington Blvd. This transportation route was referenced in USACE (2004b) as an approved trucking route. This route minimizes the distance from the sources to the project site and minimizes the noise and environmental impact of the trucks on the residential community and roads.

8.1.3 Nourishment Delivery Scenarios

In order to evaluate the performance and efficiency of beach nourishment supplied solely from upland sand sources, four specific beach nourishment scenarios were identified based upon the information received from the upland sand source vendors, the technical feasibility of transportation of the material and impacts to the roadways, and review of previously Nantasket Beach nourishment investigations (USACE, 2004b). These four scenarios are designed to represent the potential range in delivery rates during the nourishment construction. Table 8-2 tabulates the characteristics and working statistics of the four scenarios. When developing each of the nourishment scenarios, transportation logistics, community impacts, and environmental impacts were accounted for to ensure that each scenario was designed using realistic assumptions. In each incremental scenario the total volume of sand delivered to the project site per season is increased.

Table 8-2. Nantasket Beach nourishment scenarios used in performance evaluations.

Scenario	Total Volume per Season (cy)	Individual Load Volume (cy)	Loads per Day	Truck Passage Frequency (min.)	Project Time (Seasons)
1	25,000	12 cy	16	14	28
2	50,000	26 cy	16	15	14
3	75,000	26 cy	30	8	9.3
4	100,000	26 cy	60	4	7

One assumption that was kept constant in each of the four scenarios was the amount of workdays available to transport and spread sand on Nantasket Beach in one complete nourishment season. Environmental regulations and recreational usage requirements limit the period of beach nourishment construction to the 7-month-long off-season, lasting approximately from October through April. Based on this work period it was assumed that 120 workdays would be available to perform the nourishment each season. This is a conservative estimate that takes into account a 5-day work week over 28 weeks, subtracting 6 days for inclement weather (4% contingency), and 14 days of holiday time. This conservative estimate also allows for the possibility that the construction period could reach up to 133 workdays with satisfactory working weather and the minimum amount of holidays (7 days). The 120 days represents an aggressive, yet feasible number of working days through the environmental time window. All of the scenarios represent a significant community impact during each nourishment season. Truck passage frequency will

be high in all scenarios, and will also be occurring consistently throughout the entire nourishment season (October through April) over a number of years.

Scenario 1

Scenario 1 was designed to represent the lowest quantity of material that may be delivered from upland sources per nourishment season (Table 4-1). Over a single nourishment season Scenario 1 calls for 25,000 cy of sand to be delivered to Nantasket Beach. In this scenario, only a limited volume of sand will be delivered to the project site in dump trucks with a 12 cy capacity. The reasoning behind this scenario is that cost, environmental, roadway, and community requirements and regulations limit the delivery method to the smaller volume truck and less trips to the site per day. For example, during the construction of the revetment work on Nantasket Beach, approximately 40,000 to 60,000 cy of material and debris were transported over the existing roadways with little overall impact to the road conditions. Therefore, this may be a realistic scenario in that the 12 cy dump trucks have a lower impact on noise pollution, air quality, roadway and bridge wear, and potentially financial cost, when compared to the larger 26 cy capacity dump trailer. In reducing the impact of these concerns, Scenario 1 keeps the truck passage frequency down; however, this drastically reduces the total volume of material that can be delivered to the beach per nourishment season, regardless of financial cost. The project-wide impact of Scenario 1 to the nourishment is that the project time for the placement of 700,000 cy is 28 years. This is an unrealistic timeline considering that annual losses due to natural processes will require the placement of additional material. For example, the USACE (2004b) estimated that 18,000 cy of material would be lost each season, requiring an additional 504,000 cy of sand to be placed on the beach to meet the nourishment template. The rate of construction in Scenario 1 is inefficient in time, materials usage, and financially, thus preventing the successful completion of the nourishment template. Nonetheless, WHG completed a performance evaluation and modeling of the Scenario 1 nourishment to determine if it was infeasible.

Scenario 2

Scenario 2 calls for a total nourishment volume of 50,000 cy of sand per work season (Table 8-2). The material will be transported to the project site in 26 cy capacity dump trailers, which amounts to 16 loads per workday over the course of the nourishment season. The delivery rate for this scenario equates to a truck passage frequency of 15 minutes along the delivery route. Under Scenario 2, it will require 14 seasons to deliver the total nourishment project volume of 700,000 cy, not including overfill for lost (eroded) material. Scenario 2 was designed to increase the total volume of nourishment material delivered each season without increasing the truck passage frequency or significantly impacting the condition of the existing roads. Scenario 2 is clearly a more efficient and economical choice than Scenario 1. The increase in total volume of Scenario 2, provided by using trucks hauling larger loads, is desirable because it accelerates the rate of project construction without a drastic environmental and community impact when compared with Scenario 1.

Scenario 3

Scenario 3 calls for a total nourishment volume of 75,000 cy of sand per work season (Table 8-2). As in Scenario 2, the material will be transported to the project site in 26 cy capacity dump trailers, requiring approximately 30 loads per workday over the course of the nourishment season. The delivery rate for this scenario equates to a truck passage frequency of 8 minutes along the delivery route. Scenario 3 will require 9.3 seasons to deliver the total nourishment project volume of 700,000 cy, not including overfill for lost material. As the successful and efficient completion of this upland nourishment project is limited by the delivery rate of sand, this scenario was developed as a compromise between construction interests and potential environmental and community interests. The scenario requires a total volume of 75,000 cy per nourishment season, which is a logistically attainable value for this construction methodology. The compromise to increasing construction efficiency is to increase the negative impact of the construction to the environment and community adjacent to the material transportation route.

Scenario 4

Scenario 4 calls for the greatest volume of nourishment material of the four scenarios presented in this investigation. The total nourishment volume of Scenario 4 is 100,000 cy of sand per season (Table 8-2). The material will be transported to the project site in 26 cy capacity dump trailers, requiring approximately 60 loads per workday. The delivery rate for this scenario equates to a truck passage frequency of 4 minutes along the delivery route. Scenario 4 will require 7 seasons to transport the total nourishment project volume of 700,000 cy to Nantasket Beach. However this estimate does not include overfill for lost material. Based upon communications with upland sand supply contractors, it is logistically possible to deliver 100,000 cy of sand to Nantasket Beach each season, and it is preferable from a project efficiency standpoint. However, due to the constraints of the work period and workday, the rate of delivery required to meet the total nourishment volume of Scenario 4 is very high, and may be prohibitive to the project because: (1) construction rates for template spreading at the project site may be outpaced by delivery leaving no place to dump materials, and (2) the truck passage rate of 4 minutes may cause significant annoyance to residents along the truck route by increasing noise levels, dust/debris levels, traffic, and excessively deteriorate road conditions. Scenario 4 represents the most aggressive upland-based source nourishment approach, and is likely at the upper limit of what is logistically feasible.

8.1.4 Evaluation of Nourishment Scenario Performance

Using the modeling results completed as a component of the alternatives analysis (Chapters 4, 5, and 7), each of the four upland-based scenarios was evaluated for feasibility and performance at Nantasket Beach. The design assumptions were the same as those used in the alternatives analysis, including:

- *Nourishment Length:* The goal project length (extending alongshore) is 6,800 feet, spanning the entire DCR portion of Nantasket Beach. This corresponds to the preferred nourishment length evaluated in the alternatives analysis. However, since the upland-based nourishment approach requires the nourishment effort span multiple seasons, the

length of each yearly nourishment varies. This length variation is described in detail under the placement methodology described below.

- *Berm Width:* Berm widths of 25, 50, 75, and 100 feet were evaluated in the original alternatives analysis. In that assessment, berm widths of 25 and 50 feet did not maintain adequate performance and were eliminated. In the upland-based source analysis presented herein, initial berm widths of 75-100 feet (varies alongshore) were used. These berm widths resulted in the placement of approximately 100 cy per linear foot of beach.

- *Berm Height:* An initial berm elevation of 12 feet NGVD was used for all nourishment scenarios in the current evaluation. Berm heights of both 10 and 12 feet were evaluated in the alternatives assessment.

- *Offshore Slope:* For all berm templates and length scenarios, an offshore slope of 1V:25H was incorporated.

- *Nourishment Volume:* Nourishment volumes were determined for all scenarios based on the design beach nourishment template. In the alternatives assessment, the preferred volume templates ranged from 610,000 to 789,000 cy of material. Therefore, for this feasibility analysis, a total nourishment volume of 700,000 cy was assumed to be reasonable to assess the feasibility of a multi-year nourishment approach.

- *Grain Size/Source:* In the alternatives assessment, three specific grain size combinations were evaluated. These included: (1) a grain size of 0.25 mm that matches the native beach sand, (2) a grain size of 0.45 mm, as slightly coarser grain size than native, and (3) a mixed grain size of cobbles and sand that currently resides on Nantasket Beach. In order to assess the feasibility of an upland-based source, a grain size of 0.25 was used. This represents the most conservative performance evaluation since this material would have the fastest erosion rate.

Placement Methodology

Using the parameters listed above, material was placed on Nantasket Beach for each of the four delivery scenarios. The length of each nourishment episode varied based on the volume of sand delivered. For example, if 25,000 cy of material was delivered during the nourishment season, then the length of the nourishment spanned approximately 250 feet alongshore. The placement sequencing and location also changed for both the initial and subsequent nourishments. As such, the performance modeling evaluates the most effective construction sequencing and methodology. Three specific construction sequence approaches were evaluated as listed below. This produced 12 specific nourishment performance evaluations (4 delivery scenarios with 3 construction sequences).

- **Construction Sequence A:** Initial placement in the center of the DCR portion of Nantasket Beach, with subsequent annual placements also in the center of the DCR portion of Nantasket Beach. The initial placement would include a berm width of approximately 100 feet, and subsequent nourishments would intend to return the berm

width to the initial 100 foot width. For this construction approach, each subsequent nourishment would (1) extend in length and (2) naturally spread across the 6,800 foot total nourishment area.

- **Construction Sequence B:** Initial placement in the center of the DCR portion of Nantasket Beach, and subsequent annual placements on alternating, adjacent sides (north and south) of the initial placement. For this construction approach, subsequent nourishments would extend in length due to the presence of material from the proceeding nourishments.

- **Construction Sequence C:** Initial placement in the southern corner of the DCR portion of Nantasket Beach, and subsequent placements advancing northward. For this construction approach, a performance gain is expected due to the natural headland boundary that exists to the south.

Beach Nourishment Performance Results

For this performance analysis, where nourishment is provided in an incremental fashion from upland-based sand sources, sediment will only be considered to be "eroded" once the sediment leaves the full project area (the 6,800 feet of DCR beach). Therefore, although sediment may be lost from the area where it was initially placed, it is not considered a loss from the larger project area. For example, incremental nourishment may only span 500 feet of shoreline, and although sediment may leave this incremental nourishment region, it may not be lost from the 6,800 feet comprising the larger project area. For example, a significant portion of the material will naturally spread alongshore, remaining within the 6,800 feet of the larger project area.

Figure 8-1 presents the beach performance results for all four scenarios using construction sequence A, as well as the performance of a single initial nourishment of 700,000 cy (as presented in Chapter 7). The horizontal axis shows time in years, while the vertical axis shows the percentage of sediment that remains (or is maintained) in the entire project area (6,800 feet of the DCR portion of Nantasket Beach). This percentage is normalized by the total design nourishment volume (700,000 cy). Each scenario is simulated until a total volumetric amount of 700,000 cy is placed. For example, Scenario 2 includes the addition of 50,000 cy each year for 14 years to reach the total design volume of 700,000 cy. Scenario 1 does not produce an increase in beach width to any significant degree, and therefore is not recommended.

Upland-based source Scenarios 2 to 4 show a general increase in volume through time as additional material is continually supplied into the nourishment area. Eventually, the amount of material in the nourishment area will surpass the amount of material remaining from a single initial nourishment of 700,000 cy. For example, after 6 years of delivery and grading of 75,000 cy of sediment, Scenario 3 has the same amount of material in the template region as the initial single nourishment.

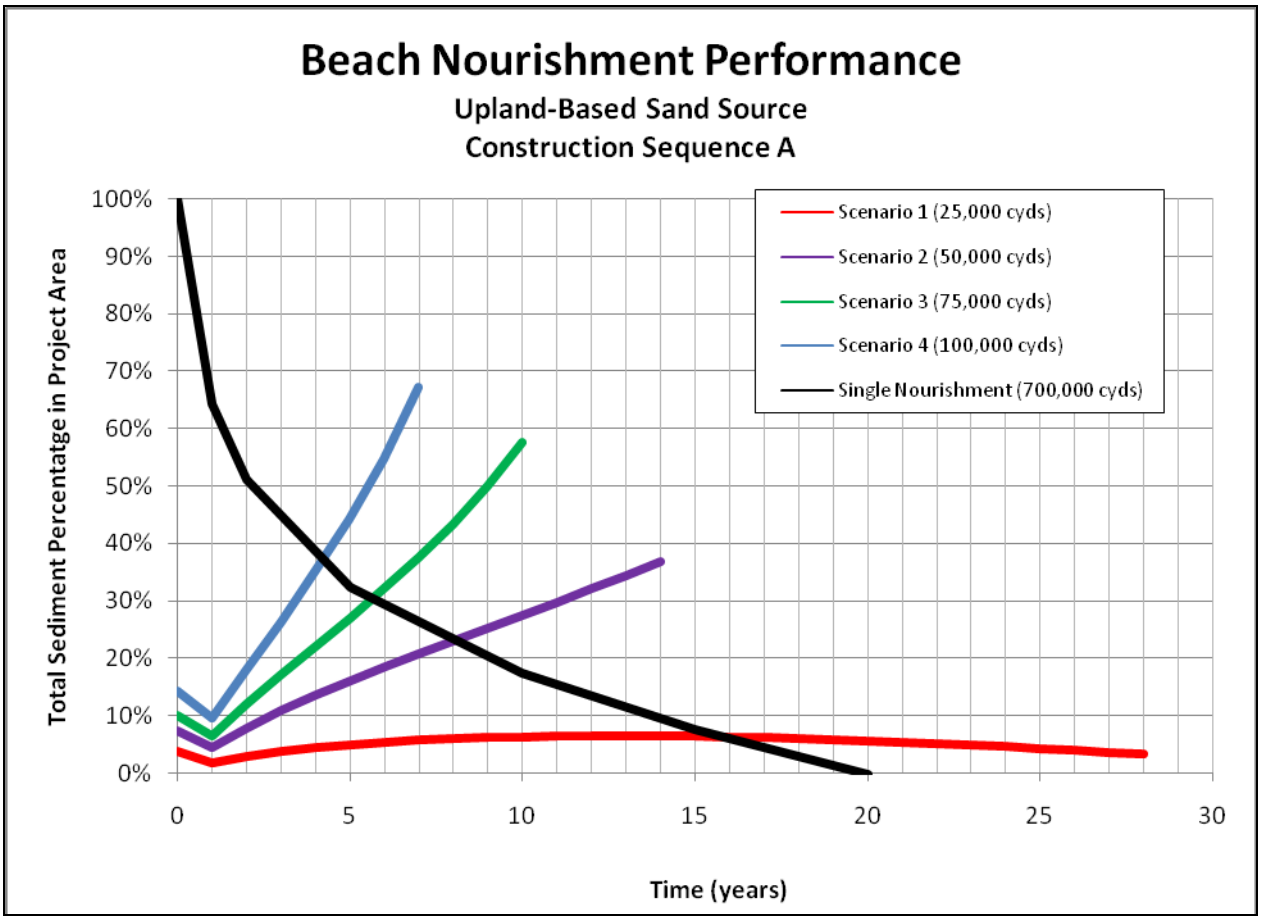

Figure 8-1. Beach nourishment performance for all multi-year upland-based scenarios using Construction Sequence A. Results are compared to a single nourishment from a potential offshore source (black line).

With the exception of scenario 1, all the multi-year nourishment scenarios perform reasonably well. However, there are some technical limitations. The upland-based source scenarios would require additional years of nourishment (overfill) to reach the initial design template. This also means that the designed beach width would never be attained without total nourishment volumes exceeding 700,000 cy. Additionally, the beach/seawall would be vulnerable to damage from a single storm event for a number of years. Until the nourishment percentage reaches approximately 30%, a single storm event would be capable of eroding all of the nourishment volume that had been placed in the previous seasons. For example, for scenario 2, the entire nourishment could be eroded in a single storm event until 11 years of nourishment episodes are complete. This storm erosion results in potential serious consequences for the structural stability of the seawall; however, this does not mean that sand is completely removed from the system. A portion of the sand may likely return to the project region after the storm event as seasonal waves transport the material back onshore.

Figures 8-2 and 8-3 present similar beach performance results for Construction Sequences B and C. The figures show similar performance to Sequence A; however, construction sequence B does show reduced performance compared to Sequences A and C. Therefore, continuous

nourishment episodes placed at the center of the DCR portion of Nantasket Beach, or nourishment placement starting at the southern end of the DCR portion of Nantasket Beach, is preferred over staggered nourishments throughout the proposed beach nourishment template. Essentially, each subsequent nourishment increment should build on the previous nourishment to increase the overall performance.

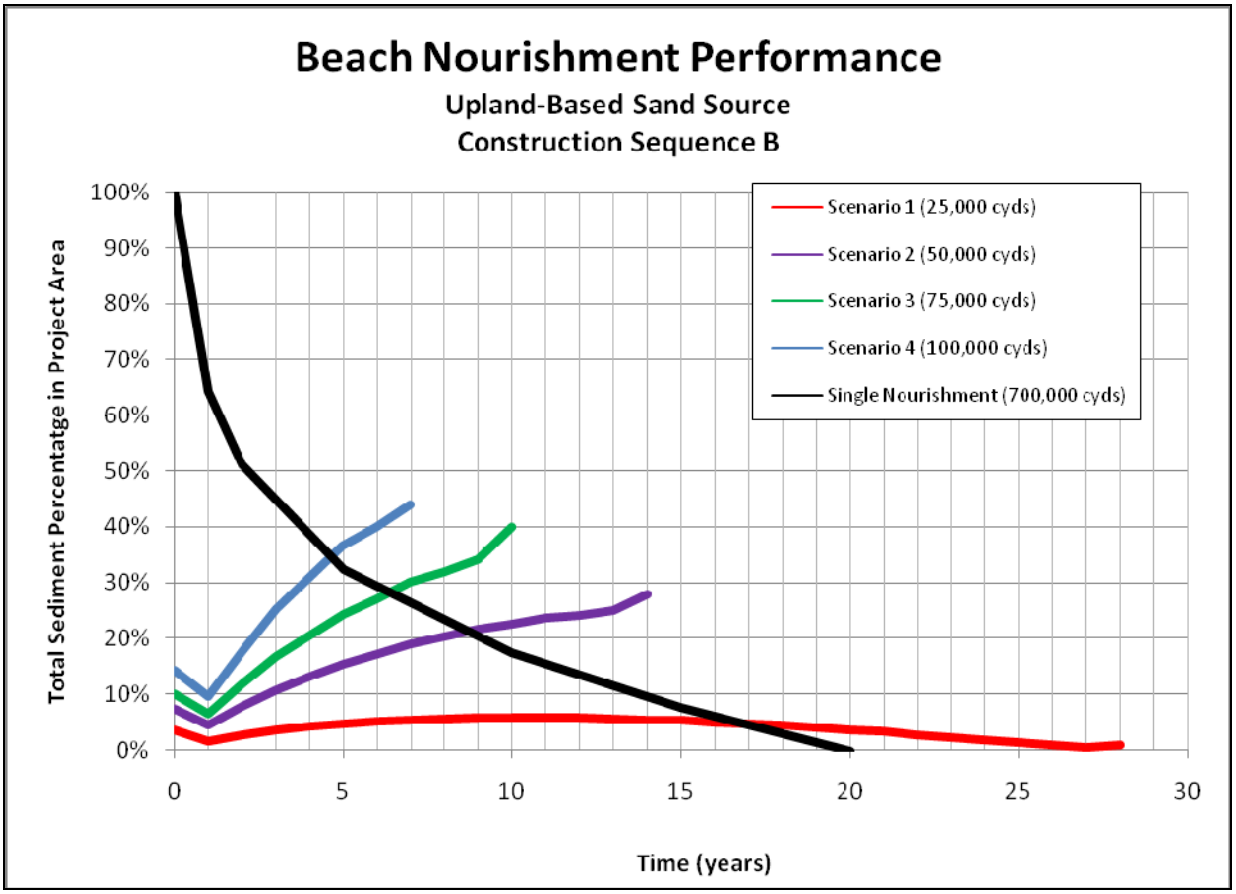

Figure 8-2. Beach nourishment performance for all multi-year upland-based scenarios using Construction Sequence B. Results are compared to a single nourishment from a potential offshore source (black line).

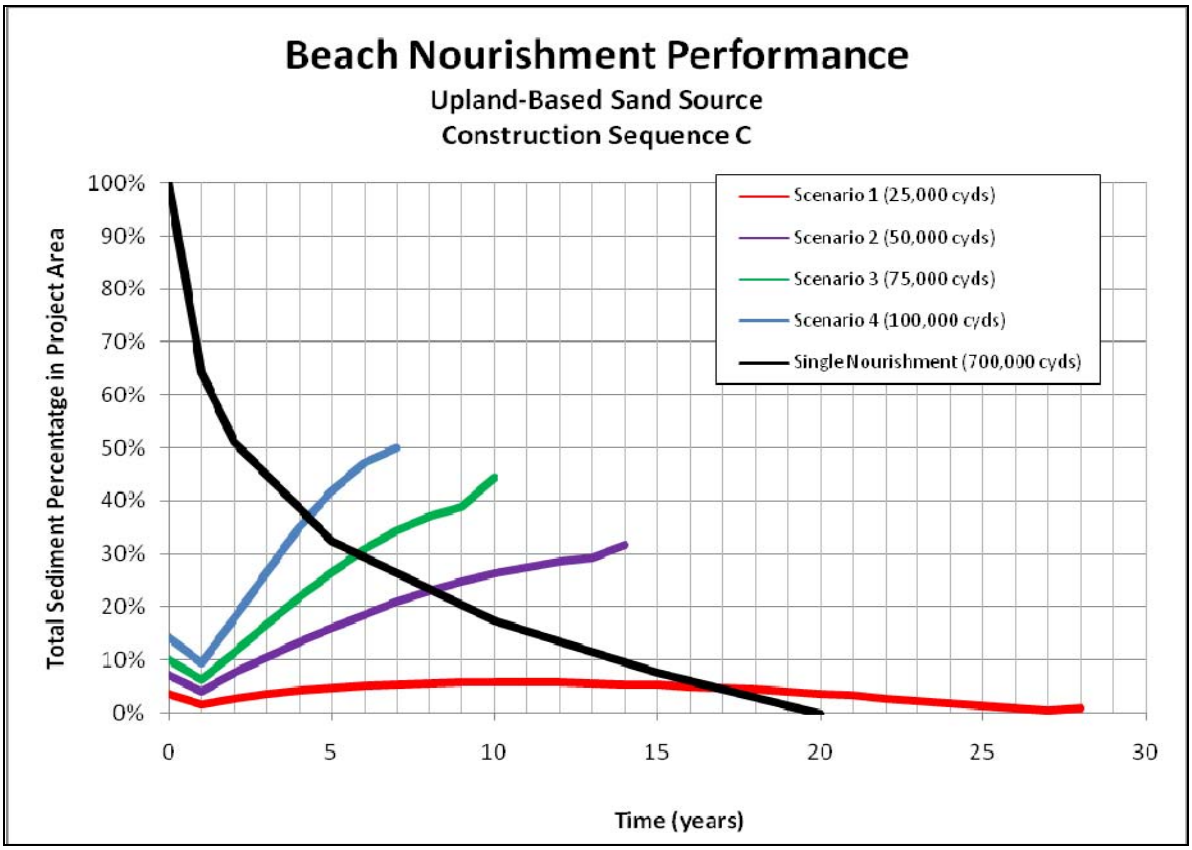

Figure 8-3. Beach nourishment performance for all multi-year upland-based scenarios using Construction Sequence C. Results are compared to a single nourishment from a potential offshore source (black line).

To further illustrate the variations in construction sequencing, Figure 8-4 shows the beach nourishment performance of Scenario 3 for all 3 construction sequence options. The horizontal axis presents the time in years, while the vertical axis presents increased beach width. The solid lines for each construction sequence represent the increase in beach width at the center of the nourishment, while the dashed lines represent the increase in beach width at a distance approximately 3,000 feet north and south (near the ends of the DCR portion of Nantasket Beach). Therefore, throughout the nourishment timeframe, the increased width of the beach should lie in-between the solid and dashed lines. This illustrates the relative improved performance of Construction Sequences A and C.

The technical assessment and modeling indicate that an upland-based sediment source does appear technically feasible for nourishing Nantasket Beach. However, there are some limitations using a multi-year nourishment approach as well. Specifically, the following limitations should be considered:

- In order to achieve the full design template and beach width, an increased amount of additional material (overfill) will be required. Ultimately, the amount of material needed will extend the number of years that nourishment will be required and increase the volumetric requirements and cost.

- If multi-year upland nourishment is selected, Nantasket Beach and its seawall would be vulnerable to potential damage from a single large storm event for a number of years. Until the nourishment percentage reaches approximately 30%. Until the 30% amount is achieved, a single storm event would be capable of eroding all of the nourishment volume that had been placed in the previous seasons. This leaves the beach and seawall vulnerable over these initial seasons. For example, for Scenario 2, the entire nourishment could be eroded in a single storm event until 11 years of nourishment episodes are complete. This storm erosion results in potential serious consequences for the structural stability of the seawall; however, this does not mean that sand is completely removed from the system. A portion of the sand may likely return to the project region after the storm event as seasonal waves transport the material back onshore.

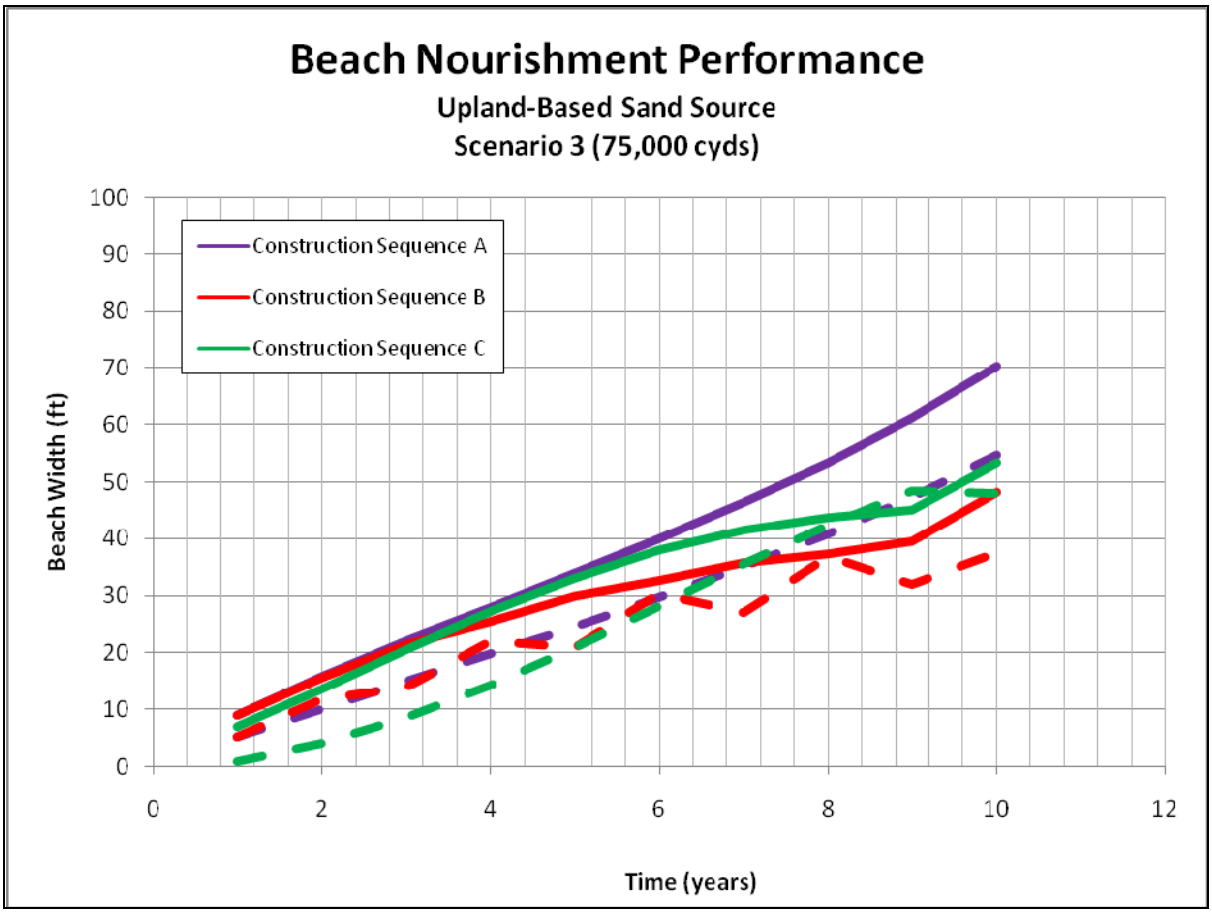

Figure 8-4. Beach nourishment performance for scenario 3 comparing Construction Sequencing A, B, and C. The solid lines show the beach width at the center of the nourishment template, while the dashed lines show the beach width at the edges of the nourishment template (approximately 3,000 feet to the north and south).

8.1.5 Costs Associated With Upland Sources

The cost for a multi-year upland-based source nourishment is expensive, especially when the nourishment extends through multiple nourishment seasons. Simply applying 2008 rates, upland based nourishment of 700,000 cy is approximately $16 million; whereas an offshore borrow location would cost between $7 million and $10 million (see Section 8.2). Additional costs can be expected due to future inflation rates. For example, if only 50,000 cy is brought to the beach each year (Scenario 2), then it will take over 14 years to get the full nourishment completed. Therefore, increased costs can be expected for mobilization, transportation, and grading in each future year. It is also likely that additional sediment will be required (in addition to the 700,000 cy) to complete the desired design template, adding further costs. Prior to final selection of an upland-based sediment source, a financial assessment accounting for future costs should be conducted. Additionally, more detailed comparisons to potential offshore source options should be evaluated. Based on similar projects in the New England region, identification and permitting of a compatible offshore source may take in excess of 10 years and $1 million for field observations, study, and permitting costs. Therefore, a benefit to using upland-based sources is that they can more quickly be permitted and placed on the beach.

8.2 OFFSHORE SAND SOURCES

Utilizing an offshore subaqueous sediment source or material from a navigational channel that requires dredging are alternatives to the use of upland sand sources for the proposed nourishment at Nantasket Beach. Beneficial reuse of sand dredged from navigation channels is desirable, provided the sand is clean and beach-compatible, since costs of nourishment can be shared with the navigation interests, and the environmental impacts can be minimized (i.e., eliminate or reduce needs for additional impacts associated with offshore dredging). Considering the quantity of material that is required to nourish Nantasket Beach, as well as the limited navigational channels that lie within a reasonable distance to Nantasket Beach, the feasibility of beneficially reusing sediment from dredge navigation projects is minimal. As such, the use of an offshore borrow source is likely the most cost-effective alternative capable of providing the quantity and quality of beach compatible material.

Currently, there are no approved offshore borrow sites in the waters of the Commonwealth of Massachusetts, nor has there been any studies undertaken to identify a specific offshore borrow site for Nantasket Beach due to the inability to obtain permits for offshore sand mining. However, use of a nearby offshore sand source for a nourishment project could provide substantial benefits in reducing the project costs and timeline, as well as reducing impacts on the local communities, when compared to land-based sources. However, there are additional environmental impacts to be considered when evaluating an offshore borrow site for nourishment purposes. Numerous studies have been conducted in the past to investigate sand resources immediately offshore Nantasket Beach. One study estimated that there were 13 million cubic yards of sediment available for mining within 1.5 miles of the shore (Smith, 1993). More recent investigations have adjusted that figure to less than 1 million cubic yards (Byrnes et al., 2000); however, this would still be more than an adequate amount for nourishing Nantasket Beach. Geological and geophysical studies of the seafloor material offshore Nantasket Beach indicate that the sediment is compatible to the native beach material and characterized the material as

well-sorted, fine-grained sand (Ackerman et al., 2006). The results of these preliminary investigations, as well as a more recent study performed in 2005, indicate that there is a significant volume of beach compatible sand available for nourishment in the waters off Nantasket Beach (USACE, 2006). A more comprehensive and updated investigation would be required to ascertain any changes to the seabed morphology and fully assess potential offshore sand sources, as well as determine potential environmental impacts associated with a nearshore borrow site.

Sand from offshore sources is most often delivered to the beach via a dredging operation. Sand obtained close to shore can typically be pumped directly to the beach via a hydraulic dredge. Sand obtained further offshore, or in locations/times of year when conditions preclude establishment of a fixed hydraulic dredge, can be dredged and pumped onto a hopper barge, which can then transport onshore and pump the sand onto the beach. Hopper dredge operations are also used to transfer sand from regional navigation dredging projects to a beach in need of sand for nourishment.

The overall cost of a utilizing an offshore sand source for beach nourishment is highly variable and is dependent upon a variety of factors. Construction methodology affects the price substantially, as does the volatility in the dredging market (e.g., equipment availability, cost of fuel, time of year, project location, etc.), the quantity of sand to be moved, and other factors. Generally, the cost of a beach nourishment operation increases with the number of times the material needs to be handled. For instance barging of upland sand to a remote beach tends to be the most expensive, since the sand needs to be handled at a quarry or pit, trucked to a barge site, loaded on the barge, barged to the beach, pumped to the beach, and graded on the beach. Costs of upland sand delivery by barge have exceeded $40/cy in some instances. By comparison, the per price of a direct hydraulic dredging operation tends to be the least expensive (typically $5 to $8/cy) once the equipment is onsite. However, equipment mobilization costs can be prohibitive for individual projects (can exceed $1 million) unless the project is very large or if the mobilization fee can be shared with a nearby project. Hopper dredge costs also are quite variable (typically $8 to $16 per cubic yard), depending upon the availability of equipment, location, and time of year.

For example, a large national dredging and marine construction contractor was recently quoted to provide an estimate for a large-scale hydraulic dredging and beach nourishment operation at Nantasket Beach. The estimate was provided for an approximately 700,000 cy nourishment project, mined by a hydraulic hopper dredge from an offshore borrow site located within 5 miles of the nourishment site. The hopper dredge would pump the sand onto the beach via pipeline with booster pumps (Figure 8-5). The cost associated with the mobilizing the construction equipment for the project was on the order of $1 million, with an additional construction cost of $12/cy, or $8.4 million. The production rate to dredge and deliver the material to the nourishment site was estimated at 15,000 cy/day. Dredging operations are ideally scheduled for the fall season, before the unpredictable winter/spring weather window, which can cause substantial weather stand-by charges to be incurred by a project. The overall construction cost and timeline, without any contingency plans or sand movement limitations on the beach, was estimated to be $9.4 million and 47 work days.

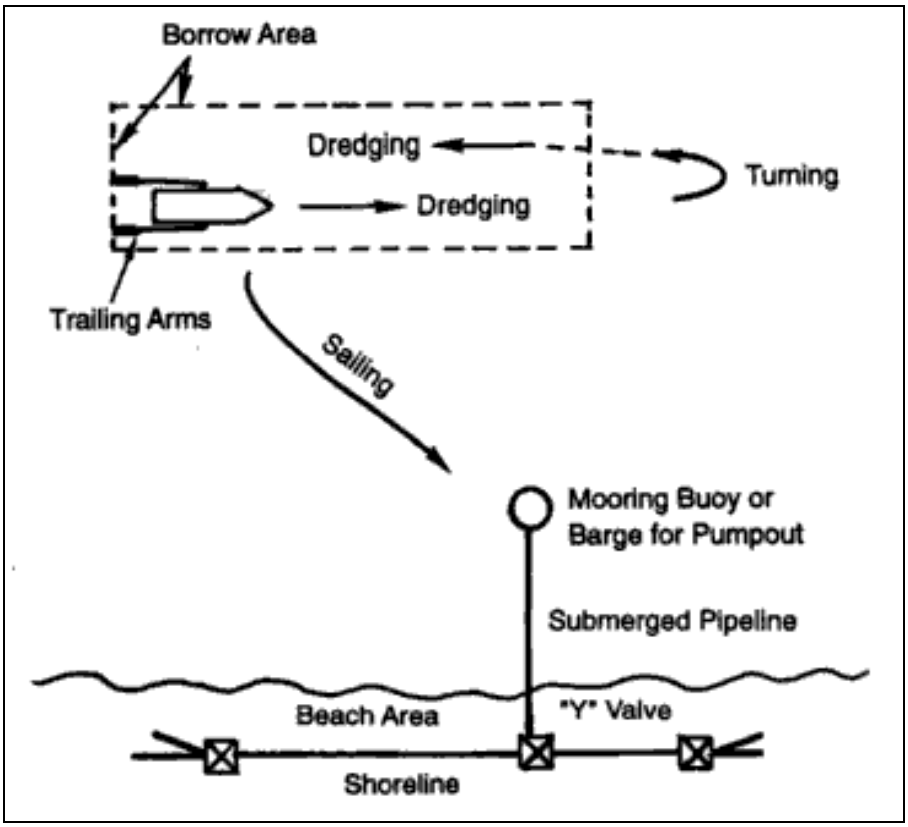

Figure 8-5. Schematic of the hydraulic hopper dredge and pipeline operation for beach nourishment (Figure from Nourishment and Protection, National Research Council, 1995).

When compared to upland sources, the use of an offshore borrow site can reduce the overall cost of a nourishment project by 50-70%. In addition, the project schedule for completing the transport of fill is drastically decreased (months versus a decade) when utilizing an offshore sand source. The marine construction production rate enables the project to be completed within a *single season*, rather than a multi-year (7-28 year) effort with trucking of upland sand. Furthermore, implementation of an offshore source will not impact the communities, environment, and roadway traffic and infrastructure along the trucking routes proposed for upland source delivery. However, there are also well-identifiable negative impacts in utilizing an offshore sand source. These include environmental impacts to the benthic habitat on the seafloor, the potential for changing offshore wave characteristics by altering existing bathymetry, as well as water quality and aesthetic impacts, to name a few. The ability to use an offshore borrow site as a Nantasket Beach nourishment source is subject to DCR obtaining permits from Federal and State regulatory agencies. These permits require comprehensive assessment of the borrow site and surrounding areas, in order to evaluate the potential for environmental harm. The costs associated with permitting and environmental studies associated with these permits can be high (although still less that the construction costs associated with trucking upland sand), and can be a lengthy process requiring data collection, analysis, reporting, and review. As such, it is expected that identifying, permitting, and approving a compatible offshore borrow source would take a minimum of 5 years.

Despite the campaigns, quality, and quantity of research that has been performed to support the use of offshore nourishment sources in Massachusetts, these permits could not be obtained. An example where this has occurred in recent years was at Winthrop Beach, MA. The Massachusetts Department of Conservation and Recreation (DCR) had plans for a nourishment project at Winthrop Beach that proposed mining an offshore sand source for approximately 500,000 cy of sand. As such, the DCR performed a comprehensive evaluation of potential site-specific impacts associated with the mining of the offshore source. Although this investigation concluded that environmental impacts to the site were nominal, and the coast at Winthrop Beach continued to degrade, the USACE denied the permit due to concerns over Essential Fish Habitat (EFH) of the bottom by the National Marine Fisheries Service (NMFS) at that location (Conti, 2008). In some ways, the situation at Winthrop Beach is similar to that at Nantasket Beach, and although it may seem logically sound to use an offshore nourishment source, the Winthrop case should pose caution in approaching the expensive investigations and permitting of an offshore source for Nantasket Beach and no guarantees.

9.0 SUMMARY AND CONCLUSIONS

9.1 EXISTING CONDITIONS

The region of Nantasket Beach represents a complex coastal setting. The following key findings were determined in the existing conditions analysis as presented in Chapters 1 through 5.

- The wave modeling results show areas of increased wave energy ("hot spots") caused by wave refraction and diffraction. Wave refraction and diffraction result in an uneven distribution of wave energy along the coast that affects sediment transport in the region. Wave modeling results provided information on wave propagation across the continental shelf and to the shoreline, revealing areas of increased erosion or areas of increased energy. The refraction and diffraction mechanisms also result in changes in the offshore wave direction that may significantly influence the rate and direction of sand movement along Nantasket Beach for specific wave conditions. On an annual basis, increased wave energy is shown along the DCR portion of Nantasket Beach, with a specific hot spot located at the northern portion of their section of coastline (the location of the previous seawall failure). As such, the DCR portion of Nantasket Beach may not behave in a similar manner to other portions along the Nantasket shoreline.

- Areas of accretion and erosion develop along Nantasket Beach due to the irregular offshore bathymetry and thus, the uneven distribution of wave energy. Sediment flux results show relatively small rates of sediment transport. There are regions along Nantasket Beach where the net sediment transport is to the south, and others where the net sediment transport is to the north. In either case, the rates are relatively small. The sediment transport model was validated through comparison to rates of shoreline change and reasonably predicted these changes.

- Net sediment transport in the DCR portion of Nantasket Beach is from south to north with the average rate of transport of approximately 4,000 to 5,000 cy/yr, and maximums varying between approximately 13,000 and 50,000 cy/yr. During certain wave conditions, sand will also move from north to south, but over an average year the sand will move from south to north.

- The cobble portion of the sediment mixture at Nantasket Beach has a net sediment transport rate that is from north to south in the DCR portion of Nantasket Beach. Cobbles are only transported during the stronger northern and north-eastern approach waves, which have enough energy to mobilize the cobble component of the Nantasket shoreline. The more commonly occurring, but lower energy, eastern and southern waves cannot mobilize the cobble. Therefore, the net transport of cobble is from north to south, while the net transport of sand (which is mobilized for all wave approach directions) is from south to north.

- There is a lack of sediment supply for the DCR portion of Nantasket Beach. The combination of the net northward sediment movement and the limited sediment supplied

by regions to the south (due to the Atlantic Hill headland) results in a lack of available sediment for the DCR portion of Nantasket Beach. Therefore, on an average annual basis, the DCR portion of the beach is erosional.

9.2 RECOMMENDED ALTERNATIVE

The recommended alternative was selected based on five key points:

1. The Nantasket Beach Seawall is Necessary and Beneficial

Although seawalls are not always the most ideal coastal protection method, in heavily developed areas, seawalls are very effective. For example, the value of a sound seawall was demonstrated in Galveston, Texas, during the passage of Hurricane Ike on September 14, 2008. The portions of Galveston located landward of the seawall experienced minimal damage, while areas without seawall protection or other coastal protection measures were significantly damaged and/or destroyed. The Nantasket Beach seawall has been in place since approximately 1915, and has been an effective protection measure throughout the years. The protective values alone provided by the seawall justify its presence in a highly developed and urban setting like Nantasket.

Additionally, leaving the seawall in place is the most cost-effective solution for satisfying the need for protection of the Nantasket Beach Reservation and upland resources owned by DCR, the Town of Hull, and private owners. The existing seawall is structurally sound, but has been compromised by the continued erosion of the beach, which has rendered the initially designed support inadequate. Specifically, the seawall no longer extends far enough into the subsurface to remain stable. Therefore, the existing seawall needs additional support through beach nourishment, toe stabilization, or both (see Point 4 below). Utilizing the current location of the seawall, coupled with a nourishment project, maintains upland area for community Master Plan improvements and layouts. Therefore, it is recommended that the existing seawall be a component of the solution at its current location.

2. Beach Nourishment is a Key Component

Nantasket Beach is a valuable, convenient recreational resource in the area and is one of the few large urban beaches in the Boston area. Nantasket Beach is very accessible, in part due to its available parking facilities. The popularity of the beach may increase with potential accessibility options such as better public bus connections, potential ferry connection, etc. Due to its open-ocean setting with an absence of rivers and major stormwater outfalls entering the beach, the beach has consistently good water quality even immediately after large storm events. However, currently because of the limited beach berm, beach visitors need to leave the beach during high tide. Therefore, beach nourishment is an important component for shoreline protection. Beach nourishment will significantly improve its recreational value, increase the storm damage protection, and provide increased economic return. Ultimately, Nantasket Beach should remain a viable recreational beach, which means that a useable, sandy beach environment needs to be provided to service a variety of beachgoers (e.g., surfers, sunbathers, families, swimmers, etc.) It is recommended that the preferred alternative should include a beach nourishment component.

3. Sediment Source for Nourishment

All feasible and preferred alternatives include beach nourishment. Therefore, important consideration needs to be given to potential sediment sources. Basically, sediment can be obtained from either an offshore borrow source, dredging of a navigational channel, and/or an upland source. A subaqueous borrow source is typically the most cost-effective option and provides a good source of beach compatible material once a suitable site is identified. However, recent experience has shown that obtaining permits to mine offshore material is a lengthy, costly process and may ultimately be unsuccessful. For example, DCR has recently tried to obtain permits to mine an offshore borrow site for nourishing Winthrop Beach, MA. The permitting process has taken over 10 years and has currently been unsuccessful. Considering that the offshore sand source was recently denied for the nourishment of Winthrop Beach, an upland-based source may be a feasible option for Nantasket Beach, at least for the foreseeable future. An offshore borrow site for Nantasket could be a difficult pursuit, at minimum resulting in a significant time commitment and delaying possible nourishment of Nantasket beach for at least 5 years.

Although significantly more expensive, based on the results of the technical assessment and modeling performed, an upland-based sediment source does appear technically feasible for nourishing Nantasket Beach. However, there are some limitations using a multi-year nourishment approach as well. If multi-year upland nourishment is selected, Nantasket Beach and the current seawall would be vulnerable to potential damage from a single storm event for a number of years. Until enough sediment (approximately 30%) is supplied to the beach, Nantasket and the seawall would remain vulnerable over these initial seasons (approximately 5 to 6 years for a reasonable upland sourced construction rate).

Therefore, it appears any sand source will leave the seawall and Nantasket exposed for the next few years. The offshore source will likely take years to permit and get approval, while upland sources will take numerous years to construct, while being exposed to storm events. Without some sort of seawall fortification, the seawall will remain at risk for the next 5 to 6 years if sand nourishment alone is the solution. Therefore, it is recommended that beach nourishment be coupled with some seawall fortification measure, with the intent that the fortification method provides insurance against storm events and does not take the place of beach nourishment. This is discussed further in Point 4 below.

4. Strengthen Seawall with Toe Protection and Start Nourishment from Upland Source(s)

At present the seawall is at risk of failure in the mid-section during a large storm. The USACE (2006) determined that the elevations in front of the seawall shall not be less than the following in order to provide adequate support:

- No-storm condition: 7 feet
- 100-year storm conditions: 9 feet

At times, elevations in front of the unprotected mid-section of the wall have decreased to an elevation below 7 feet, such as during the October 18, 2006 survey. In addition, undercutting by

waves during the December 1992 storm resulted in the collapse of a section of the seawall. This stretch of the beach was closed off for many years until the wall was recently repaired.

Nourishing the beach with sand from an ocean-source can be done rapidly over one season, thus limiting the exposure of the seawall to the risk of collapse during a severe storm. However, as discussed, the potential availability of an ocean-based sand source may take numerous years to permit, leaving the seawall and the Nantasket Beach Reservation vulnerable during this time. Additionally, nourishing the beach from upland sources, although feasible, would also leave the seawall and Nantasket vulnerable for a number of years. For example, based on an assessment of feasible scenarios, nourishing the beach with 700,000 cy of sand will require approximately nine to ten years (at 75,000 cy/year) and the added sand will not provide adequate protection for the seawall for the first 5 years, until sufficient sand has been added to the beach.

It is recommended that seawall fortification (specifically toe protection) be included in the preferred solution. Once adequate volumes of sand are placed on the beach, rocks would be covered by sand. Thus, the beach would be similar in appearance as nourishment without added toe protection in the mid-section of the seawall. Additionally, the toe protection would provide a second line of defense during major storms.

The added protection of is also recommended given the changes in global climate over the last decades. Specifically, while official NOAA rates for annual sea level increases have been incorporated in our analyses, other predictions indicate that even greater increases may be possible over the next century.

5. Pursue an Offshore Sediment Source for Long-term Nourishment

A commitment by DCR to nourish the beach implies that the beach will require renourishment in the future, as the sand will erode over time. Using upland sources for sand is significantly more expensive than using ocean sources. Therefore, we consider it important, and fiscally wise, to pursue an appropriate sand borrow site for beach nourishment. An approved offshore borrow site would also allow for cost-effective and rapid future nourishments for Nantasket Beach.

Affected communities and organizations such as the CAC can assist in furthering the goal of having an appropriate offshore site authorized. It is likely that using offshore sand sources will have lower overall environmental impacts and a lower carbon-footprint than using land sources, considering issues such as air quality, noise, traffic, etc.

Further, identifying and permitting an appropriate offshore borrow site will not just be important for Nantasket Beach but also for other beaches and its surrounding communities in the Commonwealth.

Conclusion

The technical team recommends Alternative 5 for the preferred Alternative at Nantasket Beach. Alternative 5 (toe protection and nourishment) should be coupled with short-term nourishment from an upland source and long-term offshore nourishment. This solution provides immediate protection for the seawall and upland infrastructure, as well as a second line of defense when needed. An offshore sand source should be pursued vigorously as it will also be needed by other coastal communities in the Commonwealth in the future.

Shore protection with beach nourishment, coupled with planned improvements of the upland portion of the Nantasket Beach Reservation, will considerably enhance the value of this important recreational asset in the Commonwealth. Despite its urban setting, the beach has excellent water quality, and should continue to be enjoyed by the greater community, as it has been over its long and storied past.

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APPENDIX A

Numerical Wave Transformation Results

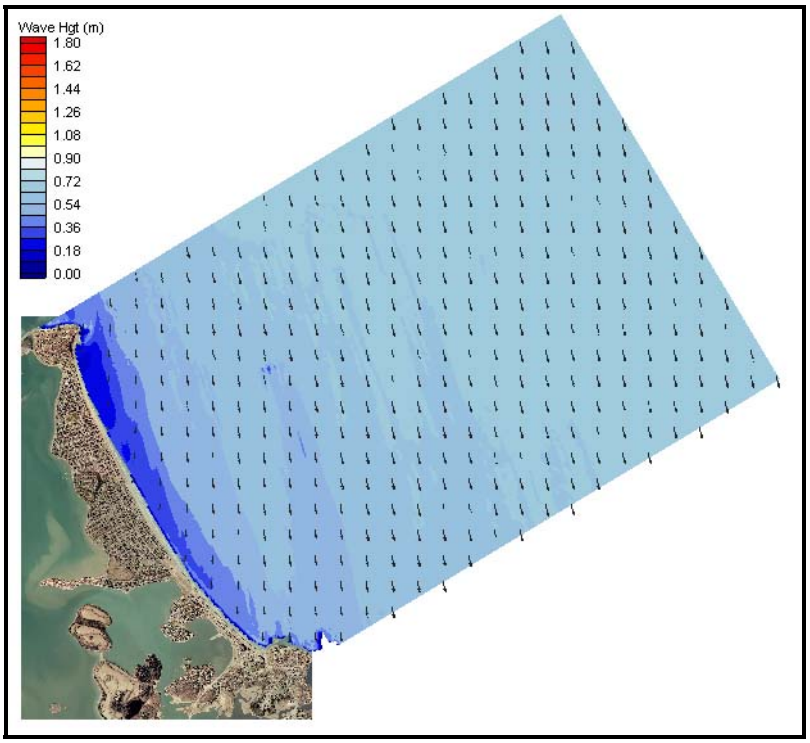

Figure A-1. Spectral wave modeling results for a north-northwest approach direction (329-351.5 degree bin) in the Nantasket Beach region.

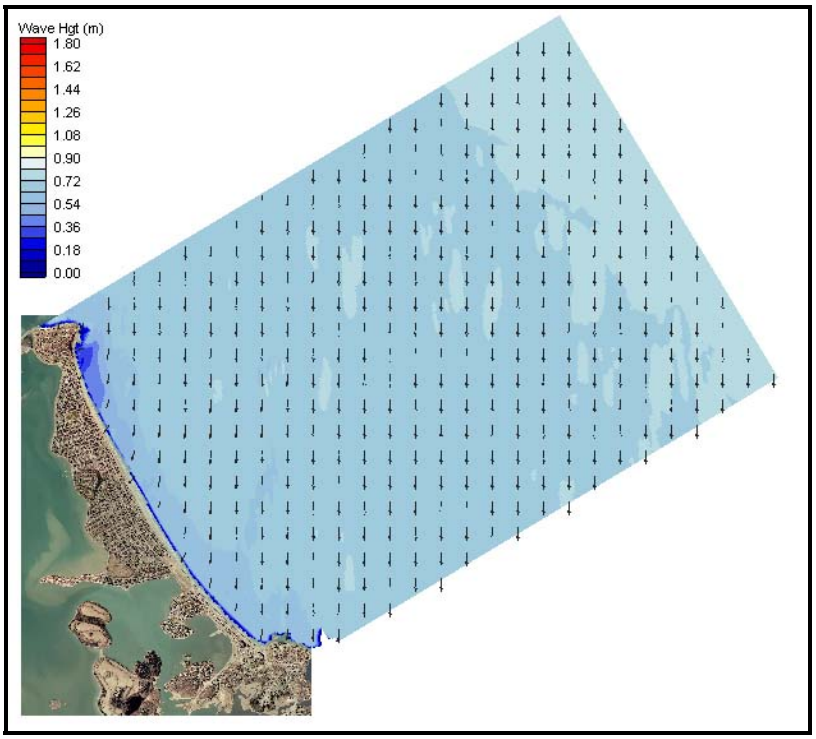

Figure A-2. Spectral wave modeling results for a north approach direction (351.5-14 degree bin) in the Nantasket Beach region.

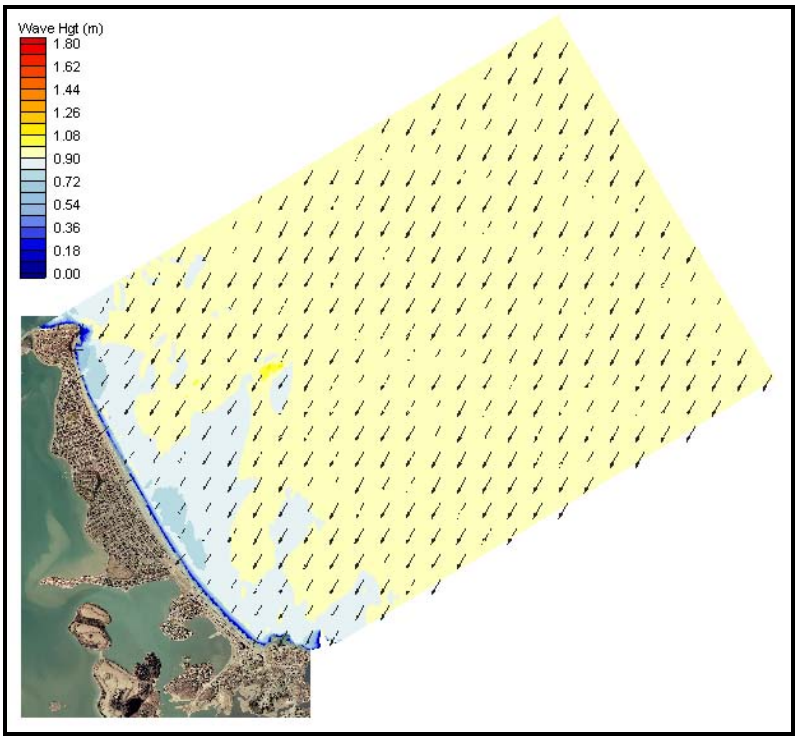

Figure A-3. Spectral wave modeling results for a north-northeast approach direction (14-36.5 degree bin) in the Nantasket Beach region.

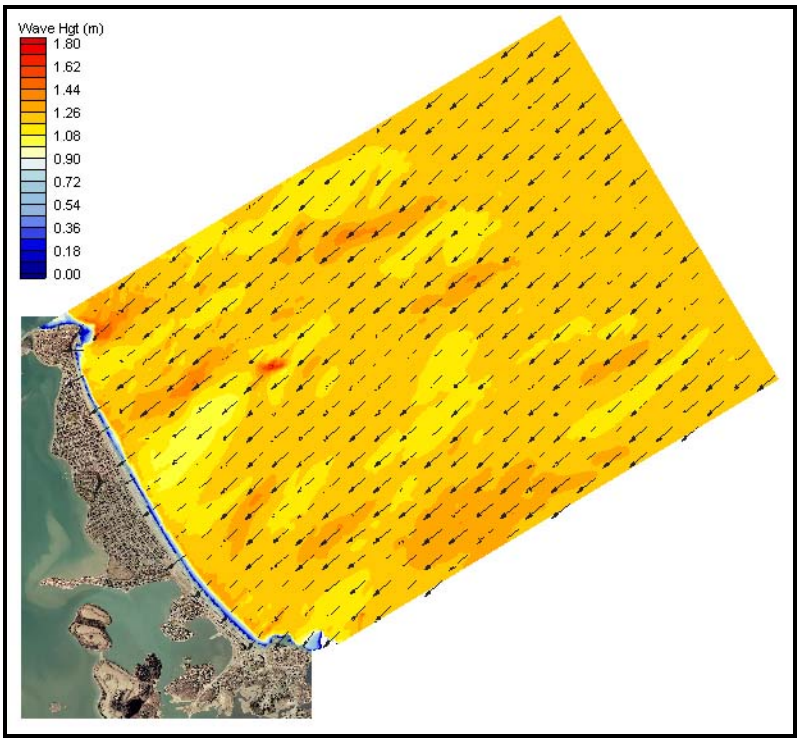

Figure A-4. Spectral wave modeling results for a northeast approach direction (36.5-59 degree bin) in the Nantasket Beach region.

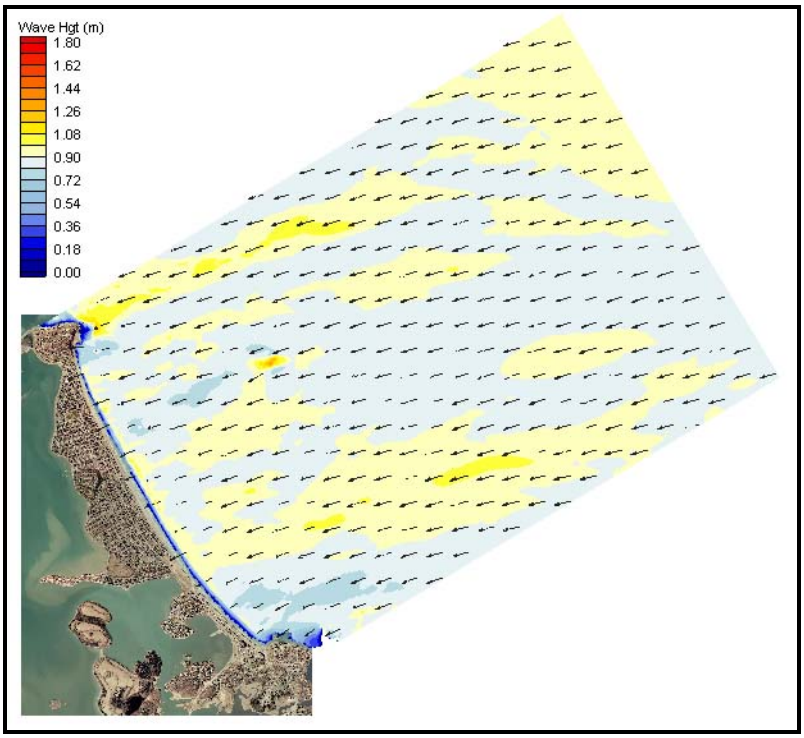

Figure A-5. Spectral wave modeling results for an east-northeast approach direction (59-81.5 degree bin) in the Nantasket Beach region.

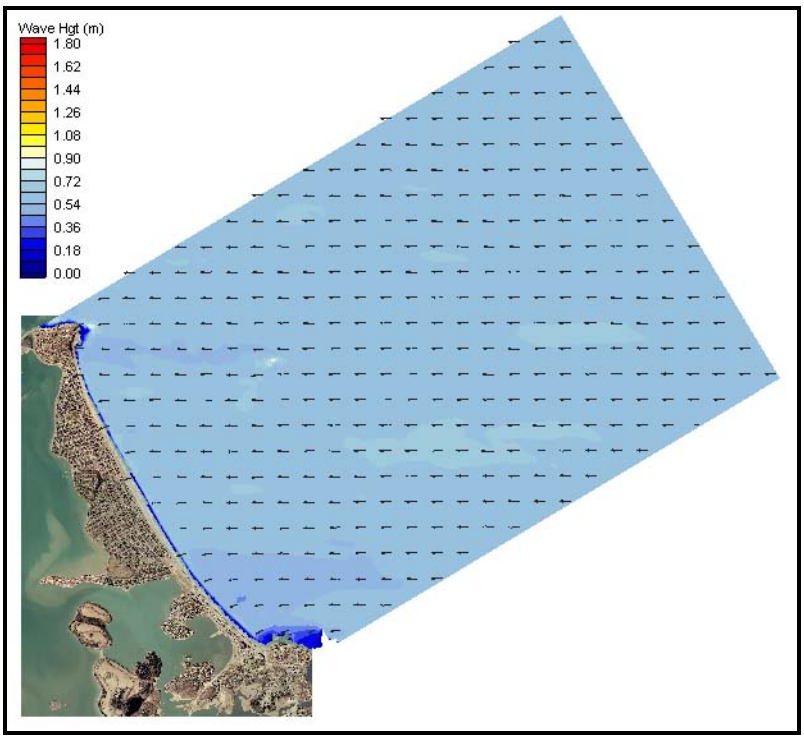

Figure A-6. Spectral wave modeling results for an east approach direction (81.5-104 degree bin) in the Nantasket Beach region.

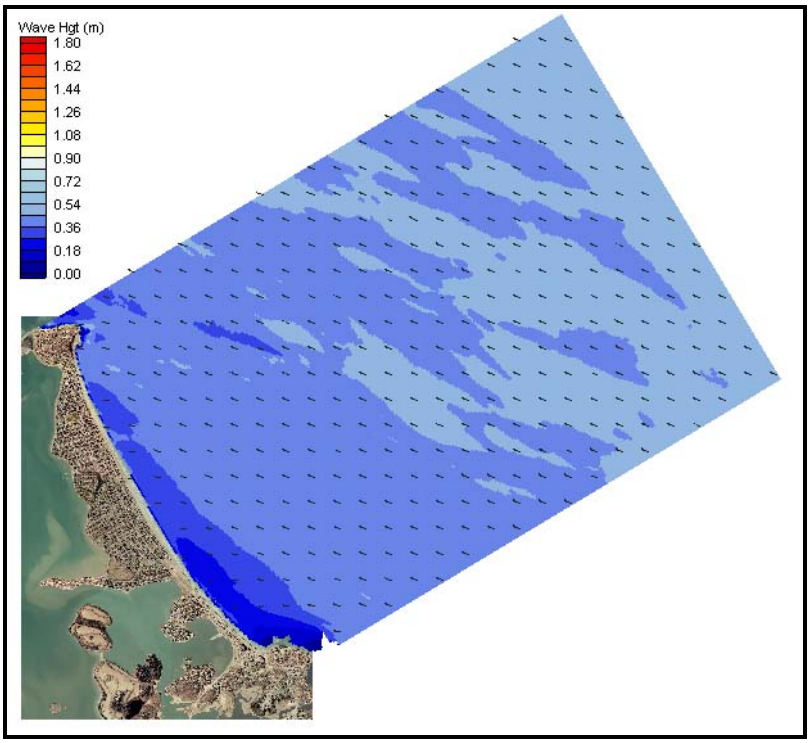

Figure A-7. Spectral wave modeling results for an east-southeast approach direction (104-126.5 degree bin) in the Nantasket Beach region.

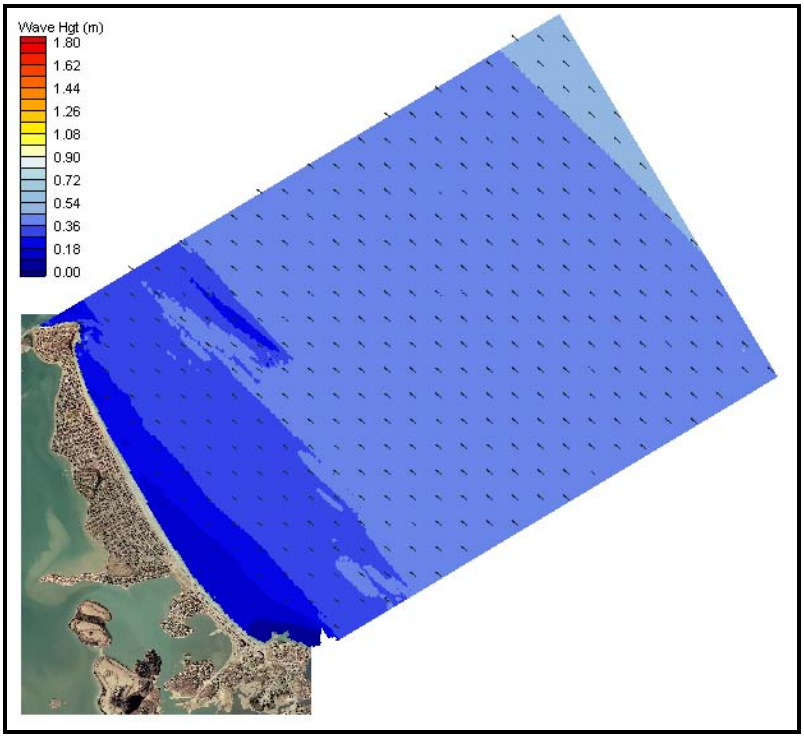

Figure A-8. Spectral wave modeling results for a southeast approach direction (126.5-149 degree bin) in the Nantasket Beach region.

Appendix C

Feasibility Report and Environmental Assessment, Nantasket Beach (2014)

USACE, 2014

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Coastal Storm Damage Reduction Report

Feasibility Report and
Environmental Assessment

NANTASKET BEACH
DCR Reservation
Hull, Massachusetts

US ARMY CORPS
OF ENGINEERS
New England District

December 2014

EXECUTIVE SUMMARY

This Feasibility Report and Environmental Assessment for the Nantasket Beach Coastal Storm Damage Reduction Project was prepared under Section 103 of the1962 River and Harbor Act, as amended, which authorizes the US Army Corps of Engineers to participate in the cost of projects and antecedent studies for reducing coastal storm damage. Study funds were also available through Public Law 113–2—January 29, 2013, which provided resources to deal with the consequences of Hurricane Sandy in the Northeast. Nantasket Beach experienced the effects of Hurricane Sandy in October 2012 in the form of high winds and a rise in water level (surge plus tide) of about 7.41 feet NAVD88 based on data recorded at the Boston Harbor NOAA station, north of Weymouth, MA. Report elevations in NGVD29 can be converted to NAVD88 by subtracting 0.814 feet. For example, a crest elevation of 10.0 feet NGVD29 is 9.2 feet in NAVD88. This report responds to a request from the Commonwealth of Massachusetts, Department of Conservation and Recreation (DCR), for a study to investigate the flooding and erosion problem at Nantasket Beach and its causes, and to present feasible solutions for reducing damage in the Nantasket Beach backshore. The study is the product of detailed investigations conducted by the New England District of the US Army Corps of Engineers in cooperation with the DCR and other state and Federal agencies.

The study area for the Nantasket Beach Coastal Storm Damage Reduction Project consists of the DCR's Nantasket Beach Reservation and the adjoining backshore area. It is located in the town of Hull, Plymouth County, Massachusetts, approximately 12 miles southeast of the city of Boston. See Figure 1. The study area is the southerly 6,800 foot long portion of an elongated spit extending along a SE-NW axis into Massachusetts Bay from the Atlantic Hill section of Hull to Point Allerton. Beginning at its southern end, the backshore is protected by an approximately 5,400-foot long sea wall, and its 1,400-foot long northerly end by a combination of sand fill and rip rap revetment and jersey barriers.

Coastal storms cause extensive damage to the publicly owned Nantasket Beach, its protective works and backshore public, commercial, and residential properties. Storm driven waves from the east are responsible for the removal of sand in front of the concrete sea wall and the consequent lowering of the beach. The sea wall footings have been exposed and undermined in some places. By December 1992, the conditions had deteriorated to such an extent that a coastal storm with an approximately 10-year recurrence interval caused the failure and weakening of about 650 feet of sea wall at its northern end. The lowering of the beach and the sea wall breach increased ocean overtopping during coastal storms and the flooding of the backshore.

DCR reconstructed the portion of the sea wall lost in the 1992 storm with a new structure called the Northern Revetment, and placed a stone revetment known as the Temporary Seawall Fortification (TSF) at the south end of the Reservation. This improved protection to those areas of Hull Shore Drive and Nantasket Avenue, the only roadway links between the mainland and portions of the town to the north. The central portion of the DCR reservation, historic seawall, and commercial properties in the backshore have no similar protection, and suffer from greater seasonal material losses and higher storm wave overtopping volumes. The portion of the town north of this area contains an estimated two-thirds of the town's land area and 80 percent of the population of approximately 10,500 persons, in addition to elementary and high schools, the Pemberton Coast Guard Station, and a number of commercial and public properties.

If a plan to reduce flooding and erosion is not implemented, the Nantasket shoreline, fronted by its older sea wall, would be vulnerable to storm damage from wave overtopping or wall failure. The DCR has invested an estimated $2M to restore the bathhouse. This investment would be at risk if a project were not undertaken to protect the sea wall. An initial screening process eliminated an offshore breakwater as a possible solution for reducing damage due to coastal storms at Nantasket Beach due to economic reasons. We identified three plans which warrant further consideration: elevating 13 structures above the 100-year floodplain, sand fill nourishment, and a stone revetment might reduce recurring storm damage and be economically feasible. Our analysis indicated that, although a plan to elevate 13 structures is feasible, a high level of residual damage to properties (about 75 percent) would remain if this plan was implemented. Two beach fill nourishment plans to protect Zone 2, the 2,200-foot middle portion of the DCR reservation, were economically feasible, however their cost exceeded what is allowed under Section 103. Two stone revetment plans to protect Zone 2 were also found to be economically feasible. A revetment plan for 10-year level of protection showed a higher benefit-to-cost ratio than a plan offering 25-year level of protection, so that is the recommended plan.

Since the stone revetment plan for protecting 2,200 feet of sea wall (Zone 2) is economically feasible, maximizes coastal storm damage reduction benefits (annual benefits minus annual costs), and meets pertinent environmental and cultural resources criteria, it is the National Economic Development (NED) Plan and therefore qualifies for further Federal participation. The NED Plan calls for construction of a stone revetment approximately 2,200 feet long in front of the sea wall with an 8.25 foot wide crest at elevation 10 feet NGVD and a lV:3H slope to the existing beach.

The Section 103 authority, under which this present study was conducted, provides for Federal participation of 65 percent of first costs, including construction, contingencies, Engineering and Design (E&D), and Construction Management (CM) up to $5M in Federal costs, including the Federal share of reconnaissance and feasibility studies, which amount to $869,194.48. The project first cost of $6,353,300 would be cost shared. A projected annual maintenance cost of $1,100 per year during the 50-year life of the project would be a non-Federal responsibility.

The project was economically justified at the 2013 Price Level with an annual net benefit of $812,300 and a Benefit to Cost Ratio (BCR) of 4.09. Project costs were updated to the January 2014 price level using the FY14 Federal interest rate of 3.5 percent and the Civil Works Construction Cost Index for Breakwaters and Seawalls (EGM 1110-2-1304, 31 March 2014). The economic cost of the project in 2014, including interest during 4 months of construction, amounts to $6,382,200. Annual Cost over the 50-year project life is $273,200 with Net Benefits of $827,000. The resulting BCR of 3.03 supports the recommended project.

At the start of second quarter FY15, the TPCS spreadsheet was updated to reflect the current schedule. The program year price level was adjusted from 2014Q2 to 2015Q1 which increased the project first cost from $6,463,000 to $6,499,000. The Midpoint of Design was also updated from 2015Q2 to 2015Q3 and the Midpoint of Construction was updated from 2016Q1 to 2016Q2 which then increased the total project cost from $6,595,000 to $6,631,000. The resulting Federal Cost is $4,310,000 and the Non-Federal Cost is $2,321,000.

The New England District Engineer recommends construction of 2,200 foot long stone revetment project in front of the sea wall in Zone 2. We found the project to be technically (engineering) and economically feasible, and environmentally and culturally acceptable, for reducing storm damage due to flooding and erosion in the Nantasket Beach backshore. The DCR intends to repair and rehabilitate the seawall in front of where the recommended Federal project would be built.

NANTASKET BEACH DCR RESERVATION
HULL, MASSACHUSETTS

Coastal Storm Damage Reduction Report

Photo source: http://www.flickr.com/photos/jeffcutler/8135566996/in/photostream/

U.S. Army Corps of Engineers
New England District
696 Virginia Road
Concord, MA 01742

December 2014

ABBREVIATIONS

ARA	Abbreviated Risk Analysis
BCR	Benefit-Cost Ratio
CENAE	Corps of Engineers, New England District
CM	Construction Management
cfs	cubic feet per second
cy	cubic yards
E&D	Engineering and Design
EOEA	Executive Office of Environmental Affairs
FCSA	Feasibility Cost Sharing Agreement
ft	feet (foot)
FY	Fiscal Year
GPM	gallons per minute
H	Horizontal
HRA	Hull Redevelopment Authority
LERRD	Lands, Easements, Rights-of-Way, Relocation, Disposal
LF	Linear Feet
MHW	Mean High Water
MLW	Mean Low Water
NED	National Economic Development
NGVD	National Geodetic Vertical Datum
RC	Reinforced Concrete
S&A	Construction Management
SF	Square Feet
SY	Square Yard
TPCS	Total Project Cost Summary
V	Vertical

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MAIN REPORT

1: INTRODUCTION

BACKGROUND

The study area for the Nantasket Beach Coastal Storm Damage Reduction Project consists of the Massachusetts Department of Conservation and Recreation's (DCR) Nantasket Beach Reservation and the adjoining back shore area. It is located in the town of Hull, Plymouth County, Massachusetts, approximately 4 and 12 miles southeast, respectively, of the main entrance to Boston Harbor and the city of Boston. See Figure 1. The study area is the southerly 6,800 foot long portion of an elongated spit extending along a SE-NW axis into Massachusetts Bay from the Atlantic Hill section of Hull to Point Allerton. Beginning at its southern end, the back shore is protected by a sea wall approximately 5400-foot long and at its northern end by a combination of sand fill and rip rap revetment. The open ocean borders the study area to the east and Sagamore Hill and Hingham Bay to the west.

Figure 1 – Nantasket Beach Study Area Location Map

Nantasket Beach's location on the Atlantic Ocean and close proximity to the urban areas of greater Boston results in a substantial increase in local population and usage of the DCR reservation and beach during the summer months.

Storm driven waves from the east have caused extensive loss of beach material in front of the concrete sea wall and the consequent lowering of the beach. In turn, this has left the existing sea wall vulnerable to damage and undermining as a result of tidal and wave action. In addition, the sea wall has been subject to increased risk of overtopping during coastal storms, which has increased the flood risk to public, commercial and residential properties in the back shore.

The DCR maintains Nantasket Beach Reservation and its facilities, including the sea wall and revetment, the pavilion, a bathhouse, parking areas, etc. in the Nantasket Beach back shore. Nantasket Beach faces east and is exposed to direct attack from Atlantic storms, in particular New England' s famed Nor'easters. The erosion of sand from the beach has exposed the footings of the sea wall over most of its length, and in some areas the footings are undermined. The October 1991 storm, an approximately 17-year recurrence event (based on still water elevation), caused extensive damage to the sea wall including stairways and ramps. By December of 1992, the sea wall had deteriorated to such an extent that a less severe 10-year storm event caused the failure and weakening of approximately 650 linear feet of sea wall at its northern end.

DCR recognized the wall failure greatly increased the risk of storm damage to several backshore properties and public infrastructure. They asked the Corps to provide design assistance for a wall/revetment to replace the failed and severely damaged wall sections. The result of the work was the Northern Revetment, which DCR constructed in 2006.

The land west of the DCR reservation includes Hull Shore Drive and Nantasket Avenue, arterial streets that provide the only links between the mainland and the portion of the town to the north, which contains an estimated two thirds of the town's land area and 80 percent of the population of approximately 10,500 persons. Many commercial properties, public schools, a fire station, and the United States Coast Guard Station at Pemberton are located north of the beach and rely on the roadway links that run parallel to the Nantasket shoreline.

STUDY AUTHORITY

This investigation has been prepared under the Continuing Authorities Program and authorized in Section 103 of the 1962 River and Harbor Act, as amended. The maximum Federal cost for planning, design, and construction of any one economically justified project is $5,000,000. Study funds have also been made available through Public Law 113–2—January 29, 2013, which made resources available to deal with the consequences of Hurricane Sandy in the Northeast.

STUDY OBJECTIVE AND SCOPE

The purpose of this Feasibility Study is to determine the most technically and economically feasible, and socially, environmentally and culturally acceptable project, if any, to control damages to the sea wall and the storm driven ocean flooding of back shore properties due to overtopping of the seawall.

Figure 2 – Nantasket Beach Study Area Map

Photo 1 A view of the south end of the sea wall in Zone 2 with the DCR bath house and other public infrastructure behind it.

Photo 2 A view of the sea wall at the north end of Zone 2 with commercial properties lining Hull Shore Drive beyond.

Photo 3 This view of the sea wall taken after a storm shows the portion of the wall footing is exposed.

PRIOR STUDIES, REPORTS, AND PROJECTS

- Cooperative beach erosion control studies for Nantasket Beach have been conducted by the Corps of Engineers with the Metropolitan District Commission.

The first report, Beach Erosion Control Report on Cooperative Study of Metropolitan District Commission Beaches, Massachusetts, Part D Nantasket Beach, was submitted to the Chief of Engineers on 1 June 1949. The report concluded that Nantasket Beach was stable and recommended that the problem of maintenance of the beach for recreational use be accomplished entirely by local interests at their expense by burying and covering stone deposits or by the removal of stones and replacing them with equal volumes of sand.

The second report, Beach Erosion Control Report on Cooperative Study of Revere and Nantasket Beaches, Massachusetts was submitted to the Chief of Engineers in March 1968. The report recommended the direct placement of suitable sand fill along 6,800 feet fronting the Metropolitan District Commission Reservation to a berm width of 75 feet and an elevation of 12 feet above NGVD, thus furnishing a protective and recreational beach averaging 190 feet wide above the mean high water line. The project was subsequently authorized by Congress in 1970. Due to a lack of local cooperation, the project was never constructed and was subsequently deauthorized in January 1990.

- New England Division, Corps of Engineers, Blizzard of '78, Coastal Storm Damage Study, February 1979 covered the New England coastline between Orleans, Massachusetts and New Castle, New Hampshire. It compiled the estimated costs and losses, attributable to water related damage, from the Blizzard of 1978.

- Federal Emergency Management Agency, Flood Insurance Study, Town of Hull, 1980.

- Camp Dresser and McKee, Inc. (CDM) Evaluation of Coastal Protection Measures at Nantasket in Hull, Massachusetts, June 1980. This report summarizes damages from the Blizzard of February 1978 for both the North Nantasket Beach Study Area and the Metropolitan District Commission's (DCR) Nantasket Beach located south of North Nantasket Beach. No measures for protecting Nantasket Beach were recommended.

- New England Division, Corps of Engineers, Reconnaissance Report, Nantasket Beach Shore Protection Study, Hull, Massachusetts, August 1993. With the continuing loss of sand in front of the reinforced concrete sea wall and lowering of the beach, significant damage to and undermining of the sea wall and back shore flooding due to the overtopping of the sea wall, the Reconnaissance Report found that a sand fill nourishment project constructed seaward of the sea wall was economically justified and that a Feasibility Study was warranted.

2: EXISTING CONDITIONS

PHYSICAL SETTING

The study area for the Nantasket Beach Coastal Storm Damage Reduction Project consists of the DCR reservation and the adjoining back shore area. See Figure 2. The open ocean borders the study area on the east and Sagamore Hill and Hingham Bay on the west. The study area is the southerly approximately 6,800-foot long portion of an elongated spit averaging about 500 feet in width and extending along a SE-NW axis into Massachusetts Bay from the Atlantic Hill section of Hull to Point Allerton. Since approximately 1915, the back shore has been protected on the east by a 5,400-foot long reinforced concrete sea wall, whose crest ranges in elevation between 14.4 and 17.0 feet above the National Geodetic Vertical Datum (NGVD).

From the south end of the reservation, the sea wall is fronted by a 2,000 foot-long stone revetment known as the Temporary Seawall Fortification, or TSF. The TSF was placed in 2004 as an emergency action in response to beach erosion that had reached a point where no dry beach in front of the sea wall existed at high tide. At the northernmost end of the sea wall, a 650 foot-long portion of the sea wall failed or was weakened, including a segment that collapsed seaward, as a result of a December 1992 storm. DCR rebuilt that portion of the sea wall in 2008 as the 900 foot-long Northern Revetment. Beyond the Northern Revetment to the north, shoreline protection is provided by sand fill in combination with stone riprap revetment or jersey barriers.

In addition to these protective works, the DCR reservation includes property in the immediate back shore. The agency maintains a pavilion, a bath house, restrooms and parking areas. Further back, Nantasket Avenue provides the sole link between the mainland and the northerly portion of Hull comprising more than two-thirds of the town of Hull's land area and about 80 percent of its population. Further west into the back shore are primarily commercial establishments serving the recreational interests and residential structures, including a high-rise condominium development.

The relatively flat study area has been divided into three hydrologic zones that are shown on Figure 2. A further description of the three zones is provided below.

- Zone 1 is located between the south end of the sea wall the end of the TSF near Wharf Avenue. When high volume overtopping occurs, ocean water first ponds in the area adjacent to the sea wall and then flows into the parking lot of Horizon Condominiums on Park Avenue and then over the George Washington Boulevard into Hingham Bay.

- Zone 2 is located between the end of the TSF near Wharf Avenue and the end of the Northern Revetment near Water Street. When coastal storm waves overtop the sea wall, ponding occurs in the DCR parking lot, and between Nantasket Avenue and the George Washington Boulevard.

- Zone 3, located between the end of the Northern Revetment near Water Street and Phipps Street, is partially protected from ocean overtopping by sand fill, stone rubble revetment, jersey barriers at the northern end and further south by the Northern Revetment. Overtopping in this zone has been observed to flow through Bay Street and into Hingham Bay.

Photo 4 The Nantasket Beach Resort Hotel complex is situated at the north end of Zone 2, directly across Hull Shore Drive from the sea wall.

GEOLOGICAL SETTING

Nantasket Beach was formed primarily from materials eroded from drumlin islands located north of Atlantic Hill. It has been postulated that five (or more) drumlins located east of the existing beach have been partially or completely destroyed as a result of erosion. Based on a slight variation in grain size, it appears that a small amount of material is still being added to Nantasket Beach from the continuing erosion of the remnant drumlins offshore. The presence of coarse material on the beach adjacent to Allerton Hill, and the fining of beach materials to the south indicate that Point Allerton and Allerton Hill were also contributing material to the beach until sea walls were built to protect them from erosion. Recent beach profiles conducted for the study indicate that the shoreline is moving inland. At high tide the entire beach in front of the sea wall is inundated. The Corps conducted a study to characterize the profiles and material distribution in 2006. That study is presented as Appendix A. The geology of the study area is discussed in detail in Appendix D.

ENVIRONMENTAL SETTING

The large intertidal sand flat grades seaward from the beach along the length of the study area. Site visits were undertaken in preparation of the 1993 Reconnaissance Report and this feasibility report to determine the benthic community of the intertidal and sub tidal area. No dunes, beach grass, or other ecologically significant natural resources were observed. Benthic investigations conducted in May 1996 indicated a low number of species and individuals along the beach. No commercial shellfish were observed except for blue mussel spat, and one recently dead surf clam spat. A low density would be expected considering current, wave conditions and human disturbances. An inventory of surf clams was prepared in 2007 to better understand what impacts implementation of a beachfill alternative might have on their population. The waters offshore from Nantasket Beach support a viable lobster Homarus americanus population. No eel grass Zostera marina was found in the project area. No threatened or endangered species are known to inhabit the study area.

HISTORICAL/CULTURAL SETTING

The town of Hull, Massachusetts, originally called Nantascot by the Wampanoag Indians, dates from 1644, when the town was named for a seaport town in Yorkshire, England. Although initially a fishing and agricultural town, the town became a popular big hotel summer resort beginning in the early 1880's and continuing until the First World War. Concurrent with the genesis of the hotel industry was the construction of private summer homes ranging in size from bungalows to mansions. Typically, oceanfront lots contained larger homes than those further inland. In 1905 Paragon Park (amusement center) was constructed in the southern part of the town. The old inns and hotels have since disappeared along with Paragon Park. The Metropolitan District Commission, now DCR, assumed control of the Nantasket Beach Reservation in 1899 and has managed the popular beach since that time. The DCR bathing facilities located on Nantasket Avenue were built in a variation of the Spanish Mission Style circa 1905-1915.

Between 1915 and 1940, bungalow style homes were predominant in the area surrounding the beach. There was widespread alteration and demolition of existing commercial structures after World War II as other resorts became popular. The rise of strip development along Nantasket Avenue also became prevalent during this period.

The Hull Redevelopment Authority (HRA) acquired properties by eminent domain in the 1970’s that had been occupied by cottages and small businesses. Located in the study area between Water and Phipps Streets, a parcel of 33 acres, of which some 14 acres are buildable, is zoned for office, retail and residential use. Although there have been development proposals, this land remains undeveloped. The implementation of a plan to protect the Nantasket Beach back shore could reduce the risk of damages to the future development of this parcel.

Photo 5 The DCR bath house is located very close to the sea wall in Zone 2.

3: PROBLEM IDENTIFICATION AND OPPORTUNITIES

STATEMENT OF PROBLEM

Coastal storms cause extensive damages to the publicly owned Nantasket Beach, its protective works and back shore recreational, commercial and residential properties. Protection of the back shore is provided by a 5,400-foot long sea wall and a combination of revetment, sand fill and jersey barriers along the northerly 1,400 feet portion of the Beach. Storm driven waves from the east are responsible for the removal of sand in front of the concrete sea wall and the consequent lowering of the beach. The sea wall footings have been exposed and undermined in some places. By December 1992 the conditions had deteriorated to such an extent that an approximately 10-year recurrence event caused the weakening and failure of about 650 feet of sea wall at its northern end. In addition, the lowering of the beach and the sea wall breach has increased the risk of ocean overtopping during coastal storms and the flooding of properties in the back shore.

For the purpose of formulating plans to protect the back shore, Nantasket Beach has been divided into three zones: Zone 1 includes the shoreline occupied by a 2,000-foot long portion of the sea wall from Atlantic Hill to Wharf Avenue, Zone 2 includes the shoreline occupied by a 2,200-foot long portion of the sea wall from Wharf Avenue to the south end of the Northern Revetment near Water Street and Zone 3 extends 1,400 feet from the south end of the Northern Revetment to Phipps Street. The Northern Revetment is the result of the reconstruction of the portion of the sea wall damaged in the December 1992 storm, restoring some protection to the Nantasket Beach back shore. The remainder of Zone 3, between the Northern Revetment and Phipps Street, has little or no backshore development. The presence of the TSF since 2005 has bolstered another critical section of the old sea wall in Zone 1. The likelihood of sea wall failure in Zone 1 and Zone 3 is reduced by the newer works in front of the old sea wall, and only wave overtopping will contribute to backshore flooding for most postulated storms. The risk of wall failure in Zone 2 is greater, and, in the event of wall failure, areas within the two adjacent zones would be affected by flooding.

FUTURE CONDITIONS WITHOUT A FEDERAL PROJECT ESTABLISHED

Methodology

In a memorandum dated 23 March 1994 (see Appendix F), the Corps of Engineers Headquarters, Policy and Planning Division prescribed that the without project condition for determining the National Economic Development (NED) benefits of reducing damages in the Nantasket Beach back shore will 1) determine the condition, probability, and extent of failure of the sea wall based on engineering analysis, and 2) assume that the approximately 650 feet of failed and weakened seawall is repaired to its former design standards, but not further repaired during the period of analysis. After the initial reconstruction, the sea wall would, therefore, be permitted to lose its protection and eventually fail.

Without Project Condition

Without the benefit of a Federal project, it has been assumed that the DCR, with FEMA assistance, would continue to maintain the sea wall and other public infrastructure on its Nantasket Beach Reservation. Despite the DCR's efforts to seal cracks and perform other repairs to the sea wall, the position of the sea wall is fixed, and its stability is subject to change when storm waves remove sand and cobble to expose its footing.

Surveys have shown Nantasket Beach experiences significant seasonal erosion and accretion. Erosion of the beach in winter contributes to the vulnerability of the sea wall at the time of year when many significant storms occur. MACZM has concluded that the position of the sea wall at Nantasket Beach is more seaward of where the natural shoreline would be. That could be one reason why the high wave impacts associated with overtopping have been concentrated in this area during past storms. Consequently, high end losses are expected for any proposed beach fill project, and it is likely that the north end of the DCR seawall will continue to be a location where wave energy is focused after a project is constructed. DCR manages the 6,800 foot long beach reservation so that visitor safety and quality recreational experience are priorities.

The without project condition for Zone 2 encompasses two situations. The first is prior to sea wall failure but with the sea wall and the adjacent dune and concrete barriers north of the sea wall overtopped during storm conditions with their associated flooding and damages to the back shore properties. The second condition is after the failure of the sea wall has occurred. Based on the existing wall conditions and the high probability of failure, the estimated annual damages would be incurred from flood water flowing over the collapsed wall and reaching the backshore properties. Overtopping of the protective works in adjacent Zones 1 and 3 would continue to add some additional volume of water to the Zone 2 backshore. Sea wall failure in Zone 2, however, would increase associated backshore flood stages and damages. The 34 commercial structures and 31 residential structures within the FEMA-designated 100-year flood plain would experience flood damage. The 65 structures include homes, shops, restaurants, and a hotel. Land would also be lost to erosion as a result of sea wall failure. The DCR bathhouse, the sidewalk, parking areas and parts of Hull Shore Drive behind the wall are the most immediately vulnerable, along with the utilities that exist there.

The existing sea wall in Zone 2 is constructed out of concrete sections, and its design and functioning relies upon the existing beach providing scour protection for the structure. No toe stone was included in the original design because the width and height of the beach at that time was adequate to ensure no undermining of the structure would occur due to erosion. The structure functioned to protect against wave action and storm surge, but relied upon the existing beach for protection of its footings. Since its construction, there have been noticeable reductions in the beach width and height due to seasonal variations and the beach's response to storms. The beach conditions have eroded to the point where the existing beach is not of an adequate width to prevent the undermining of the wall. There are portions of the wall where the toe of the structure is exposed, and the wall is subject to attack from very frequent storms.

Based upon the fact that 1) the existing wall design depends upon a beach for scour protection, 2) that the beach under current conditions does not meet the design requirements, 3) that the beach conditions will continue to degrade, and 4) that under current conditions a relatively small storm event could result in the wall failure, it is reasonable to forecast that by the project base-year that the wall would fail. Since the existing structure is constructed of concrete segments, it is reasonable to expect that when the wall fails that there is no residual protection that is provided by the structure.

When the age and current condition of the wall in Zone 2 and the Corps prior inspection results for the adjacent segments are considered, the seawall in the study area cannot be depended on as a reliable flood risk reduction structure and should not be considered in the without project condition. The benefit analysis will assume existing ground elevations and should not assume a specific level of protection is afforded by the existing structure.

In the absence of a Federal project, the properties in the Nantasket Beach back shore are expected to incur significant average annual damages due to flooding, as well as losing some land to erosion. Failure to protect the sea wall will jeopardize DCR's investment of over $2 million for the pavilion restoration and bathhouse renovation as well as increasing future risk of damages to the infrastructure behind the wall segments that are most at risk. The key to protecting the sea wall is to prevent instability by keeping material against the wall face to a critical height where the wall will not topple and the wall footing is not exposed.

Photo 6 Seasonal work performed at Nantasket Beach.

OPPORTUNITIES AND RESPONSE TO PROBLEMS

Problems and opportunities are derived from current areas of public concern and from future concerns that would be a consequence of predicted conditions in the study area in the absence of Federal measures to address these consequences. The following opportunity statements are in response to problems in the study area.

In the first instance, they define how the water and related land resource management needs can enhance the National Economic Development (NED) account for proposed corrective measures for protecting Nantasket Beach. NED increases the nation's output of goods and services by improving its economic efficiency as the result of corrective measures. A Federal project could:

- Alleviate damages due to coastal storms by reducing overtopping and subsequent flooding of back shore public, commercial and residential infrastructure and properties.

- Reduce erosion and the risk of erosion due to coastal storms. Protection of the sea wall will reduce the risk that a storm event will affect the Nantasket Beach back shore between Wharf and Water Streets to an extent that northern parts of Hull would be isolated from the mainland.

- Reduce damages, due to wave action, on the back shore and back shore structures such as the sea wall, the newly reconstructed bathhouse and other facilities.

In addition to the NED objective, other planning considerations are Environmental Quality, Regional Economic Development, and Other Social Effects. Opportunities in these respects are to:

- Contribute to enhancement of the well-being of people and physical, historical and cultural environments.

- Enhance the economic strength, recreational opportunities and well-being of the area.

- Minimize the negative impacts on residents of the study area.

PLANNING CONSTRAINTS

Planning constraints are limitations that are incorporated into the planning process. These limitations are based on a wide range of concerns such as natural conditions, social and environmental factors, economic limits, and legal and regulatory restrictions.

The following constraints were found to be relevant to the study. The formulated plans should be consistent with the geographic limitations of the study area and avoid or minimize negative effects on adjacent shores, on the environment, including plant and animal life, and on historical resources. They should address the concerns and desires of the sponsor and residents of the study area and be consistent with the requirements of local, state and Federal regulatory agencies.

The following knowledge and information became known during the course of the study, and influenced details of some of the alternatives that were considered:

- A characterization of Nantasket Beach material revealed it has a very bi-modal composition, consisting of very fine sand and cobbles. Such a mix results in a relatively flat beach. A protective beach berm of compatible material would require a very high volume of fill to construct. Prior to the characterization, use of coarser-grained sand for beach fill had been considered. Coarser-grained material would allow the construction of a stable berm with a steeper slope thereby needing lesser volumes to provide a given level of protection. However a coarser material mixture would not be compatible with the existing beach.

- Construction of the TSF in 2005 and the Northern Revetment in 2008 changed the level of protection afforded to the backshore in Zones 1 and 3 respectively. With the TSF in place the sea wall behind it is adequately protected for the higher frequency storms up to ten year return. The Northern Revetment affords a much higher level of protection due to its robust design and construction. With these remedies in place, the volume of water due wave overtopping and wall failure risk in Zone 1 and Zone 3 are significantly reduced. The focus of the study became how to reduce damages due to wave impacts and flooding in Zone 2 where the sea wall remains vulnerable.

4: PLAN FORMULATION

PRELIMINARY SCREENING

Significant actions taken by the DCR at the Nantasket Beach Reservation in the last ten years included construction of the TSF as an emergency measure in 2005 and construction of the new Northern Revetment in 2008. These measures changed the level of protection afforded to the

backshore in Zones 1 and 3, as the volume of water due wave overtopping and wall failure risk in Zone 1 and Zone 3 are significantly reduced. The 2,200 foot-long Zone 2 and its sea wall remains most vulnerable to wave attack, overtopping and possible failure. Four alternative methods were considered for reducing flooding and erosion due to coastal storms in the Nantasket Beach's Zone 2.

- Offshore Breakwater

- Revetment

- Elevation of Structures

- Beachfill Nourishment

Offshore Breakwater

An offshore breakwater would provide protection to an area of shoreline located leeward of the structure. Breakwaters protect the shore by causing waves to break prior to reaching the shoreline. A seven thousand-foot long rubble-mound breakwater, placed in a depth of 5.5 feet of water about 900 feet offshore with a crest width of approximately 24 feet and a crest elevation of 10 feet (NGVD) for a 10-year level of protection was considered for reducing damages due to coastal storms at Nantasket Beach. The breakwater would be long enough to trip waves approaching the shore from directions from north to east and would offer protection for all three zones. A breakwater would impact the recreational surfing at the DCR Reservation and create deposition of material between it and the shore. Construction and annual costs for the breakwater have been estimated at $68.5 and $ 5.3 million respectively. These costs are far in excess of estimates of annual benefits. The breakwater is not economically feasible and, therefore, does not warrant further consideration.

Revetment

Seawalls are constructed for the purpose of protecting property immediately behind them from erosion, flooding and wave action and for separating ocean water from the land. They provide protection by deflecting wave energy but are poor dissipaters of wave energy. As a result, waves impacting sea walls cause scour as some of the wave energy is deflected downward. The loss of sand in front of the sea wall at Nantasket Beach has resulted in the lowering of the beach elevation, the exposure of footings, more frequent overtopping and the failure of a portion of the sea wall. Placing a rock revetment in front of the sea wall can be effective in breaking waves prior to their reaching the sea wall and reducing overtopping and scour.

The Corps had initially considered alternative plans, including a revetment, to protect the DCR reservation's entire 6,800-foot length. Loss of sand in front of the sea wall at the south end of the reservation created a critical condition that was addressed by the DCR in 2004 when the TSF was constructed. The TSF has provided reliable toe protection to the wall behind it and performed better than expected. Later, the DCR constructed the Northern Revetment to replace the failed seawall north of Water Street, leaving the 2,200 foot reach that comprises Zone 2 as the only segment of sea wall not protected by a revetment. A revetment could provide toe protection to the

unprotected wall and reduce overtopping of the sea wall by breaking storm waves before they reach the face of the wall. For these reasons, a stone revetment will receive further consideration.

Elevation of Structures

Non-structural measures, such as the elevation of structures, reduce the vulnerability of private and public properties to flooding, but do not reduce the flooding itself. Flooding, beginning at the first floor, is responsible for a large part of the damages to structures. By elevating structures above flood waters some damages can be avoided. Corps experience indicates that elevating those structures receiving one foot or more of flooding above the first floor level is likely to be economically feasible.

Beachfill Nourishment Alternatives

Placement of beach fill nourishment on a beach can enlarge the existing beach berm profile so that storm waves will break before they reach the sea wall. Scour at the base of the wall and overtopping of the wall could be reduced by this measure. The area of dry beach would be increased for this alternative, so permissible recreational benefits would accrue

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RESULTS OF PRELIMINARY SCREENING

A preliminary analysis of the costs and benefits of a stone revetment, elevation of structures, and sand fill nourishment alternatives indicates that they warrant more detailed consideration for reducing damages in the Nantasket Beach back shore.

ALTERNATIVE PLANS

With Project Conditions

The with project condition is the most likely condition that is expected to exist in the study area during the 50-year planning horizon if a Federally-assisted project is undertaken. Our alternatives evaluation was driven by results of the Corps SBEACH model that are presented in Appendix B. There are as many with project conditions as there are alternative plans and options, which are presented below for each alternative.

Revetment

The sea wall along Zone 2 at Nantasket Beach has direct exposure to storm waves that can move material away from its footings, placing it at risk of failure similar to what occurred at Nantasket in 1992. Placing a rock revetment in front of the sea wall can be effective in breaking waves prior to their reaching the sea wall and reducing overtopping and scour. Two rock revetment plans offering 10-year and 25-year levels of protection were formulated. The two plans have similar layouts and dimensions with the principal difference being the size and weight of the armor stone that is specified. The TSF design was used as a practical starting point, since the Corps and DCR

both agree its performance has met expectations. It has proved to be effective protection for the wall footing. The plans created have a deeper toe and a more robust cross section than the TSF with provisions to accommodate existing beach access stairs and ramps. Details of the concept design are found in Appendix E of this report.

Elevation of Structures

Non-structural measures, such as the elevation of structures, reduce the vulnerability of private and public properties to flooding, but do not reduce the flooding itself. Flooding, beginning at the first floor, is responsible for a large part of the damages to structures. By elevating structures above flood waters some damages can be avoided. An estimated 65 structures in Zone 2 are subject to flooding in the Nantasket Beach back shore. Of these, an estimated 13 structures receive one foot or more of flooding above the first floor level. Corps experience indicates that elevating those structures receiving one foot or more of flooding above the first floor level is likely to be economically feasible.

The implementation of an alternative plan to raise 13 structures would not affect flooding conditions nor prevent erosion in the study area. Only for those structures that are raised above the flood waters would conditions improve, thereby avoiding less than 25 percent of the annualized flooding damages. That means that a vast majority of damages would not be addressed by this measure. Due to the high level of residual flood damages, this plan was rejected.

Beachfill Nourishment System

Beachfill would be placed seaward of the existing sea wall to protect the toe of the sea wall and to cause storm waves to break further offshore to reduce overtopping of the sea wall. Periodic nourishment is an integral part of a beach fill plan. Its purpose would be to replace sand lost to littoral and offshore movement. Two beach fill plans offering 10-year and 25-year levels of protection have been considered in the analysis.

<u>Design and Costs</u> The modeling and analysis for the beach fill plans are presented in Appendix B. For 10-year protection of Zone 2, the direct placement of 246,000 cubic yards of sand seaward of the existing sea wall in Zone 2 is required. The project would be built to a 50 foot wide level berm with an elevation of 9.25 feet NAVD88 and then slope at a maximum rate of lV:l5H until it intersects the existing beach. For 25-year protection of Zone 2, the direct placement of 378,000 cubic yards of sand seaward of the existing sea wall in Zone 2 is required. The project would create a level berm 75 feet wide at elevation 9.25 feet NAVD88 and then slope at a maximum rate of lV:l5H until it intersects the existing beach. In both cases, this initial material placement would equilibrate to a stable width over time. The 2,200 foot length of Zone 2 is small with respect to the size of DCR's Nantasket Beach Reservation and Nantasket Beach as a whole. Due to that small size, it is estimated that a beach fill project to protect Zone 2 only would suffer high end losses over time in proportion to the volume of material initially placed. Should DCR move to implement a similar level of beach fill protection in the adjacent Zones 1 and 3, then the anticipated end losses for a Federal storm damage reduction project in Zone 2 would be small. The beach fill costs in the project cost estimate Appendix G1 assume a land-based source of sand.

Beachfill A materials availability survey of offshore and land-based sources was conducted for the beach fill required for a beachfill nourishment system and is reported in Appendix D.

Two potential offshore sources of beachfill were examined: (1) maintenance dredged material from nearby harbors and (2) underwater materials in Massachusetts Bay. While the option of using materials to be dredged from nearby harbors seems attractive, an examination of the test data for the samples collected from these harbors reveals that less than 60,000 cubic yards of material consists of sand. This material is finer than the required specification. For these reasons, material dredged from nearby harbors as part of the Corps maintenance program would be unsuitable for the sand fill options.

Sediments of western Massachusetts Bay have been the subject of several studies since the early 1970's, which looked at the offshore geology and the potential for suitable borrow and disposal sites. No permittable borrow sites have been identified to date.

With respect to land-based sources, there are several well-established sand and gravel sources in the Plymouth/Kingston area operating within 30 miles of the study area that are capable of producing the required quantities of clean material having a gradation that meets the New England District sand fill specification. In addition, the DCR has expressed an interest in investigating the possibility of using a DCR-owned stockpile of sand located in Revere that was originally intended for the construction of Route I-95. The quantity of material would have to be determined, and the material tested for gradation. Depending on the testing results, the material may require processing to remove large particles, and washing to remove fines. The material would have to be hauled about 30 miles and possibly through downtown Boston.

In conclusion, the required quantities of suitable material can be readily supplied by land-based sources located within an approximately 30-mile radius of the study area. At least two sources have the capability to barge their land based source to the project site. Significant environmental compliance and permitting issues exist at potential offshore borrow and would have to be resolved, which would increase the costs and delay completion of a beach fill project. Costs of offshore materials are generally competitive with land-based sources. Due to economies of scale, unit costs tend to decrease as quantities increase. Offshore dredged materials would probably not be cost effective for smaller quantities required for renourishing the project given the high mobilization and demobilization costs, unless the material is stockpiled for later use. Environmental concerns dictate the placement of sand between September 1 and May 31. The cost of dredging in the winter months can be significantly higher (up to 50 percent) due to the slower rate of production caused by working in rougher seas.

Conditions with Beachfill Nourishment Repair of cracks in the existing seawall is a prerequisite to the implementation of the beachfill nourishment plans. Implementation of a beachfill nourishment plan, including nourishment to periodically restore the dimensions of the beachfill and its design level of protection, would cause waves to break further offshore and reduce wave run up. The reduction in run up would thus provide protection to the sea wall or dune from ocean overtopping and consequent flooding and damage to back shore properties. In addition, the reduction in overtopping would prevent the buildup of hydrostatic pressure on the back of the sea wall and thereby increase stability against overturning. The beachfill in front of the sea wall would prevent the scouring of sand at its toe and possible undermining of the sea wall footing and reduce

the long-term risk that continued erosion would cut off northern Hull from the mainland. The dry beach area created by the beachfill would provide recreational opportunities for beachgoers.

Periodic nourishment refers to the practice of periodically replacing sand fill to replenish sand volume that is lost to erosion. The DCR would be responsible for the entire costs and implementation of periodic sand fill nourishment if a sand fill nourishment project is implemented.

REAL ESTATE

All of the considered alternatives for reducing erosion and flooding of the Nantasket Beach backshore would be constructed on DCR property. Space for construction staging and access will be necessary for the implementation of these alternatives. There are no outside acquisitions needed for construction. It is conceivable that some local traffic patterns or traffic signal timing could be altered to minimize delays and disruption of through traffic as trucks delivering materials enter and leave the construction area; however no lands or easements should be necessary to implement that type of temporary change. The Real Estate Planning Report for the study is Appendix H.

Photo 7 Waves overtop the sea wall in front of the DCR bath house.

Photo 8 These sand bags are a necessary off season measure to prevent water coming over the sea wall from entering the DCR bath house.

5: EVALUATION OF ALTERNATIVE PLANS

ECONOMIC EVALUATION

Methodology

The economic analysis of the alternative plans to reduce coastal storm damages at the Nantasket Beach study area is addressed in Appendix F. Economic benefits are based on damages prevented by the project for different storm events. A stage damage function was developed to correlate damages with still-water flood elevations of each coastal storm event. The damages prevented by each level of protection provide the benefit for each alternative. The benefits and costs were then annualized using a CRF (Capital Recovery Factor) of 0.00457 based on the FY 2013 interest rate of 3.75% for a 50 year project life. For each plan, annual benefits are divided by annual costs to determine the benefit-cost ratio (BCR). Those projects with benefit-cost ratios equal to or greater than one are economically feasible. The Federal government may participate in plans that have benefit-cost ratios of at least one. The National Economic Development (NED) plan is an economically feasible plan that maximizes net benefits or the net value of national goods and services resulting from implementation of the plan. The NED plan is the plan with the largest net annualized benefits after deducting annualized costs. The detailed cost estimates are included as Appendix G.

Benefits

Benefits are the differences in damages and losses without and with each plan. Inundation damages were developed for each property using a typical stage damage function for residential, commercial and institutional structures. The stage or elevation at which flood damage begins is at the ground elevation for each property. Estimates of potential damages were made in one foot increments of stage, to a level six feet above the first floor. Dollar value estimates were made for physical damages to site, structure, contents and utilities. Project benefits are measured by the reduction in storm related damages, prevention of long term erosion, reduction in flood insurance overhead costs and incidental recreation. Incidental recreation benefits associated with beachfill alternatives are restricted to 50 percent of the benefits required for economic justification. The economic analysis employs the limited incidental recreational benefits, where applicable, required for economic justification in the evaluation of each improvement plan. See Tables 1-4.

Analysis

The economic analysis indicates that the 10-year and the 25-year level of protection stone revetment alternatives for Zone 2 are economically feasible. See Tables 1 and 2. However the revetment offering a 10-year level of protection is the plan that maximizes net benefits. The sand fill nourishment plans offering 10-year or 25-year level of protection to Zone 2 show economic justification, however their first costs are far in excess of the ceiling for Federal expenditures per project under Section 103. See Tables 3 and 4. The Zone 3 backshore is partially protected by DCR's Northern Revetment. Few properties are located in the Zone 3 backshore; hence there is an absence of economic benefits in that area. Consequently, no project can be recommended in Zone 3.

Nantasket Beach, Hull, MA

SUMMARY OF ECONOMIC ANALYSIS FOR STUDY ALTERNATIVES

Table 1 10-yr Stone Revetment Plan

COSTS AND BENEFITS

Construction Cost	$5,133,686
Interest During Construction	$24,114
E&D	$308,021
S&A	$410,695
Project Cost	$5,876,516
Annual Cost	$261,941
Annual O&M	$1,100
Total Annual Cost of Alternative	**$263,041**
Annual Benefit	**$1,075,300**
Annual Net Benefit	$812,259

BCR	**4.09**

Table 2 25-yr Stone Revetment Plan
COSTS AND BENEFITS

Construction Cost	$5,800,224
Interest During Construction	$27,245
E&D	$348,013
S&A	$464,018
Project Cost	$6,639,500
Annual Cost	$295,951
Annual O&M	$800
Total Annual Cost of Alternative	**$296,751**
Annual Benefit	**$1,075,300**
Annual Net Benefit	$778,549
BCR	**3.62**

Table 3 10-yr Beach Nourishment Plan
COSTS AND BENEFITS

Construction Cost	$15,457,528
Interest During Construction	$268,463
E&D	$927,452
S&A	$1,236,602
Renourishment	$36,350517
Project Cost	$54,240,562
Annual Cost	**$2,417,731**
Annual Benefits	$1,408,100
Annual Recreational Benefit	$1,197,400
Total Annual Benefits	**$2,605,500**
Annual Net Benefit	$187,769
BCR without Recreational Benefits	**0.58**
BCR with Recreational Benefits	**1.08**

Table 4 25-yr Beach Nourishment Plan
COSTS AND BENEFITS

Construction Cost	$25,868,782
Interest During Construction	$449,284
E&D	$1,552,127
S&A	$2,069,503
Renourishment	$19,885,274
Project Cost	$49,824,969
Annual Cost	**$2,220,909**
Annual Benefits	$1,408,100
Annual Recreational Benefit	$1,197,400
Total Annual Benefits	**$2,605,500**
Annual Net Benefit	$384,591
BCR without Recreational Benefits	**0.63**
BCR with Recreational Benefits	**1.17**

ENVIRONMENTAL, HISTORICAL AND CULTURAL CONSIDERATIONS

Evaluation of the project site and for possible construction of the three plans that are economically feasible (elevation of structures, a stone revetment, and the sand fill nourishment options) indicate that there are no unacceptable impacts on environmental, historical, archaeological, and cultural resources. There are no threatened or endangered species in the project area.

Any negative environmental impacts would generally be minor and short term in nature. The trucking of stone, sand fill and other construction materials to the site would create noise along the trucking route. Construction of the plan would cause minor noise and dust impacts. Placement of sand fill would generate minor turbidity in near shore waters. Operating equipment on the beach could also cause local turbidity depending upon the tide.

COMPARATIVE EVALUATION OF PLANS

Elevate structures - A plan to elevate some 13 of the most flood-prone structures in the study area is economically feasible, but would benefit only those structures that are elevated. The remaining structures for which elevation is not economically feasible would continue to incur damages from flooding due to coastal storms. Some 75 percent of residual damages would remain. This high level of residual damages was the basis for dismissing raising structures as an effective storm damage reduction measure.

Sand fill beach nourishment - The sand fill nourishment plans for a berm placed seaward of the existing sea wall, including periodic nourishment, would cause storm waves to break further offshore and reduce ocean water overtopping of the sea wall and consequent flooding of the back shore and damages to structures and properties. The sand fill plans would provide protection against an approximately 10-year and 25-year recurrence storm events, respectively. The combination of less ocean overtopping, which reduces the potential for increases in the hydrostatic pressure on the back of the sea wall, and sand fill in front of the wall would increase the stability of the sea wall against overturning. The sand fill would guard against scouring at the toe of the sea wall and possible undermining of the sea wall footing. In addition, the plan would protect the DCR facilities and other public infrastructure as well as commercial properties. The dry beach area created by the berm would allow an increase in the number visitors that the reservation can be accommodated. The economic feasibility of the sand fill plans can be demonstrated, however the first cost of each of the plans was far in excess of the limit for Federal expenditures under the continuing Authorities Program's Section 103. The length of a sand fill project to adequately protect the 2,200 foot-long Zone 2 would be greater than 2,200 feet. If a sand fill berm were constructed as a stand-alone project, the expected end losses would be considerable due to the dimensional differences between it and the existing beach. Frequent maintenance would be a direct consequence of those material end losses. Unless the DCR elected to place sand fill over the remainder of its reservation in a coordinated construction effort, the practicality of maintaining such a relatively short berm would be marginal.

Stone Revetment - The stone revetment plans to build a revetment placed seaward of the existing sea wall would cause storm waves to break of the sea wall and reduce ocean water overtopping and consequent flooding of the back shore and damages to structures and properties. Revetment plans would provide approximately 10-year and 25-year protection against recurring storm events. The revetment would protect the toe of the sea wall from scour and the possible undermining of its footing. In addition, the plan would protect the DCR facilities and other public infrastructure close to the sea wall.

IDENTIFICATION OF RECOMMENDED PLAN

Based on the maximization of NED benefits, the recommended plan to provide shore protection for Zone 2 at the DCR Nantasket Beach Reservation is a stone revetment approximately 2,200 feet long designed to afford a 10-year level of protection to the backshore. The plan meets economic, engineering and cultural criteria for implementation, so the Federal government may participate in its final design and construction. Its cost of implementation falls within the expenditure limits for Section 103 projects and the net annual benefit of the plan is $812,559 with a benefit to cost ratio of 4.09. The costs associated with the recommended plan are presented in Table 5.

Table 5 10-yr Stone Revetment Plan
2,200-foot long Stone Revetment in front of existing wall in Zone 2

COSTS AND COST APPORTIONMENT

PLANNING PHASE COSTS

Activity	Total Cost	Federal Share (50%)	Non-Federal Share (50%)
Feasibility Study	$869,194.48	$434,597.24	$434,597.24

RECOMMENDED PLAN (10-YR LOP) IMPLEMENTATION PHASE COSTS

Activity	Total Cost	Federal Share (65%)	Non-Federal Share (35%)
Construction Cost	$5,134,000	$3,337,100	$1,796,900
Engineering and Design (E&D)	$308,000	$200,200	$107,800
Construction Management (S&A)	$411,000	$267,150	$143,850
Total Project Cost	$5,853,000	$3,804,450	$2,048,550

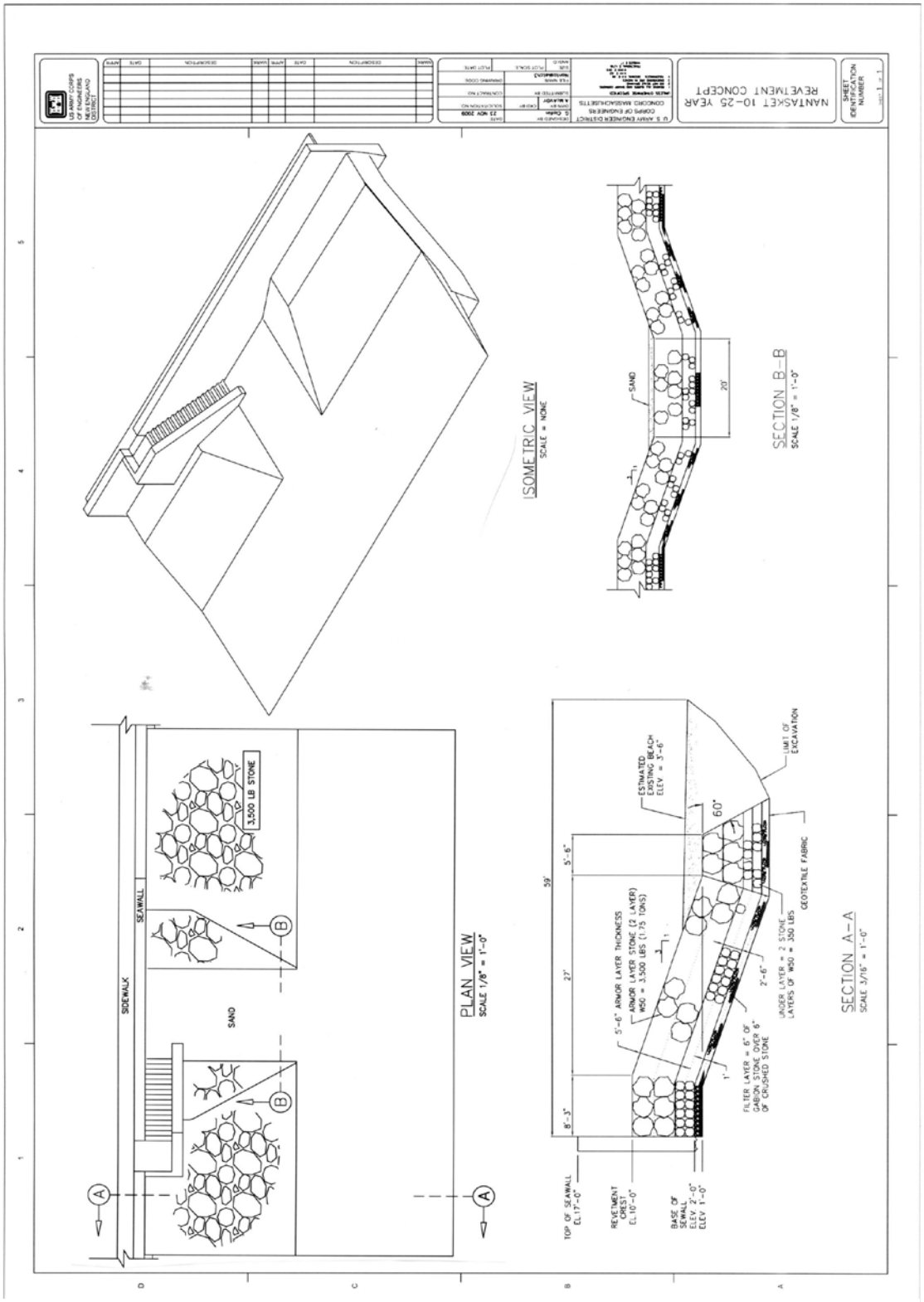

Figure 3 – Concept Stone Revetment for 10-year level of protection for Nantasket Beach

6: COSTS AND RESPONSIBILITIES

IMPLEMENTATION RESPONSIBILITIES

Cost Apportionment

The Section 103 authority, under which this present study has been conducted, provides for Federal participation of 65 percent of all project costs, including construction, contingencies, Engineering and Design (E&D) and Construction Management (CM) up to $5,000,000 in Federal costs, including the Federal share of reconnaissance and feasibility studies. The non-Federal sponsor, the Department of Conservation and Recreation, is responsible for all operation and maintenance costs.

For the Nantasket Beach Project, Federal study costs are $434,597.24 thereby leaving up to $4,565,402.76 in Federal funds remaining available for design and construction of a Section 103 project. The apportionment of costs between the Federal government and non-Federal sponsor for the recommended plan are presented in Table 5. Federal and Non-Federal first construction costs respectively are $3,804,450 and $2,048,550 for a total of $5,853,000. Periodic maintenance costs over the 50-year period of analysis estimated to be $1,100 annually and are a non-Federal responsibility. The estimated Federal share of the project implementation cost shows the project is within the $5 million limit for Section 103 projects; however careful consideration should be given to both the project specifications and the acquisition strategy so the possibility of exceeding the limit is minimized.

Cost Methodology

An Abbreviated Risk Analysis (ARA) was conducted and a Total Project Cost Summary (TPCS) prepared for the recommended plan. The exercise resulted in a changed project contingency, however these costs are relative, and recognizing the recommended plan benefit to cost ratio was 4.09, it is reduced to 3.03 but the report recommendation does not change.

Updated project costs and cost apportionment are presented in Table 5a. The revised Federal and Non-Federal first costs respectively are $4,129,700 and $2,223,600 for a total of $6,353,300.

Seawall Repairs

If the benefits attributable to a project to construct a stone revetment seaward of the sea wall are to be realized, minor repairs to the sea wall must be made by the sponsor as prerequisite to the construction phase of the project.

Table 5a 10-yr Stone Revetment Plan
2,200-foot long Stone Revetment in front of existing wall in Zone 2
Project costs with TPCS contingency applied

COSTS AND COST APPORTIONMENT

PLANNING PHASE COSTS

Activity	Total Cost	Federal Share (50%)	Non-Federal Share (50%)
Feasibility Study	$869,194.48	$434,597.24	$434,597.24

RECOMMENDED PLAN (10-YR LOP) IMPLEMENTATION PHASE COSTS

Activity	Total Cost	Federal Share (65%)	Non-Federal share (35%)	
			Non-Federal cash	Lands (100% non-Fed)
Construction Cost	$5,537,600	$3,622,700	$1,914,900	------
Lands	$35,800	------	------	$35,800
Engineering and Design (E&D)	$338,400	$220,000	$118,400	------
Construction Management (S&A)	$441,500	$287,000	$154,500	------
Total Project Cost	$6,353,300	$4,129,700	$2,187,800	$35,800

MEPA Schedule and Permits

The local sponsor will be responsible for compliance with the Massachusetts Environmental Protection Act (MEPA) and for the distribution of the draft Environmental Impact Report (EIR) to all appropriate parties and to the MEPA office for a statement on the adequacy of the draft EIR. Based on the comments received on the draft EIR, a final EIR will then be prepared by the local sponsor and be distributed to interested parties. The Secretary of the Executive Office of Environmental Affairs (EOEA) will then make a determination as to whether or not the final EIR is in compliance with MEPA. Upon a finding of compliance with MEPA, the local sponsor will prepare a Section 61 Finding.

During the Engineering and Design phase of this project, and after completion of the final EIR, the local sponsor will obtain the Local Order of Conditions, and Chapter 91 License. The Corps of Engineers will obtain the Water Quality Certification and a Coastal Zone Consistency Determination.

Maintenance

Maintenance applies to the upkeep, repair and care of work constructed for the project. Maintenance includes inspection to detect any deterioration that would adversely affect the performance of the project and undertaking the repair or replacement as required. The requirements for maintaining the project would be addressed in a Corps-prepared operation and maintenance manual and future maintenance would be the responsibility of the local sponsor.

Project Partnership Agreement

After the completion of this Feasibility Study and final design during the E&D phase, a Project Partnership Agreement (PPA) defining the responsibilities of the parties for the construction of the project, will be executed by the Federal and non Federal parties. In the PPA, the sponsor will agree to pay its share of project implementation costs and provide the lands, easements and rights of way required to construct the project.

Construction

In an effort to control temporary increases in noise levels, the contractor will be required to restrict truck traffic through the town of Hull to reasonable hours. It is expected that much of the construction activity can be accomplished during low and mid-tides. Negative impacts to water quality will be minimized by not allowing equipment into the water to the maximum practical extent.

7: CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The publicly owned Nantasket Beach Reservation is exposed to erosion and flood damage from coastal storms its protective works (sea wall, sand fill, revetments, etc.) and backshore recreational, commercial and residential properties. The Massachusetts Department of Conservation and Recreation has taken steps to prevent or reduce damages by providing toe protection for the vulnerable sea wall at the south end of their reservation and reconstructing a failed portion of their sea wall at the north end of their reservation. The threats of erosion, flood damages and risk of undermining the remaining portion of the sea wall are projected to continue if a project is not undertaken to address that segment of the beach. This study concludes that, of the plans considered for reducing coastal storm damages at Nantasket Beach, the construction of a stone revetment to provide a 10-year level of protection to the central portion of the DCR reservation and its backshore is economically justified and is a locally-preferred plan in which the sponsor would participate. The proposed revetment would be approximately 2,200 feet long and would be constructed directly in front of the existing sea wall once DCR has performed repairs to all cracks, etc that are identified prior to new construction.

The revetment will consist of a layer of geotextile fabric, a 6" thick filter layer of crushed stone, a 2'-6" under layer of stone, W50 = 350 lbs (2 stones thick), and a 5'-6" armor layer of stone, W50 = 3,450 lbs (2 stones thick).

The excavation limits can be determined by viewing Section A-A on the attached concept plan Figure 3. The footprint of the revetment concept conforms to the approved MEPA footprint according to DCR. The bottom of the excavation will be -8.0 ft NGVD.

One impact of the revetment in Zone 2 would be the reduction of dry beach area equal to the size of its footprint. There should be no impacts to surf clams, and the number of trucks required to bring materials over local roadways to the site will be significantly less than what was estimated for the beachfill alternative.

Building the revetment is the National Economic Development (NED) Plan and qualifies for Federal participation in its final design and construction. It would be environmentally and culturally acceptable. None of the improvement plans to provide additional protection fot Zone 1 where the sea wall is fronted by the TSF, Zone 3 with the Northern Revetment or the 1,400 portion of the shoreline north of the sea wall, were found to be economically feasible.

RECOMMENDATIONS

I recommend the construction of the 2,200-foot long stone revetment in front of the sea wall at an elevation of 10 feet (NGVD), with a lV:3H slope to a toe buried below the existing beach and maintained periodically to restore the geometric configuration and level of protection of the plan. It is the most technically and economically feasible and socially, environmentally and culturally acceptable project for reducing storm damages due to flooding and erosion at Nantasket Beach. The project is estimated to have a first cost of $6,353,300 with annual maintenance during the life of the project is estimated to be $1,100. The Federal cost is limited to $5,000,000 under Section 103

guidelines. The Federal share of the costs of prior studies is $434,597.24 and the estimated Federal cost of construction is $4,129,700.

I have considered all significant aspects in the overall public interest including engineering and economic feasibility and environmental, cultural, and social effects in concluding that the approved plan described herein is the best implement able alternative meeting the objectives of this investigation.

I further recommend that this Feasibility Report be the basis for proceeding with Engineering and Design and construction of the approved plan under the authority of Section 103 of the 1962 River and Harbor Act, as amended.

This recommendation to proceed to the Engineering and Design Phase is contingent on a commitment on the part of the Department of Conservation and Recreation, to perform repairs, as deemed necessary, to the sea wall in Zone 2, prior to the construction of the approved project.

The recommendations contained herein reflect information available at this time and current Department of the Army policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of the national civil works construction program nor the perspective of higher review levels of the Executive Branch. Consequently, the approval may be modified before transmission for authorization and /or implementation.

_____ _____

Date

Christopher J. Barron
Colonel, Corps of Engineers
District Engineer

NANTASKET BEACH
HULL, MASSACHUSETTS

CONTINUING AUTHORITIES PROGRAM
Section 103
Coastal Storm Damage Reduction

http://www.nantasketbeach.com/pictures.php/20

ENVIRONMENTAL ASSESSMENT
FINDING OF NO SIGNIFICANT IMPACT
AND
CLEAN WATER ACT SECTION 404 (B)(1) EVALUATION

U.S. ARMY CORPS OF ENGINEERS
696 Virginia Road
Concord, Massachusetts 01742-2751
November 2013

NANTASKET BEACH ENVIRONMENTAL ASSESSMENT
Continuing Authority Program
Section 103 Coastal Storm Damage Reduction

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FINDING OF NO SIGNIFICANT IMPACT

The proposed Nantasket Federal coastal storm damage reduction project is intended to provide protection for the backshore areas of Nantasket Beach, Hull, Massachusetts. Protection from coastal storms and their associated tidal surges is required to protect public and private backshore properties along Nantasket Beach. Currently, considerable damages are sustained by the Town of Hull, private property owners, and the Massachusetts Department of Conservation and Recreation (DCR) from flooding and wind and wave action. The screening of several alternatives resulted in the selection of an action plan consisting of the construction of a rock revetment along 2,200 feet of the Nantasket Beach Reservation. The rock revetment is being built adjacent to an existing seawall and will displace approximately 129,800 square feet of cobble-sand beach.

Work is authorized under the continuing authority of Section 103 of the River and Harbor Act of 1962, as amended. I find that based on the evaluation of environmental effects discussed in this document, the decision on this application is not a major federal action significantly affecting the quality of the human environment. Under the Council on Environmental Quality ("CEQ") NEPA regulations, "NEPA significance" is a concept dependent upon context and intensity (40 C.F.R. § 1508.27.) When considering a site-specific action like the proposed project, significance is measured by the impacts felt at a local scale, as opposed to a regional or nationwide context. The CEQ regulations identify a number of factors to measure the intensity of impact. These factors are discussed below, and none are implicated here to warrant a finding of NEPA significance. A review of these NEPA "intensity" factors reveals that the proposed action would not result in a significant impact—neither beneficial nor detrimental--to the human environment.

Impacts on public health or safety: The project is expected to have no adverse effect on public health and safety.

Unique characteristics: The project is located on a typical high-energy sand-cobble beach.

Controversy: The proposed project is not controversial as this term is understood in the NEPA context. State and federal resource agencies agree with the Corps impact assessment. Public support for the project has been noted.

Uncertain impacts: The impacts of the proposed project are not uncertain, they are readily understood based on past experiences the Corps has had with similar projects.

Precedent for future actions: The proposed project is authorized under an existing federal law and will not establish a precedent for future actions.

Cumulative significance: As discussed in the EA, to the extent that other actions are expected to be related to the project as proposed, these actions will provide little measurable cumulative impact.

Historic resources: Coordination with the State Historic Preservation Office and Board of Underwater Archaeological Resources has determined that no impacts to historic or archaeological resources will occur as a result of this project.

Endangered species: The project will have no known positive or negative impacts on any State or Federal threatened or endangered species.

Potential violation of state or federal law: This action will not violate federal law. The local sponsor will be responsible for obtaining necessary state and local permits.

Measures to minimize adverse environmental effects of the proposed action are discussed in the EA. These measures include using avoidance, minimization, and best management practices.

Based on my review and evaluation of the environmental effects as presented in the Environmental Assessment, I have determined that implementation of the proposed coastal storm damage reduction project will have no significant direct, indirect, or cumulative impacts on the quality of the human or natural environment. Because no significant environmental impacts will result, an Environmental Impact Statement is not required and will not be prepared.

_____
DATE

_____
Christopher J. Barron
Colonel, Corps of Engineers
District Engineer

NANTASKET BEACH
HULL, MASSACHUSETTS
CONTINUING AUTHORITIES PROGRAM
Section 103
Coastal Storm Damage Reduction
ENVIRONMENTAL ASSESSMENT

1.0 INTRODUCTION

Nantasket Beach is located in the town of Hull along the southeast coast of Massachusetts on a peninsula forming the southern boundary of Boston Harbor, about four miles southeast of the main entrance to Boston Harbor and 12 miles southeast of the city of Boston. The project area is part of a long narrow peninsula projecting into Boston Harbor, along a southeast-northwest axis from the Atlantic Hill section of Hull to Point Allerton. It is within the Massachusetts Department of Conservation and Recreation's (DCR) Nantasket Beach Reservation. The project area is approximately 6,800 feet long, and is bordered by commercial and residential areas along the backshore (Figure 1). The DCR Reservation extends from its southern limit at Atlantic Hill north to Phipps Street. DCR Reservations are regional park systems that protect land and water resources and preserve the natural and cultural resource legacies of an area while providing recreational opportunities.

2.0 PURPOSE AND NEED

The purpose of the project is to reduce damage in the project area caused by coastal storms. The concrete seawall along the DCR's Nantasket Beach Reservation was substantially damaged and undermined during the "Halloween Storm" of October 1991. A large volume of the sand beach was lost during the storm. In addition, overtopping of the seawall caused flooding of the commercial and residential backshore buildings. The most severe damages in the past 20 years occurred during the northeast storms of October 1991 and December 1992 when a 650-foot section of the concrete seawall collapsed.

The seawalls in the project area protect backshore parking areas, a recreation pavilion, and a bathhouse. Hull Shore Drive and Nantasket Avenue, which parallel the beach front, provide the sole access to the northern two-thirds of the Town of Hull and about 80 percent of its population. Approximately 65 structures including commercial, public, and residential buildings are located within the study area. Of these structures, 53 are projected to be subject to first floor flooding during a 100-year storm event.

The flooding of public, commercial, and residential properties has historically occurred and will continue if protective measures are not taken. Additionally, should no action occur, storm damage to the concrete seawall and the sidewalks adjacent to the beach will continue.

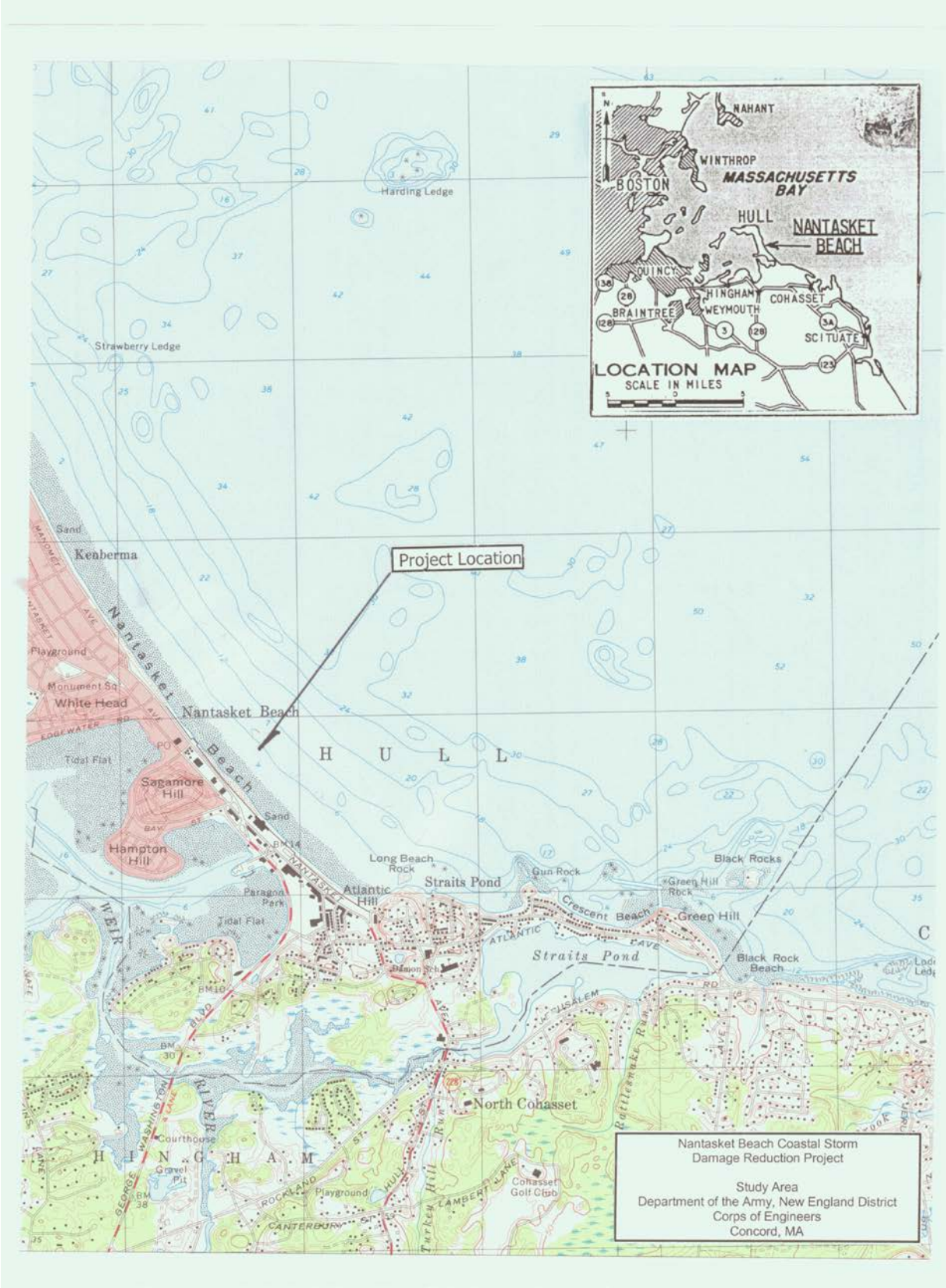


Figure 1. Nantasket Beach, Hull, Massachusetts

3.0 PROJECT HISTORY AND AUTHORITY

In March 1968, a beach erosion control report for Nantasket Beach was issued in cooperation with the DCR (formerly the Metropolitan District Commission). The report recommended that a beach erosion control project be adopted that involved beach widening by placing suitable sand fill along 6,800 feet of beach fronting the DCR Reservation. The report recommended a general backshore elevation of 17 feet above mean low water (MLW) that would furnish a recreational and protective beach averaging about 190 feet in width behind the mean high water (MHW) line.

In October 1991, a Nor'easter' storm caused extensive damage to the stone rip-rap, and concrete sea walls, sidewalks, stairs and ramps along the DCR Reservation at Nantasket Beach. The DCR requested the U.S. Army Corps of Engineers (Corps) to reactivate the previously authorized project because of the damages sustained to the seawall and backshore properties during the storm.

Due to the critical nature of this situation it was decided to conduct the reconnaissance study under the authority contained in Section 103 of the 1962 Rivers and Harbors Act, as amended, that is administered under the Corps Continuing Authorities Program. Section 103 allows the Corps to evaluate methods of protecting public facilities that have been threatened by beach erosion. While this authority allows the Corps of Engineers the ability to evaluate and construct a project, it requires the local, sponsoring agency to provide funding for future maintenance and renourishment of beaches.

The Reconnaissance Report, including a draft Feasibility Cost Sharing Agreement, was completed in August 1993 and approved by Headquarters, USACE in March 1994. In February 1995, the DCR and the Corps of Engineers entered into a Feasibility Cost Sharing Agreement to conduct the Feasibility Study. Input to the Environmental Assessment was compiled in 1996 and appeared in the draft Feasibility Report dated January 1997. The sponsor decided not to move forward with the storm damage reduction project at Nantasket Beach at that time. Subsequently, the sponsor elected to revive the project and applicable updates to the report and its economic and cost analyses were prepared by the New England District in 1999.

The Corps issued a public notice on the draft revisions in March 2003, however many of the comments received took issue with the recommendations for relatively coarse sandfill that was considered to be incompatible with Nantasket's fine grain sand. While the debate over what sand was appropriate continued, condition surveys revealed that the sea wall at the south end of the DCR reservation was severely at risk after the beach had eroded to the extent that no dry beach remained at high tide and footings were being exposed. The Corps assisted DCR by designing the Temporary Sea Wall Fortification (TSF) which was constructed as an emergency measure in 2004. DCR constructed the Northern Revetment in 2006 to replace the sea wall that was weakened and/or collapsed in 1992.

4.0 PROJECT DESCRIPTION

An overall “study area” of Nantasket Beach was initially proposed along the 6,800 foot long length of the DCR reservation (Figure 2). The study area was divided into three “zones” for study purposes. Zones 1 and 3 have been removed from the Corps Section 103 study as improvements in those areas have been completed by others.

The proposed project addressed by this document provides shore protection for Zone 2 in Figure 2. The proposed project involves constructing a 2,200 foot long stone revetment along the length of Zone 2. The revetment is proposed to be located directly in front of the existing sea wall. The revetment will consist of a layer of geotextile fabric, a 6" thick filter layer of crushed stone, a 2'-6" under layer of stone, W50 = 350 lbs (2 stones thick), and a 5'-6" armor layer of stone, W50 = 3,000 lbs (2 stones thick). The revetment will displace approximately 129,800 square feet of cobble-sand beach.

Placement of the stone will occur seaward of the existing seawall. The construction of the revetment is anticipated to take approximately 2-3 months to complete and will be constructed in the year that funds become available. No seasonal restrictions for construction are anticipated.

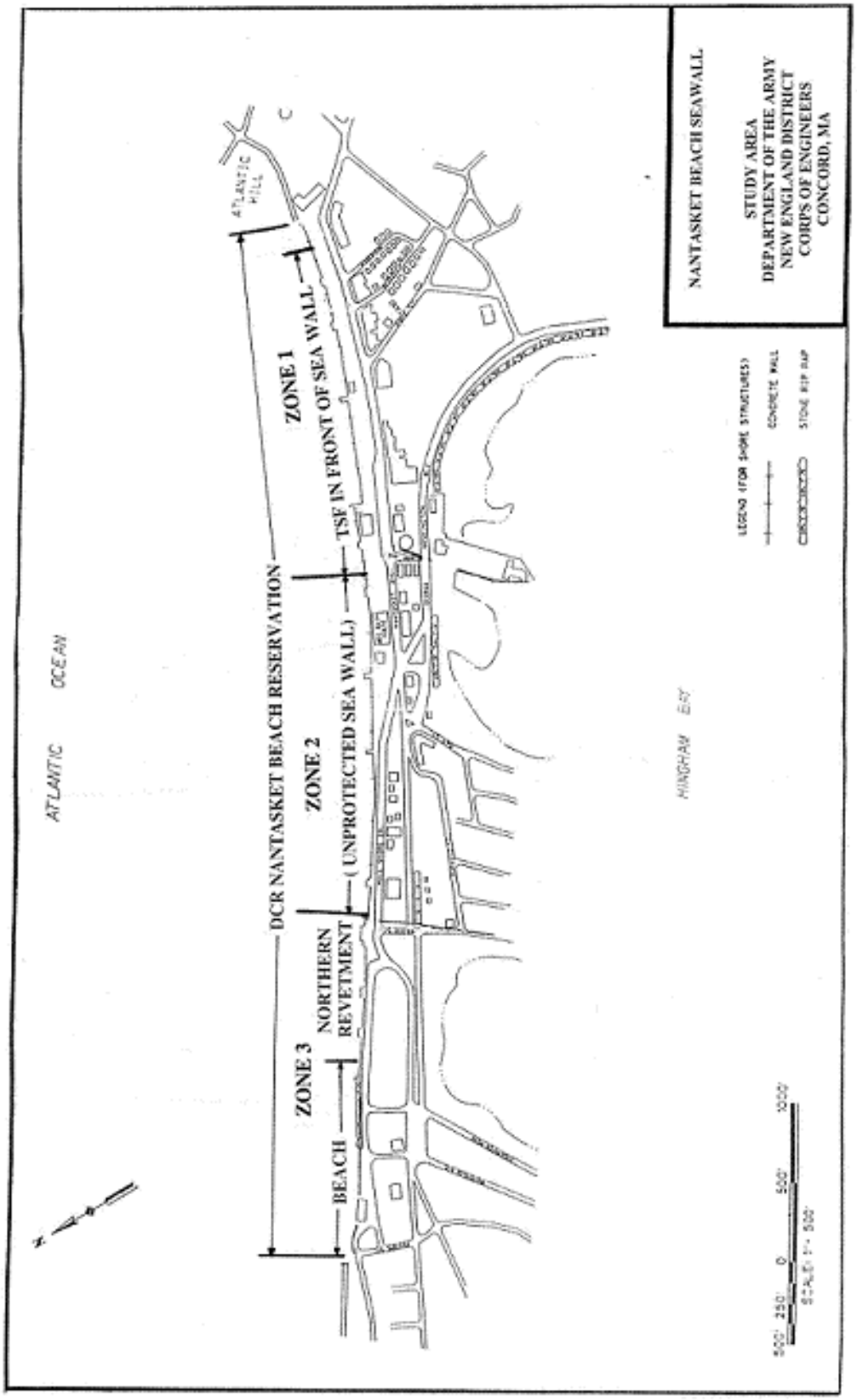


Figure 2. Nantasket Beach Reservation study zones.

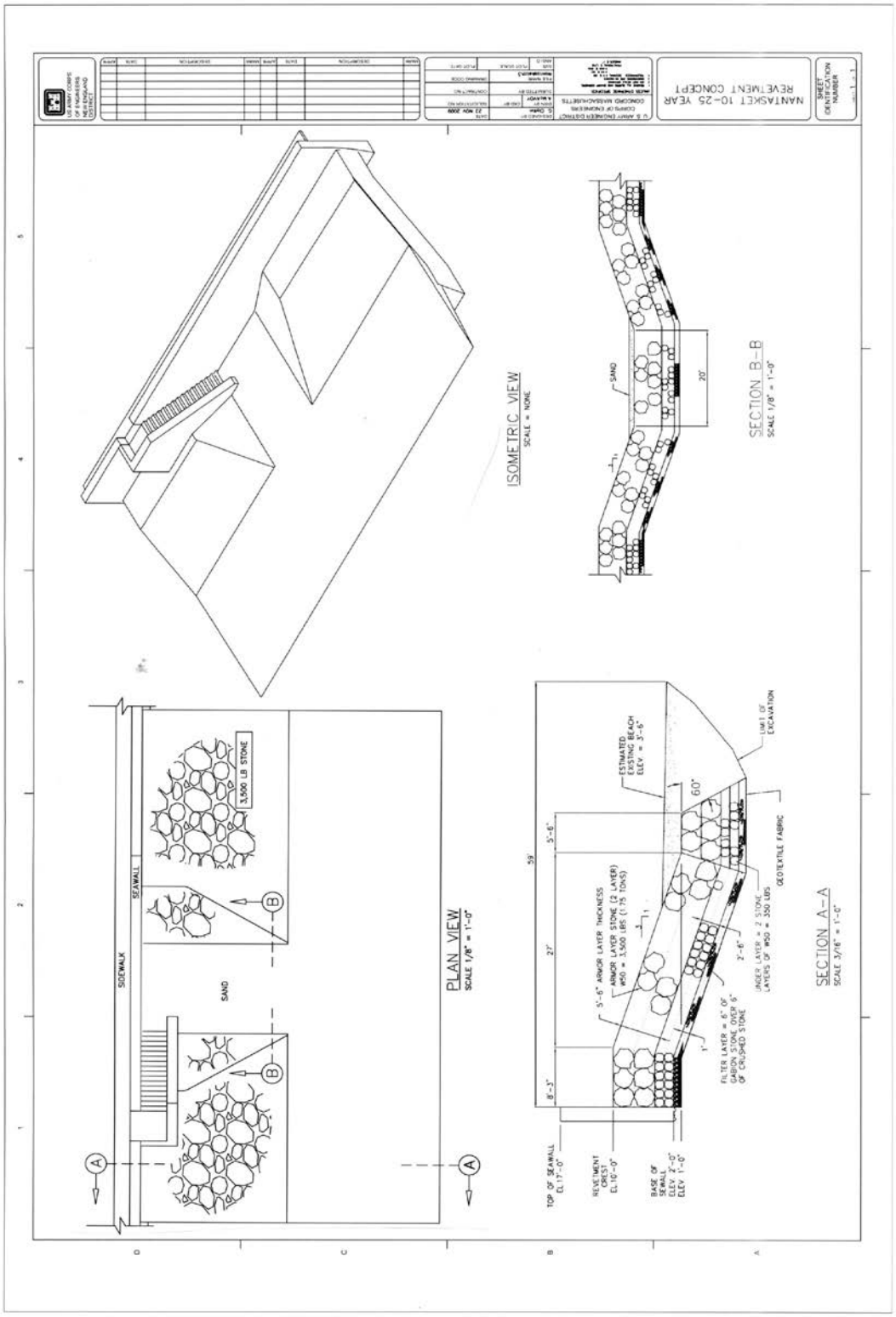


Figure 3. Proposed Nantasket Beach Reservation revetment.

5.0 ALTERNATIVES

In addition to the no-action alternative described in Section 5.1, four action alternatives were evaluated to reduce coastal storm damage along the proposed study area. The objective in identifying and evaluating project alternatives is to avoid or reduce the potential impact associated with construction and operation of the proposed facility. Potential impact factors considered may include land use effects, marine and terrestrial ecosystem disturbance, and impacts on endangered and threatened species.

The selected alternative for construction (preferred plan) must be able to comply with the Corps responsibilities associated with Section 404 of the Clean Water Act, and all other applicable laws and regulations, such as the Clean Water Act Section 401 Water Quality Certification and Coastal Zone Management consistency for the Commonwealth of Massachusetts.

5.1 No Action Alternative

Under the No Action Alternative (providing no additional protection in the project area), flooding will continue to occur along the Nantasket Beach backshore areas. Considerable damage to the concrete seawall, stairs, riprap, and sidewalks as well as flooding damages to commercial, residential, and public properties will continue without action. Seawall failure would dramatically exacerbate storm damages in the backshore. Inclusion of a no action alternative is prescribed by CEQ regulations to serve as a benchmark against which proposed Federal actions can be evaluated. The no action alternative refers to the continuation of existing conditions of the affected environment, without implementation of the proposed action. Flooding of the backshore occurs when coastal storms and their associated tidal surges and wave action undermine and overtop the seawall along Nantasket Beach.

5.2 Offshore Breakwater Alternative

An offshore breakwater in the waters adjacent to Nantasket Beach was considered. However, the cost estimates to construct a breakwater structure exceed the potential benefits gained from having the structure in place. The Corps of Engineers cannot become involved in a continuing authorities project unless the benefit to cost ratio exceeds one. Therefore, this alternative is not economically viable and was dropped from consideration.

5.3 Relocation or Raising of Structures Alternative

Non-structural measures do not control flooding but reduce the property damages from flooding. The relocation or raising of affected structures in the project area was considered. By moving vulnerable properties from the flood prone areas, some damages can be minimized and avoided. Structures may be relocated from the flood plain (a very expensive option), or flood proofed or raised above the floodplain. The relocation of structures was considered impractical due to economic considerations.

An elevation alternative was also evaluated. About 65 structures are subject to first floor flooding in the Nantasket Beach backshore from a 100-year flood. Past experience has shown it makes economic sense to raise a structure if that structure receives recurring flood damages from one foot or more of water above its first floor elevation. Elevating the first floor of 13 structures that receive one foot or more of flooding above the first floor was considered and found to be economically feasible. However, small fraction of properties would benefit from this

alternative. Flooding would still occur at most properties and therefore residual damages in the study area would be high.

5.4 Revetment Alternative

The construction of a revetment along all the “zones” of the project area was considered. This alternative was reduced to the construction of a revetment along Zone 2 only following improvements in Zones 1 and 3 by DCR. The revetment in Zone 2 would be built adjacent to the existing seawall and would displace approximately 129,800 square feet of cobble-sand beach. Prior to construction of the proposed project, the local sponsor would be responsible to complete repairs of any damaged existing seawall including the replacement of any damaged ramps and stairs. This alternative is considered feasible.

5.5 Sand Fill Nourishment Alternative

Sand fill nourishment alternatives along the entire 6,800-foot shoreline was initially considered. Sand fill berms that are 50-, 75-, and 100-foot wide having elevations of 12 feet NGVD and slopes of 1V:15V slope to the existing beach were analyzed. This alternative was considered feasible. Since that alternative was formulated, the TSF and Northern Revetment were constructed, thus changing the without project conditions. As a result, the portion of the beach considered for protection from storms became solely the area along Zone 2. Our beach characterization study revealed that a compatible beachfill design would be much flatter than what the Corps had proposed in 2003, and, as a consequence, fill volumes were higher and so were the costs for the material. While sand fill remains a feasible option, the costs associated with this alternative are far in excess of the limits that Section 103 provides.

6.0 AFFECTED ENVIRONMENT

6.1 Physical and Chemical Environment

Nantasket Beach is in the town of Hull, Plymouth County, Massachusetts. The study area is part of a peninsula extending along a NW-SE axis into Massachusetts Bay, running from the southern limit to the northern limit of the DCR Reservation (Figure 1). This beach lies on the Atlantic Ocean, facing a northeasterly direction. Swells from ocean storms directly affect this section of coast and are the cause of the coastal erosion that is being experienced. The Massachusetts Coastal Zone Management Plan area designates this area as a public beach (CZM 1977). The beach is composed primarily of sand and stone cobble running the length of the project area.

The development and existence of Nantasket Beach is derived from a number of drumlin islands located north of Atlantic Hill. Five of these drumlins were once located east of Nantasket Beach, but are now completely eroded away. It is estimated that more than 90 percent of the material in Nantasket Beach was derived from these drumlins. Strawberry Hill, Sagamore Head, and Whitehead are now protected from marine erosion by the beaches in front of them. Point Allerton and Allerton Hill are protected in most places by seawalls. Minimal amounts of material are currently being added to Nantasket Beach from these drumlins and it does not appear likely that a significant amount of material is being added from the sites of the destroyed drumlins (COE, 1968).

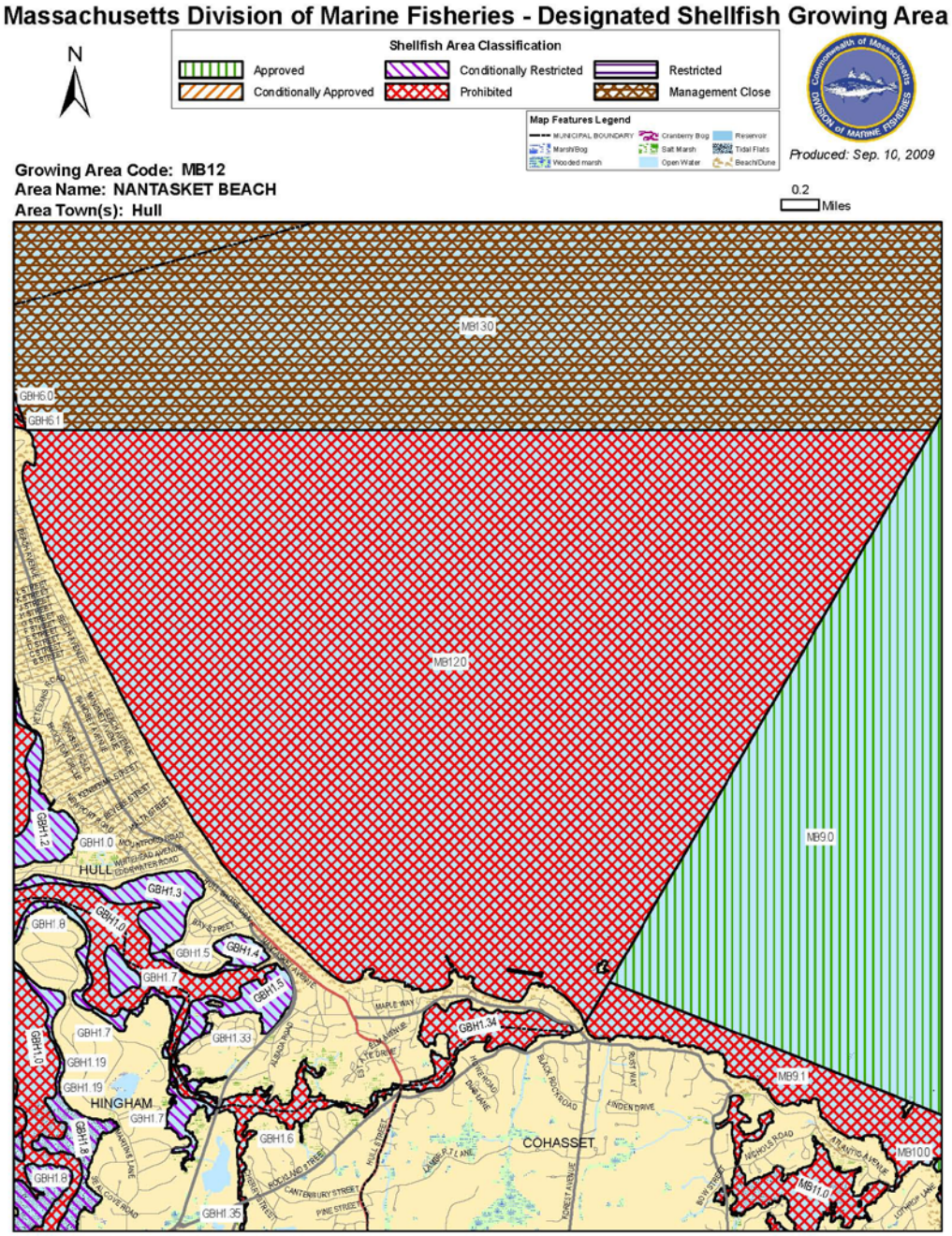
The dominant direction of wave travel during most of the year is generally straight onto the beach. As a result, there is no strongly developed longshore drift direction. However, it appears that some material moves from the south to the north (Appendix B of the Main Report). Beach profiles taken for this study indicate that the shoreline has been moving inland (USACE, 2006). The slope of the beach is very shallow (1:73 at the north end to 1:45 slope of the beach on the south end). At low tide, the beach is about 400 to 600 feet wide. At high tide, the entire beach in front of the seawall is inundated. The beach sediments are composed of fine to medium-grained brown/gray colored sand in the intertidal areas and beach slopes, while the upper beach cobble is composed of cobble and a mix of sands (USACE, 2006).

The sediment in the project area was not chemically tested as it is sand and cobble and not likely to contain contaminants.

6.2 Biological Resources

The upper beach areas of Nantasket Beach are unstable shifting sand –cobble habitats which are mostly underwater during the higher portions of the tidal cycle. These shifting sands provide little, if any, suitable substrate for biota to colonize. No dunes or sea grasses or significant environmental resources were observed from the subtidal to supratidal area during a site inspection. There are no known eelgrass beds (*Zostera marina*) located off Nantasket Beach (U.S. Fish and Wildlife, 1996; MASS-GIS, 2010).

Figure 3. Shellfish designation areas along Nantasket Beach, Hull, MA.



6.2.2 Benthic Community

Benthic communities in the vicinity of the project area are typical intertidal sandy shore assemblages. These assemblages tend to have few species and few individuals and are represented by organisms adapted for life in shifting sand habitats. Some representative organisms in the Nantasket Beach study area identified by Pratt (1996) include haustorid amphipods *(Amphiporeia virginana, Haustorius canadensis,* and *Parahaustorius longimerus),* and some species of polychaetes such as *Paraonis fulgens* and *Nephtys picta.*

6.2.1 Shellfish

A shellfish survey to assess populations of surf clams in the vicinity of the project area was performed in December of 2006 (Battelle, 2007). A hydraulic dredge was towed over 53 transects (transects were 100 meters in length) between the 30' contour and mean lower low water (mllw) contour. The survey showed that there is a population of surf clams within the subtidal areas adjacent to the project area. Surf clams were most abundant in the nearshore areas to depths of approximately 7 feet (mllw). Nantasket Beach is closed to shellfish harvesting due to bacterial contamination from the sewage treatment plant on Nut Island. However, surf clams may be harvested as bait for the cod fishery. Figure 3 details the shellfish closure areas in the project area

No lobsters (*Homarus americanus*) were collected during the shellfish survey and there was no evidence of lobster fishing (i.e., lobster traps) in the project area during the course of the survey. Lobsters are known to be harvested in the deeper offshore waters adjacent to the survey area.

6.2.3 Fishery Resources

Nantasket Beach supports a typical New England sandy beach assemblage of fish including such species as killifish, silversides, and sand lances. A number of managed fishery species, those species that are deemed recreationally and commercially important and thus have management plans developed for them, have the potential to occur in the nearshore and offshore waters adjacent to the project area. The managed species are listed in Section 6.3.

6.3 Essential Fish Habitat

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act strengthened the ability of the National Marine Fisheries Service (NMFS) and Fishery Management Councils to protect and conserve the habitat of marine, estuarine, and anadromous finfish, mollusks, and crustaceans. This habitat is termed "essential fish habitat" and is broadly defined to include "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The Act establishes measures to protect EFH. Federal agencies must consult with NMFS on all actions or proposed actions authorized, funded, or undertaken by the agency that may adversely affect EFH. The NMFS must coordinate with other federal agencies to conserve and enhance EFH, and in turn NMFS must provide recommendations to federal and state agencies on such activities to conserve EFH. These recommendations may include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on EFH resulting from actions or proposed actions authorized, funded, or undertaken by that agency. This EFH assessment has been prepared for use in determining the potential impact to the existing fish resources from the proposed revetment construction for the project area.

All of Nantasket Beach has been designated to be within EFH waters. The managed EFH species that may occur in the project area include: pollock (juveniles), red hake (eggs, larvae, and adults), white hake (all life stages), winter flounder (all life stages), windowpane flounder (all life stages), American plaice (adults), Atlantic halibut (eggs and adults), bluefish (juveniles and adults), long finned squid (juveniles and adults), short finned squid (juveniles and adults), Atlantic butterfish (eggs), Atlantic mackerel (eggs, juveniles, and adults), summer flounder (adults), scup (juveniles and adults).

6.4 Endangered and Threatened Species

It has been determined that threatened and endangered species are unlikely to occur within the project area. Piping plover (*Charadrius melodus*), a State and Federally listed threatened bird species, are generally a concern in coastal areas of Massachusetts. However the beach areas along the DCR reservation are generally inundated with tidal surge during high tides making the area inappropriate for nesting shorebirds. Additionally, the area serves as a public beach, making it inappropriate for shorebird feeding during periods of exposure.

Nantasket Beach does not provide habitat for any threatened and/or endangered species that are exclusively marine in New England waters, such as marine mammals and sea turtles, as the area is intertidal.

Coordination with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service can be found in Appendix A.

6.5 Historic and Archaeological Resources

Hull, Massachusetts was originally called Nantascot by the Wampanoag Indians. The town dates from 1644 when the town was named for a seaport town in Yorkshire, England. It is now known as Nantasket, but its official name is Hull (Bergan 1972:18).

Originally a fishing and agricultural town, the Town of Hull entered its golden age in the late 19th Century and the era of the big hotel. From the early 1880's to the First World War, several palatial inns and resorts transformed the town into a popular summer resort on the Eastern seaboard. Names such as the Rockland House, Atlantic House, Nantasket House, Ville Napoli, Pacific House and Pemberton Hotel dominated the scene. During World War I, however, the growth of the automobile had a destructive effect on the hotels, steamboats, and trolleys that serviced the area. Most of the inns and hotels from this era are now gone (ibid., 18,24,65).

At about the same time as the rise of the hotel industry, the rise of cottages, primarily as vacation homes, became dominant in the town (Sweetser 1888:76-77). These homes ranging from bungalow-sized to mansion are the late 19th-early 20th Century historic homes that occur near the project. Many examples of the Queen Anne, Victorian Gothic, neo-Tudor and Bungalow styles were built on hillsides in town. Typically, ocean front lots contained larger homes than those further inland. Many buildings of this period (1870-1915) remain in altered condition. Areas which have seen the least alteration of domestic architecture from this period include Hull Village, Allerton Hill and to a degree Atlantic Hill (Massachusetts Historical Commission (MHC) Survey Report 1979). At about the same time in 1905, Paragon Park was constructed in the southern portion of town. All vestiges of this popular amusement park are also gone with the exception of the carousel that is preserved on Nantasket Avenue.

The DCR, formerly known as the Metropolitan Parks Commission, took over control of some recreational areas in town, including Nantasket Beach in 1899 (Bergan 1972:72), and has controlled the popular beach resort since that time. DCR bathing pavilions located on Nantasket Avenue were built in a variation of the Spanish Mission style circa 1905-1915.

During the Modern period of 1915-1940, bungalow style homes were dominant while the widespread demolition and alteration of existing commercial structures after World War II became apparent as other resort areas rose in popularity. The rise of strip development along Nantasket Avenue had also become prevalent during this period (MHC 1979).

The Town of Hull published a Community Development Plan (CDP) (http://www.town.hull.ma.us/Public_Documents/HullMA_BComm/planningboard/econdevelplan.pdf) in 2004 for the Nantasket Beach area. The intent of the document was to outline potential development opportunities for the Nantasket Beach area. The CDP encouraged mixed-use development consisting of offices, cultural destinations, and retail outlets. The CDP was drafted with the intent of stimulating economic development and reconnecting the area to its history.

Properties listed on the National Register of Historic Places within Hull include the Point Allerton Life Saving Station, Telegraph Hill Historic and Archaeological District and the Hull Village Historic District. Properties eligible for inclusion on the National Register include the Metropolitan Park System of Greater Boston that includes the Nantasket Beach Reservation.

6.6 Socioeconomics

The town of Hull has a median annual wage of $70,053.00. The primary employers include the government, trade, and service industries (Commonwealth of Massachusetts, 2012). Population density, which is an indicator of the extent of development for Hull, was approximately 10,293 in 2010 (US Census, 2010).

A wide range of public services are offered by the town of Hull including full service fire departments, law enforcement, public schools, water and sewer services, recreation, and libraries. The form of government for the Town of Hull is by a Board of Selectmen, a Town Manager, and open town meetings.

The backshore of Nantasket Beach is occupied by commercial and residential properties. The beach itself is used by residents and visitors for various recreational activities.

6.7 Air Quality & Noise

Ambient air quality is protected by Federal and state regulations. The U.S. EPA has developed National Ambient Air Quality Standards (NAAQS) for certain air pollutants and air quality standards for each state cannot be less stringent than the NAAQS. The NAAQS determined by the EPA set the concentration limits that determine the attainment status for each criteria pollutant. Massachusetts has met attainment standards for ozone (with the exception of Dukes County) and for carbon monoxide (CO).

The Nantasket Beach Reservation is bounded to the east by the Atlantic Ocean and to the North, South, and West by residential communities. The noise environment is typical of a seaside, residential community with the majority of noise coming from motor vehicles and domestic activities.

6.8 Coastal Processes and Floodplains

Coastal Processes

The proposed project area of Nantasket Beach is subject to various coastal processes such as exposure to ocean waves, sediment transport, erosion, sea level rise, and flooding. The Woods Hole Group and Louis Berger Group (2010) prepared a report documenting the various coastal processes that occur within the project area. Additionally, a Coastal Engineering report was prepared for this project which details the coastal processes as they relate to the alternatives selected for this project. The Coastal Engineering Report is included as Appendix B of the Main Report.

Floodplain

The proposed project area occurs along a coastal barrier island.

7.0 ENVIRONMENTAL EFFECTS

7.1 Physical and Chemical Effects

The construction of the proposed revetment is anticipated to alter the physical environment of Nantasket Beach within the direct footprint of the structure. The revetment in being built adjacent to an existing seawall and will displace approximately 129,800 square feet of cobble-sand beach (Figure 3). The revetment is not likely to affect the physical environment outside of the direct footprint. Impacts to the physical environment from construction equipment accessing the beach areas and excavating the footprint of the revetment during low tide are anticipated to be minimal and limited to sand displacement. During periods of high tide, the suspension of sandy sediments in the water column may occur while placing or repositioning stones. However, any elevated levels should be short–term and localized as sandy material settles rapidly.

The construction of a revetment in the project area is not anticipated to alter the chemical environment of Nantasket Beach. The revetment will be composed of clean stone from a local quarry.

7.2 Biological Effects

7.2.1 Shellfish

Areas containing significant shellfish populations are not anticipated to present in the upper intertidal zone, i.e., the proposed project footprint. The shellfish resources documented adjacent to the project area (Battelle, 2007) should not be significantly affected by the construction of the proposed project. As discussed in section 7.1, the suspension of sandy sediments in the water column may occur in the construction area. However, any elevated levels should be short–term and localized.

7.2.2 Benthos

The most obvious and direct effect of revetment construction is the burial of benthic communities in the direct footprint of the project. Direct burial of motile and nonmotile forms would be lethal. Most motile species should be able to evacuate the project area at the onset of

the construction period. The project will displace approximately 129,800 square feet of cobble-sand beach and its associated benthic fauna. Benthic communities located adjacent to the project area may experience minor impacts associated with suspended sediments in the water column during construction as discussed in Section 7.1. However, these impacts would be localized to the project area and short-term, limited to the construction period.

The benthic communities located offshore of the project area are not anticipated to be affected by this project.

7.2.3 Fishery Resources

Approximately 129,800 square feet of cobble-sand beach (located in the upper intertidal zone) will be displaced by the revetment. Fishery resources would lose the ability to access the sandy bottom in the footprint of the revetment. Since the location of the displaced habitat is in an intertidal area of low benthic productivity, significant impacts to fisheries resources are not expected. Some non-significant impacts from elevated turbidity levels may be seen during construction as equipment access the site or manipulates stone during placement activities. However, since the material in the project area is sand any turbidity impacts will be short-term and localized, and not unlike conditions to be found in storm conditions. No direct or indirect significant impacts to fishery resources adjacent to the proposed project area are anticipated.

7.3 Essential Fish Habitat

In general, the placement of a revetment in the project area will alter approximately 129,800 square feet of beach from cobble-sand habitat to rock revetment habitat. Additionally, temporary increases in suspended sediments may occur in the vicinity of the construction area as a result of construction equipment accessing intertidal areas during low tides and manipulating or placing stone during low tide and high tide.

The alteration of habitat will be permanent while the increases in suspended sediments will be short-term and localized. Since the displaced habitat is in an intertidal area of low benthic productivity, the permanent loss of habitat is not anticipated to significantly alter the function of EFH for any of the managed species in the vicinity of the project area. Likewise, short-term increases in suspended sediments should not significantly alter the function of EFH for any of the managed species in the project area.

The following paragraphs represent the required Essential Fish Habitat assessment, which lists the managed species in the project area and describes specific impacts to their EFH:

Atlantic cod *(Gadus morhua)*

Essential Fish Habitat for eggs, larvae, juveniles, and adult life stages of Atlantic cod is designated within the project area. All life stages of cod are generally found in deeper waters than the intertidal zone associated with Nantasket Beach. Therefore, no impacts to Atlantic cod EFH are anticipated.

Haddock *(Melanogrammus aeglefinus)*

Essential Fish Habitat for eggs and larval haddock are designated in this area. However, the life stages of haddock are generally found in deeper waters than the intertidal zone of Nantasket Beach. Therefore, no impacts to haddock EFH are anticipated.

Pollock *(Pollachius virens)*

Essential Fish Habitat is designated within the project area for the life stages of Pollock. Eggs and larvae of pollock are generally found offshore. Juvenile pollock can be found from depths of 0 – 250 meters in high salinity waters (29- 32 ppt) with temperatures below 18ºC. Adult pollock are found from depths of 15 – 365 meters in high salinity waters (31-34 ppt) with temperatures below 14ºC. Spawning occurs in similar conditions to that of the adults, however, water temperature for spawning is generally below 8ºC. This project is expected to have no effects to EFH for pollock.

Whiting *(Merluccius bilinearis)*

Essential Fish Habitat is designated for all life stages of whiting in the project area; however, the life stages of whiting are generally found in deeper waters than the intertidal zone of Nantasket Beach. Therefore, no impacts to whiting EFH are expected.

Red hake *(Urophycis chuss)*

Essential Fish Habitat is designated in the project area for all life stages of red hake. Eggs and larvae of red hake are generally found offshore. Juvenile red hake are most often observed in low temperature (<16º), high salinity waters (31-33 ppt), while adult red hake are generally observed in waters between 10 and 130 meters deep. This project is expected to have no effects on EFH for red hake as it is in the intertidal zone of the project area.

White hake *(Urophycis tenuis)*

Essential Fish Habitat is designated for all life stages of white hake in the project area. Eggs and larvae are generally found in pelagic waters offshore. Juveniles and adults can be found in waters as shallow as 5 meters and as deep as 225 meters. No impact to white hake EFH is expected from this project.

Winter flounder *(Pleuronectes americanus)*

Essential Fish Habitat is designated in the project area for all life stages of the winter flounder. The eggs of winter flounder, which are demersal, are typically found at depths of less than 5 meters in bottom waters in a broad range of salinities (10-30 ppt). Spawning, and therefore the eggs, occurs from February to June. EFH for larvae, juveniles, and adults includes bottom habitats of mud and fine-grained sandy substrate in waters ranging from 0.1 to 100 meters in depth. Spawning adults are typically associated with similar substrates in less than 6 meters of water.

Winter flounder EFH is located within the project area. The building of a revetment will alter the intertidal sandy beach habitat to a rock habitat. Some sediments in shallow intertidal areas may become suspended if construction machinery needs to access the sea-side of the revetment during high tide periods. However, every effort will be made to access the sea-side of the revetment during periods of low tide. Therefore, this project is anticipated to have only minimal impacts upon winter flounder EFH.

Yellowtail flounder *(Pleuronectes ferruginea)*

Essential Fish Habitat for all life stages of yellowtail flounder is located in the project area; however, all life stages of yellowtail flounder are generally found in deeper waters than those found in the project area. No impacts to yellowtail flounder EFH are anticipated.

Windowpane flounder *(Scopthalmus aquosus)*

Essential Fish Habitat is designated within the project area for all life stages of the windowpane flounder. Eggs are buoyant and typically found in the water column in water depths of 1 meter to 70 meters. Larvae are found in pelagic waters. Juveniles and adults prefer bottom habitats of mud or fine-grained sand and can be found in salinities ranging from 5.5 ppt to 36 ppt. Seasonal occurrences in the project area are generally from February to November, with peaks in occurring May and October.

Although windowpane flounder EFH is located within the project area, the building of a revetment will not destroy or damage any potential EFH. Some sediments in shallow intertidal areas may become suspended if construction machinery needs to access the sea-side of the revetment during high tide periods. However, every effort will be made to access the sea-side of the revetment during periods of low tide. Therefore, this project is anticipated to have no significant impact upon winter flounder EFH.

American plaice *(Hippoglossoides platessoides)*

Essential Fish Habitat is designated within the project area for American plaice eggs, larvae, juveniles, and adults. All life stages of American plaice are generally found in waters with depths of over 30 meters. This project is not expected to affect EFH for plaice.

Ocean pout *(Macrozoarces americanus)*

Essential Fish Habitat is designated in the project area for all life stages of ocean pout. This species is a nearshore species that inhabits hard bottom substrates with salinities greater than 30 ppt. This project is not anticipated to have impacts to ocean pout EFH as it is located in the sandy intertidal zone.

Atlantic halibut *(Hippoglossus hippoglossus)*

Essential Fish Habitat for all life stages of Atlantic halibut is designated in the project area; however, all life stages of Atlantic halibut are generally found in deeper waters than in the nearshore zone of Nantasket Beach. No impacts to Atlantic halibut EFH are expected.

Atlantic sea scallop *(Placopecten magellanicus)*

Essential Fish Habitat for all life stages of Atlantic sea scallop is designated in the project area. Atlantic sea scallop ranges in North America from Labrador to North Carolina. Eggs of the Atlantic sea scallop are found in both nearshore and offshore waters, but are usually taken commercially from offshore waters. Eggs remain on the sea floor until they develop into free-swimming larvae. Eggs are reported from areas where water temperatures are generally below 63ºF (17º C). Larvae of the sea scallops are sessile typically found attached to bottom habitats consisting of gravelly sand, shell fragments and pebbles; and on various other sessile marine organisms such as red algae, hydroids, amphipods tubes, and bryozoans. Juvenile Atlantic sea

scallops are found in bottom habitats consisting of cobble, shells and silt substrates in water depths between 59 and 361 feet. Adult Atlantic sea scallops are found in bottom habitats consisting of cobble, shells and coarse to gravelly sand substrates in water depths between 59 and 361 feet. There are have been no identified populations of sea scallops occurring in the project area and the project is not anticipated to affect scallop EFH.

Atlantic sea herring *(Clupea harengus)*

Essential Fish Habitat for larval, juveniles and adult Atlantic sea herring is designated in the project area. Larvae, juvenile and adults typically prefer depths of 15 to 130 meters. These are depths that are generally deeper than those found in the project area. Therefore, no impact is expected to occur to Atlantic sea herring EFH.

Bluefish *(Pomatomus saltatrix)*

Essential Fish Habitat is designated within the project area for bluefish juveniles and adults. Although juveniles and adults are found in the surface waters of mid-Atlantic estuaries from May through October, EFH for this species is mostly pelagic waters over the Continental Shelf. Bluefish adults are highly migratory and are generally found in salinities greater than 25 ppt. The proposed project will not have significant impacts to bluefish EFH.

Long finned squid (*Loligo pealei)*

Essential Fish Habitat is designated in the project area for juvenile and adult long finned squid. This species is common inshore in warm weather months. No impacts to EFH for this species are anticipated to occur.

Short finned squid *(Illex illecebrosus)*

Essential Fish Habitat is designated in the project area for juvenile and adult short finned squid. These species are common inshore in warm weather months. No impacts to EFH for this species are anticipated to occur as the impacts will occur intertidally.

Atlantic butterfish *(Peprilus triacanthus)*

Essential Fish Habitat is designated in the project area for all life stages of Atlantic butterfish; however, all life stages of this species are generally found in deeper waters than the intertidal zone of Nantasket Beach. Therefore, no impacts to Atlantic butterfish EFH are anticipated.

Atlantic mackerel *(Scomber scombrus)*

Essential Fish Habitat is designated in the project area for all life stages of Atlantic mackerel. Since all life stages of Atlantic mackerel are generally found offshore, no impacts to Atlantic mackerel EFH are expected.

Summer flounder *(Paralicthys dentatus)*

Essential Fish Habitat is designated in the project area for adult summer flounder. Adults migrate into shallow coastal and estuarine systems during the warm summer months and then move offshore during colder months. No impacts to summer flounder EFH are anticipated from construction of the project.

Scup *(Stenotomus chrysops)*

Essential Fish Habitat is designated in the project area for juvenile and adult scup. Scup juveniles and adults have the potential to occur in estuarine systems during the spring and summer months. All life stages of scup prefer salinities greater than 15 ppt. No impacts to scup EFH are anticipated from construction of the project.

Black sea bass *(Centropristus striata)*

Essential Fish Habitat is designated for black sea bass juveniles and adults in the project area. EFH for the juveniles and adults of this species is predominantly within estuarine systems with oceanic salinities. Juveniles and adults are found in estuaries during spring and summer months in water temperatures above 6°C and salinities greater than 18 ppt. Black sea bass prefer rough, shelly substrates and can be found in natural and man-made structured habitats. No impacts to black sea bass EFH is anticipated from the project.

Surf clam *(Spisula solidissima)*

Essential Fish Habitat is designated for juvenile and adult surf clams (*Spisula solidissima*) in the project area. A commercially harvestable surf clam population exists offshore, especially between the -12 to -20 foot contours and surf clams can be found at the extreme low tide mark. The surf clam population along Nantasket Beach occurs in a habitat that is highly dynamic and subject to significant impact from seasonal storms.

Although surf calm EFH is located within the project area, the building of a revetment will not destroy or damage any potential surf clam habitat. Some suspended sediments in shallow intertidal areas may be created if construction machinery needs to access the sea-side of the revetment during high tide periods. However, these effects should be short-term and localized. Therefore, this project is anticipated to have no significant impact upon surf clam EFH.

Bluefin tuna *(Thunnus thynnus)*

Essential Fish Habitat for juvenile and adult bluefin tuna are designated in the project area; however, these life stages are generally found in deeper waters than the intertidal zone of Nantasket Beach. Therefore, no impacts to tuna EFH are anticipated.

7.4 THREATENED AND ENDANGERED SPECEIS

No threatened or endangered species are expected to be impacted from this project as the project area does not provide habitat for these species. Therefore, the Corps has made the determination that this project is not likely to affect any threatened or endangered species.

7.5 HISTORIC AND ARCHAEOLOGICAL RESOURCES

An examination of the site files at the MHC indicated that no prehistoric archaeological sites are located within the proposed project area. Two sites, 19-PL-265 and 266, were located north of the project area in the Allerton section of town. Both sites have been destroyed by urban development in the area. No historic archaeological (HA) sites are located within the project area. HA-1 is located well south of the study area in the Straits Pond area and consists of a protohistoric cemetery whose exact location is unknown. This site is also referenced as the

Atlantic Hill Site or 19-PL-268. HA-2 is located to the northwest of the study location within the Telegraph Hill section and the Telegraph Hill Archaeological District.

This project was previously coordinated with the Massachusetts State Historic Preservation Officer (MA SHPO), the Massachusetts Board of Underwater Archaeological Resources (MA BUAR), and the Wampanoag Tribe of Gay Head (Aquinnah) by letter dated March 25, 1996. At that time, the preferred alternative consisted of the placement of sand fill with periodic beach nourishment along the Nantasket Beach Reservation. We found that this alternative would have no effect upon significant historic properties due to the extensive erosion and development at this location. Repairs or rehabilitation of the existing seawall as well as construction of a revetment at this location, if selected for implementation, would also have no impact upon cultural resources as any sites that may have been present were likely previously disturbed or destroyed during construction of the original wall. The MA SHPO concurred with these determinations via letter dated April 24, 1996.

Since that time, changes to the without project condition have caused the study to be reformulated. It has now been determined that construction of a stone revetment protecting Zone 2 of the DCR Nantasket Beach Reservation is economically feasible and the preferred plan. However, as stated above, due to the disturbed nature of the present seawall and extensive erosion at this location, impacts to cultural resources are not expected. Construction of a stone revetment at this location will not impact upon the National Register eligibility of the DCR Nantasket Beach Reservation as a component of the Metropolitan Park System of Greater Boston. Coordination with the MA SHPO was initiated by letter dated February 24, 2010 and we expect their concurrence with this determination.

7.6 SOCIOECONOMIC RESOURCES

No significant impacts to socioeconomic resources are anticipated.

7.6.1 Environmental Justice

Executive Order 12898, on Environmental Justice requires the environmental analysis of proposed Federal actions address any disproportionately high and adverse health or environmental effects on minority and low-income communities. Federal agencies' responsibilities under this order also apply equally to Native American programs. Additionally, each Federal agency must ensure that public documents, notices, and hearings are readily accessible to the public.

This action would not have disproportionately high and adverse effects on any low-, or minority income communities as there are no in the project area. Therefore, this project complies with EO 12898.

7.6.2 Protection of Children from Environmental Health Risks and Safety Risks

Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks requires each Federal agency to identify and assess environmental health risks and safety risks that may disproportionately affect children; and ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. Environmental health risks and safety risks includes risks to health or to safety that are attributable to products or substances that the child is likely

to come in contact with or ingest (such as the air we breathe, the food we eat, the water we drink or use for recreation, the soil we live on, and the products we use or are exposed to). Revetment construction includes the strict use of clean material that is free of contaminants that could potentially prove to be a health risk to the general population and to children. Therefore, this project complies with EO 1305.

7.7 AIR QUALITY AND NOISE

7.7.1 AIR QUALITY

The proposed project is subject to Clean Air Act requirements. An air quality conformity analysis (Appendix C) was completed to demonstrate compliance. The conformity analysis details projected emissions that would result from the construction of the proposed project. These data are then compared to Federal and State air quality standards to determine impacts to air quality. It was determined that the direct and indirect ozone emissions from this project were considerably less than the conformity threshold value for ozone creation (which is 100 tons of mono-nitrogen oxides (NOx) per year).

The project would have no long-term impacts on air quality. During construction equipment operating on the site would emit pollutants including nitrogen oxides that can lead to the formation of ozone. In order to minimize air quality effects during construction, construction activities would comply with applicable provisions of the Massachusetts Air Quality Control Regulations pertaining to dust, odors, construction, noise, and motor vehicle emissions. This project therefore conforms to the Federal requirements for activities under the Clean Air Act within the Massachusetts State Implementation Plan.

7.7.2 Noise

Construction activities would occur along the coast and high intertidal zone along Nantasket Beach. The beach is located about 10' below the existing seawall. Stone will be placed by equipment operating from upland (above the beach) and by equipment on the beach. Construction would be intermittent and noise levels would vary depending on the equipment in use, the number of trucks transporting stone, and time of day. Nighttime noise levels would be unaffected since operation of construction equipment would be confined to daylight hours. Neighbors would hear construction equipment, particularly the hauling of material by trucks, but this noise would be similar in nature to noise generated by local construction projects. Overall, impacts would be temporary and not expected to be significant.

7.8 COASTAL PROCESSES AND FLOODPLAINS

The Coastal Processes report for this project (WHG & LBG, 2010) concludes that the proposed alternative is effective for shoreline protection in the project area. The Coastal Engineering Analysis (Appendix B of the Main Report) concludes that the project as proposed, is designed with an amply deep, buried toe, and, due to its stone construction, the revetment will, with proper maintenance, be effective over its design life regardless of any anticipated sea level rise or climate variation.

Executive Order 11988, Floodplain Management (1977) emphasizes the environmental aspects of flood plain management and requires Federal agencies to recognize the significant values of flood plains and to consider the public benefits that would be realized from restoring and

preserving flood plains. The conceptual framework of flood plain management is incorporated in agency procedures. EO 11988 identifies restoration and preservation of the natural and beneficial values of the base flood plain, wetlands, marshes, and related natural habitat as one of its objectives and for agencies to implement measures that will enhance fish and wildlife values.

The proposed project area occurs along a coastal barrier island. There will not be loss of floodplain area associated with the proposed project; therefore, the project complies with the substantial requirements outlined in EO 11988.

8.0 CUMULATIVE EFFECTS

Cumulative impact is defined by NEPA as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." Past and current activities in the Nantasket Beach project area include recreational use of the beach for swimming, walking, fishing, and other coastal recreational activities. Reasonably foreseeable future actions include the continuation of current recreational uses.

Past activities within the project area include the construction of storm damage reduction structures in Zones 1 and 3 of the project area (Figure 2). These activities coupled with the proposed project are not anticipated to change to public access to the project area and therefore should not interfere with future use of the project area. Past construction actions in the project area have not significantly altered environmental resources in the project's ecosystem and , as discussed in this EA, the proposed project is anticipated to have only minimal impacts on the resources.

To the extent that other actions are expected to be related to the project as proposed, these actions will provide little measurable cumulative impact.

9.0 COORDINATION

On March 25, 1996, a public notice for Federal, State and local agencies and the public was distributed soliciting comments on the proposed project (see Appendix B). A public hearing was requested by the Town of Hull and was held at the Hull High School on June 27, 1996 (see also Appendix F, Feasibility Report).

In response to the public notice, we received 7 letters and comments from Federal, State, and local agencies. The primary concern was scope of the EA and an evaluation of alternatives, primarily the evaluation of nonstructural solutions. The draft report was revised and a second public notice was issued in March 2003.

Upon change in project scope, a revised public notice detailing the change in project description and noticing the availability of a revised Feasibility Report and Environmental Assessment was issued on May 13, 2014. Four (4) sets of comments were received in response to the public notice. The comments and response to comments can be found in Appendix I of the 2014 Feasibility Report.

New England District staff met with our sponsor, Massachusetts Department of Conservation and Recreation (MA DCR), and the Massachusetts Department of Coastal Zone Management (MA CZM) on 21 July 2014 at the MA DCR's office in Boston to discuss the Nantasket Beach project. MA CZM had requested the meeting to discuss their coastal zone management consistency concerns prior to submitting their official response. The concerns focused on (1) the design of the recommended revetment, (2) the loss available dry beach and the impacts to recreation and (3) why a beach nourishment project was not considered. We explained the rationale behind the design and the fact that we had minimized the size to the extent possible while providing the necessary level of protection. We explained that the loss of dry beach was unavoidable. We discussed the funding limits of the Section 103 program and the fact that a beach nourishment project of the size and scale appropriate for Nantasket was not possible with a $5 million Federal limit. We explained that the focus of the recommended plan was to protect the wall and acknowledged that the project would not prevent flooding damages from wave or surge overtopping the wall. We stressed that the construction of the revetment would not preclude the future construction of the beach and said we would work with them toward that goal either through our Regulatory program or as part of a possible future project. Following the meeting, MA CZM submitted their comments. New England District staff also met with MA DCR and Town of Hull officials on 27 August 2014 in Hull to discuss the project. The Town's concerns were similar to those of MA CZM concerning the loss of dry beach and the desire for the construction of a beach to provide shore protection benefits. The Corps explained the rationale for the revetment project and the fact that loss of dry beach could not be avoided if a project was constructed to protect the existing wall. The Corps agreed that a beach nourishment project would benefit the Nantasket Beach area and expressed a willingness to work with all parties on any future initiatives.

The proposed project has been coordinated with the following Federal, State, and Local agencies:

Federal Agencies

- U.S. Environmental Protection Agency, Region 1,
- U.S. Fish and Wildlife Service, New England Field Office.
- National Marine Fisheries Service, Habitat Conservation Division & Protected Resources Division

State and Local Governments

- Massachusetts Office of Coastal Zone Management.
- Massachusetts Department of Environmental Protection
- Massachusetts Department of Conservation and Recreation
- Massachusetts Natural Heritage Program
- Massachusetts Department of Marine Fisheries
- Massachusetts Historical Commission.
- Town of Hull, Board of Selectmen.
- Town of Hull, Conservation Commission

10.0 COMPLIANCE WITH FEDERAL ENVIRONMENTAL STATUTES, EXECUTIVE ORDERS AND EXECUTIVE MEMORANDUM

10.1 Federal Statutes

1. Archaeological Resources Protection Act of 1979, as amended, 16 USC 470 et seq.

Compliance: Not applicable; Issuance of a permit from the Federal land manager to excavate or remove archaeological resources located on public or Indian lands signifies compliance.

2. Preservation of Historic and Archeological Data Act of 1974, as amended, 16 U.S.C. 469 et seq.

Compliance: Not applicable; the project does not require mitigation of historic or archaeological resources.

3. American Indian Religious Freedom Act of 1978, 42 U.S.C. 1996.

Compliance: Not applicable. The site does not include areas considered by Native Americans to be sacred sites, prevent possession of sacred objects, or prevent the freedom to worship through ceremonials and traditional rites.

4. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

Compliance: The project has been coordinated with the State Historic Preservation Office as to determine whether historic or archaeological resources listed or eligible for listing on the National Register of Historic Places would be affected by the proposed project.

5. Native American Graves Protection and Repatriation Act (NAGPRA), 25 U.S.C. 3000-3013, 18 U.S.C. 1170

Compliance: Regulations implementing NAGPRA will be followed if discovery of human remains and/or funerary items occur during implementation of this project.

6. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

Compliance: Public notice of the availability of this report to the Environmental Protection Agency is required for compliance pursuant to Sections 176c and 309 of the Clean Air Act. Sections 6.7, 7.7, and Appendix C of the EA address impacts to air quality during and following construction.

7. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972) 33 U.S.C. 1251 et seq.

Compliance: A Clean Water Act Section 404 (b) (1) Evaluation and Compliance Review has been incorporated into the Environmental Assessment. An application will be filed for State Water Quality Certification pursuant to Section 401 of the Clean Water Act.

8. Coastal Zone Management Act of 1972, as amended, 16 U.S.C. 1451 et seq.

Compliance: NAE has reviewed the Massachusetts Office of Coastal Zone Management program policies for Coastal Hazards, Energy, Growth Management, Habitat, Ocean Resources, Ports and Harbors, Protected Areas, Public Access, and Water Quality and made the preliminary determination that the proposed project is fully consistent with each policy. A Coastal Zone Management consistency determination shall be provided to the Commonwealth for review and concurrence that the proposed project is consistent with the maximum extent practical with the approved state CZM program during the design phase.

9. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

Compliance: The project is being coordinated with the U.S. Fish and Wildlife Service and National Marine Fisheries Service. The Corps has made the preliminary determination that the proposed project is not likely to affect any threatened or endangered species or affect critical habitat.

10. Estuarine Areas Act, 16 U.S.C. 1221 et seq.

Compliance: Not Applicable; coastal storm damage reduction projects are authorized by the Rivers and Harbors Act, and are not submitted to Congress.

11. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq.

Compliance: 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.

12. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.

Compliance: This project is being coordinated with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Massachusetts Division of Marine Fisheries, and the Massachusetts Office of Coastal Zone Management. This coordination signifies compliance with the Fish and Wildlife Coordination Act. The District Engineer has given full consideration to fish and wildlife conservation in evaluating this project.

13. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq.

Compliance: 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.

14. Marine Protection, Research, and Sanctuaries Act of 1971, as amended, 33 U.S.C. 1401 et seq.

Compliance: Not Applicable.

15. National Environmental Policy Act of 1969, as amended, 42 U.S.C 4321 et seq.

Compliance: Preparation of the Environmental Assessment signifies partial compliance with NEPA. Full compliance shall be noted at the time the Finding of No Significant Impact is issued.

16. Rivers and Harbors Act of 1899, as amended, 33 U.S.C. 401 et seq.

Compliance: No requirements for projects or programs authorized by Congress. The proposed coastal damage reduction has been Congressionally approved by the Continuing Authority program of the Rivers and Harbors Act.

17. Watershed Protection and Flood Prevention Act as amended, 16 U.S.C 1001 et seq.

Compliance: Floodplain impacts have been considered in project planning and are discussed in the Environmental Assessment.

18. Wild and Scenic Rivers Act, as amended, 16 U.S.C 1271 et seq.

Compliance: Not Applicable. The project is not located in a listed water-body or proposed for inclusion as a Wild and Scenic River by the Department of the Interior.

19. Magnuson-Stevens Act, as amended, 16 U.S.C. 1801 et seq.

Compliance: Coordination with the National Marine Fisheries Service and inclusion of a discussion of impacts to Essential Fish Habitat in the Environmental Assessment signifies compliance.

10.2 EXECUTIVE ORDERS

1. Executive Order 11593, Protection and Enhancement of the Cultural Environment, 13 May 1971.

Compliance: Coordination with the State Historic Preservation Officer signifies compliance.

2. Executive Order 11988, Floodplain Management, 24 May 1977 amended by Executive Order 12148, 20 July 1979.

Compliance: Public notice of the availability of this report or public review fulfills the requirements of Executive Order 11988, Section 2(a)(2).

3. Executive Order 11990, Protection of Wetlands, 24 May 1977.

Compliance: Public notice of the availability if this report for public review fulfills the requirements of Executive Order 11990, Section 2 (b).

4. Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, 4 January 1979.

Compliance: Not applicable to projects located in the United States geographical boundaries.

5. Executive Order 12898, Environmental Justice, 11 February 1994.

Compliance: The project will not have a disproportionate impact on minority or low-income population, or any other population in the United States. Therefore, the proposed project is compliant with this Order.

6. Executive Order 13007, Accommodation of Sacred Sites, 24 May 1996

Compliance: Not applicable. The project is not on Federal lands. The New England District has no obligation for accommodating access to and ceremonial use of Indian sacred sites by Indian religious practitioners, and avoids adversely affecting the physical integrity of such sacred sites.

7. Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks. 21 April, 1997.

Compliance: The project would not create a disproportionate environmental health or safety risk for children. Therefore, the proposed project is compliant with this Order.

8. Executive Order 13061, and Amendments – Federal Support of Community Efforts Along American Heritage Rivers

Compliance: Not applicable. The project is not connected to an American Heritage River.

9. Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, 6 November 2000.

Compliance: Consultation with Indian Tribal Governments, where applicable, and consistent with executive memoranda, Department of Defense Indian policy, and USACE Tribal Policy Principles signifies compliance.

10.3 EXECUTIVE MEMORANDUM

1. Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980.

Compliance: Not applicable. There are no prime agricultural lands in the project area.

2. White House Memorandum, Government-to-Government Relations with Indian Tribes, 29 April 1994.

Compliance: Consultation with federally-recognized Indian Tribes, where appropriate, signifies compliance.

11.0 REFERENCES

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Appendix D

Suitability Assessment of Piscataqua River Sand Source for Nourishment of Nantasket Beach (2018)

Louis Berger, 2018 (*)

(*) Main report. The complete report with all attachments was submitted to MEPA on February 27, 2018, and is included on the CD as a separate file

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Suitability Assessment of Piscataqua River Sand Source for Nourishment of Nantasket Beach

Submitted to:

dcr | *department of* Conservation and Recreation

Submitted by:

Louis Berger

February 2018

Cover Photo: Piscataqua River site to be dredged, looking east toward the Maine shoreline (November 2017)

NANTASKET BEACH SEAWALL REPAIR AND RESERVATION MASTER PLAN SERVICES

SUITABILITY ASSESSMENT OF PISCATAQUA RIVER SAND SOURCE FOR NOURISHMENT OF NANTASKET BEACH

REPORT

Prepared for:

Massachusetts Department of Conservation and Recreation
251 Causeway Street
Boston, MA 02114

Prepared by:

Louis Berger
117 Kendrick Street, Suite 400
Needham, MA 02494

With input by:
Woods Hole Group
East Falmouth, MA 02536

Submitted by Louis Berger to the Massachusetts Department of Conservation and Recreation for Contract DSP 080 P99-1979-D2A

February 2018

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Acronyms and Abbreviations

BUAR	Massachusetts Board of Underwater Archaeological Resources
CCME	Canadian Council of Ministers of the Environment
cm	centimeter
cy	cubic yards
CZM	Coastal Zone Management
DCR	Massachusetts Department of Conservation and Recreation
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene (pesticide breakdown product)
DMF	Massachusetts Division of Marine Fisheries
EENF	Expanded Environmental Notification Form
EIR	Environmental Impact Report
ENF	Environmental Notification Form
ERL	Effects Range Low (NOAA sediment quality guideline value)
ERM	Effect Range Median (NOAA sediment quality guideline value)
ft	foot or feet
GZA	GZA Geoenvironmental, Inc.
HMW	high molecular weight
ID	Inner diameter
ISQG	Interim sediment quality guideline
LMW	low molecular weight
m	meter
MA	Massachusetts
MAEPH	Massachusetts Extractable Petroleum Hydrocarbon
MassDEP	Massachusetts Department of Environmental Protection
MDL	Method detection limit
ME	Maine
MEPA	Massachusetts Environmental Policy Act
mg/kg	milligram per kilogram (part per million)
MHC	Massachusetts Historical Commission

MHW	Mean high water
MLLW	Mean lower low water
MLW	Mean low water
mm	millimeter
MSL	Mean sea level
NAD83	North Atlantic Datum of 1983
NEPA	National Environmental Policy Act
ng/kg	nanogram per kilogram
NHESP	Massachusetts Natural Heritage and Endangered Species Program
NHPDA	New Hampshire Pease Development Authority
nm	nautical mile(s)
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
OSI	Ocean Survey, Inc.
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PEL	Probable effects level
PFC	Perfluoro compound
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfanate
pg/g	picogram per gram (part per trillion)
PNEC	Probable No Effect Concentration
RCS	Reportable concentrations
RIM	Regional Implementation Manual (USEPA and USACE, 2004)
RL	Reporting limit
RSL	Regional Screening Levels
SOP	Standard Operating Procedure
TEF	Toxic Equivalence Factor
TEQ	Toxic equivalence
TMDL	Total Maximum Daily Load
TOC	Table of Contents

TPH	Total petroleum hydrocarbon
ug/kg	microgram per kilogram (part per billion)
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	Volatile organic compound
WGS84	World Geodetic System of 1984
WPA	Wetlands Protection Act
WQC	Water quality certification

Executive Summary

This report assesses the suitability of sediment to be dredged from an area in the Piscataqua River (along the border of Maine and New Hampshire) as a potential nourishment source for Nantasket Beach, Hull, Massachusetts. The assessment compared the physical characteristics (grain size and color) and chemical characteristics of sediments at the two locations, and also considered the feasibility of implementation (dredging, transportation, and placement) and permitting requirements for a beach nourishment project using the sediments from the Piscataqua River. The study was performed under contract to the Massachusetts Department of Conservation and Recreation (DCR).

For the Piscataqua River site, the sediment assessment was based on surveys conducted in 2007, 2009, and 2016. In addition, sediment cores were collected in November 2017 from 17 stations in the planned dredging area to a depth of -37 ft mean lower low water (MLLW). Sampled sediments were analyzed for grain size and chemical parameters. For Nantasket Beach, the assessment of existing sediment type was based on sediment surveys conducted in 2004 and 2005.

The findings of the assessment are briefly summarized below. The particle size distributions within the Piscataqua River sediments and existing Nantasket Beach sediment are comparable. The detected chemical concentrations in the Piscataqua River sediments were lower than the Massachusetts Department of Environmental Protection (MassDEP) RSC-1 and RSC-2 guidance values for soil, and risk screenings indicate that exposure to Piscataqua River sediments used for beach nourishment would not affect the health of biota or recreationists that contact them.

Physical Characteristics

The predominant material type in the Piscataqua River dredging area is sand (approximately 70%), with lower concentrations of gravel (20%) and silt/clay (10%). These percentages may vary spatially within the sediment body to be dredged. The predominant grain size is fine sand (comprising 40 to 50% of the total sediment volume), specifically in the 0.15 to 0.42 mm size range.

At Nantasket Beach, pits dug in the intertidal zone contained 1.6% cobble, 22.3% gravel, 75.6% sand, and 0.5% silt/clay (mean values). The mean sand, gravel, and silt/clay concentrations in cores collected along transects perpendicular to the beach were 86%, 13%, and 1%, respectively, along the beach and in the intertidal zone. The predominant grain size is also fine sand (75 to 85%), specifically in the 0.074 to 0.25 mm size range. There are slightly higher concentrations of the finer-grained particles in the subtidal zone.

The two sites compare as follows (Figure ES-1):

- ***Sand:*** The Piscataqua River sediments are more poorly-sorted than those at Nantasket Beach; however, the predominant material at both sites is fine sand, particularly in the particle size fraction of 0.15 to 0.25 mm. Total concentrations of this fine sand fraction are not as high at the Piscataqua River site as at Nantasket Beach; instead, the medium and coarse sand fractions are higher at the Piscataqua River site. As such, the sand fraction would be slightly coarser from the potential borrow source than at Nantasket Beach.

- ***Silt/clay:*** The Piscataqua River sediments contain approximately 10% silt/clay; Nantasket Beach sediments contain less than 3%. If Piscataqua River sediments were placed at Nantasket Beach, much of the silt and clay in the dredged material would eventually be re-suspended by waves and transported offshore such that the remaining material would trend toward the existing particle-size distribution over time. Overall, the difference in silt/clay content is small. Silt/clay that is resuspended and transported offshore would be accounted for in the placement design by appropriate overfill to reach the target nourishment volumes.

- ***Gravel:*** The mean fine and coarse gravel content observed in the Nantasket Beach sediments was 22% in the pit samples, 13% in the beach and intertidal zone, and 11% in the subtidal zone. These concentrations are comparable to the mean gravel concentration of 16% in the 56 Piscataqua River samples from the 2017 borings.

- ***Cobble:*** Cobbles accumulate along the seawall at Nantasket Beach, although the pit samples did not contain high concentrations of cobble. The concentration of cobble in the Piscataqua River sediments is not known. Bottom photographs from 2009 show that some cobble and rocks can be expected, although the comparatively uniform grain size distribution observed in many of the borings from the planned dredging area suggests that the cobble content in the Piscataqua sediments is small to minimal.

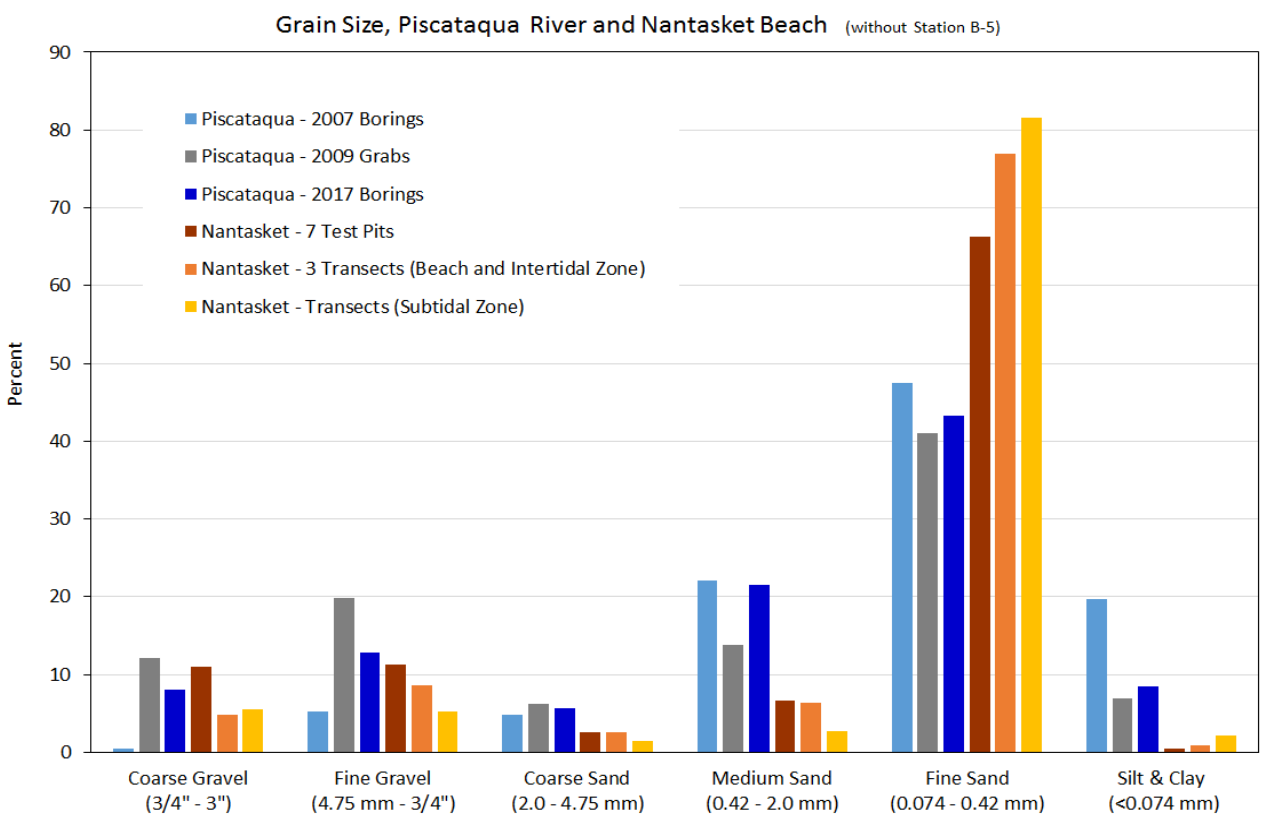

Figure ES-1. Mean grain size distribution by major size fractions for sediment samples from the Piscataqua River and Nantasket Beach

- ***Color:*** Dry Piscataqua River sediments are predominantly yellowish brown; wet sediment are predominantly light olive brown. Dry Nantasket Beach sediments are predominantly gray; wet sediments are predominantly dark gray. Overall, the sediments from the Piscataqua River site are more yellowish than the Nantasket River sediments (Figure ES-2). Over time, Piscataqua River sediment placed at Nantasket Beach would be bleached, changing the color to more closely resemble native conditions.

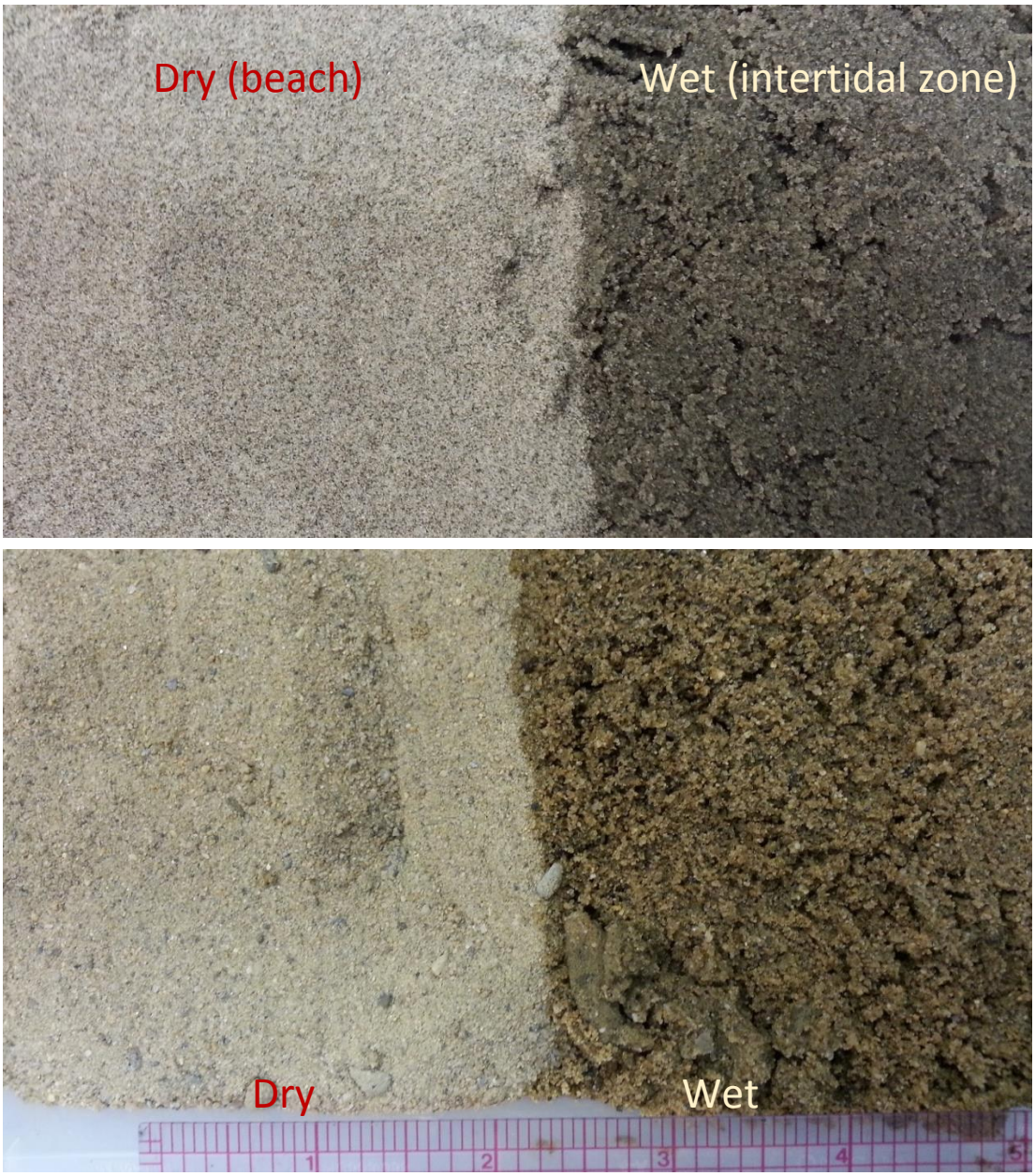

Figure ES-2. Comparison of the color of sediments from Nantasket Beach (top) and the Piscataqua River site (bottom)

Chemical Characteristics

Chemical analyses were conducted on sediment samples collected from the upper 5-ft depth interval of 12 of the 17 stations cored at the Piscataqua River site during November 2017. In addition, seven deeper core segments (up to 20 ft deep) were analyzed at selected stations. A total of 19 samples were submitted for laboratory analyses.

- ***Human Health Risk:*** All detected chemical concentrations in Piscataqua River sediment samples were lower than health risk-based screening levels protective of individuals that contact the sediment while recreating at a beach. Also, all detected chemical concentrations in the sediment samples were lower than MassDEP reportable concentrations (referred to as Category RCS-1 and RCS-2) for soil. The more stringent Category RCS-1 values apply to locations with the highest potential for exposure, and are defined as "at or within 500 ft of a residential dwelling, a residentially-zoned property, school, playground, recreational area or park." In summary, the risk screening evaluation, as conducted, indicates that dredged sediments used for nourishment of Nantasket Beach would not affect the health of recreationists that contact them.

- ***Ecological Health:*** As stated, all measured concentrations were below the background concentration in natural, undisturbed soils (MassDEP, 2002). None of the concentrations of any compound exceeded the NOAA "Effects Range Median" (ERM) guideline values; the ERM value is indicative of concentrations above which adverse biological effects frequently occur. Some samples slightly exceeded the NOAA "Effects Range Low" (ERL) guideline value for arsenic (12 samples); the ERL value is indicative of concentrations below which adverse biological effects rarely occur. The measured arsenic concentrations most likely reflect natural background conditions; all measured arsenic concentrations were below the background concentration in natural, undisturbed soils listed in MassDEP (2002) as 20 mg/kg. One sample had exceedances for mercury, total PCBs, and the pesticide DDE. In addition, a dioxins/furans concentration in one sample exceeded the interim sediment quality guideline (ISQG) developed by the Canadian Council of Ministers of the Environment (CCME); ERMs and ERLs are not available for these compounds. Considering that sampling was conducted in the upper 5 feet of the sediment body to be dredged where contaminants of man-made origin tend to accumulate, and considering mixing of the sediment during dredging, the average metal and organic compound concentrations of the entire sediment body to be dredged are expected to be below the ERL, except for arsenic. In summary, the risk screening evaluation, as conducted, indicates that Piscataqua River sediments used for beach nourishment at Nantasket Beach would not affect the health of biota that contact them.

Dredging, Transportation, and Placement of Dredged Material

Dredging would likely occur over a six-month period between mid-October and mid-April, as dictated by the permits. An evaluation would be performed with input from dredge/marine construction contractors to determine the most efficient transportation and placement methodologies; consideration would be given to cost, time frame, mobilization, equipment types, and environmental impact.

In general, it is likely that the dredged sediment would be placed into scows, towed by tug boat from the Piscataqua River to Nantasket Beach over a distance of 60 nautical miles. At Nantasket Beach, the dredged sediment would be pumped to the beach from the scow using a slurry pump that would be moored approximately one half mile offshore. The sediment pumped onto the beach would be dewatered and moved using bulldozers and other heavy equipment to construct the beach nourishment design.

After placement of the dredged material at Nantasket Beach, there would be a period of sorting of the nourishment material by coastal processes. This sorting process of different grain sizes would reestablished the zonation of sediment textures that presently characterize the beach.

Permitting Requirements

Required permits and related documentation for the use of the Piscataqua River sediment as beach nourishment material are expected to consist of the following:

- **MEPA:** Expanded Environmental Notification Form (EENF), and request for a Waiver from preparation for Environmental Impact Report (EIR). An alternative process could consist of preparing a two-step EIR (Draft and Final). (To be discussed with MEPA.)

- **Hull Conservation Commission:** Notice of Intent (NOI) review under the Massachusetts Wetlands Protection Act (WPA).

- **MassDEP:** Chapter 91 Waterways License.

- **MA Office of Coastal Zone Management (CZM):** Federal CZM consistency review and certification.

- **United States Army Corps of Engineers (USACE):** If the nourishment project is funded by the State of Massachusetts (without federal funding), the project would either require a General or Individual Permit to address Section 10 and Section 404 permit requirements. In case of federal funding for the project, these requirements would be addressed by the USACE as part of their requirements under the National Environmental Policy Act (NEPA).

Suitability – Conclusion

In summary, the Piscataqua River sediment from the planned dredging area is considered suitable for nourishment of Nantasket Beach. The slightly coarser mean sand size of the Piscataqua River sediments would have the benefit of extending the life expectancy of the nourishment effort, since the larger particles would be more resistant to resuspension and transport away from the beach due to wave action.

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1. Introduction

Dredging is planned in the Piscataqua River along the border of New Hampshire and Maine (Figure 1). The dredging project was designed to widen the existing 800-foot (ft) wide turning basin at the upstream end of the federal navigation channel to 1,200 ft (USACE and NHPDA, 2014). The site has an area of area of 890,350 square feet. The water depth of the site varies from elevation -1 to -40 ft mean lower low water (MLLW). The design dredging depth is -35 ft MLLW plus 2 ft of overdepth.

The volume of material to be removed is approximately 728,000 cubic yards (cy) of sand and gravel and approximately 25,000 cy of rock. The material is to be removed by a mechanical dredge between mid-October and mid-April to protect biological resources (*e.g.*, sturgeon, shellfish, lobster). At present, dredging is expected to start either in the fall of 2018 or the fall of 2019. After first removing the sediment, the bedrock will be removed by blasting and excavated thereafter.

The U.S. Army Corps of Engineers (USACE) and the New Hampshire Pease Development Authority (NHPDA) stated that the dredged material would be disposed nearshore, off the coast of Wells, ME; and/or utilized for beach nourishment in Salisbury, Newburyport, and Newbury, MA; the final distribution of the material is to be coordinated by those parties during final design (USACE and NHPDA, 2014). In the spring of 2017, Nantasket Beach, MA was added to the potential list of recipients for the dredged material.

If not beneficially used for beach nourishment, the dredged material could be disposed at an ocean disposal site (partially or entirely). The Federal base plan is for disposal at an ocean site about 11 nm offshore of the mouth of Portsmouth harbor, halfway between the Isles of Shoals and Boon Island in about 300 ft of water.

The objective of this study was to assess the suitability of the Piscataqua River dredging project as a potential sand source for nourishing Nantasket Beach. The study evaluated the following primary features:

- Physical characteristics of the Piscataqua River source material and the existing sediments at Nantasket Beach
- Chemical characteristics of the source material in comparison to environmental regulatory criteria and risk-based criteria for human and ecological health.

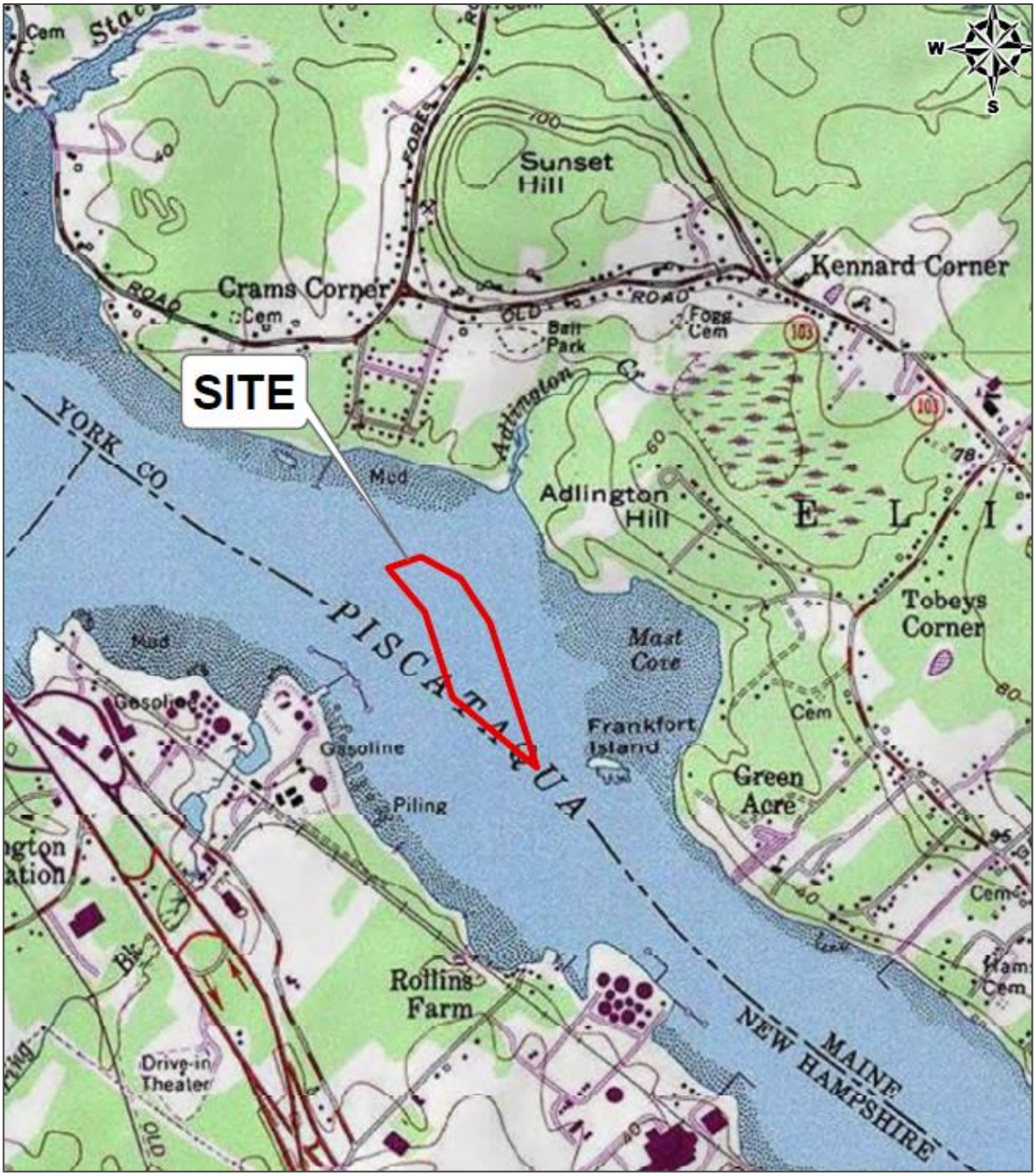

Figure 1. Dredging area in Piscataqua River. (Source of map: GZA, 2016)

2. Data Sources

The suitability assessment was based on data from surveys conducted at the Piscataqua River dredging area from 2007 to 2017 and surveys conducted at Nantasket Beach in 2004 and 2005.

2.1 Sediment Sampling in the Piscataqua River

Borings were conducted in 2007, 2016, and 2017 to collect sediment samples from the material to be dredged at the Piscataqua River site. Grab sampling from the sea-bed was conducted in 2009.

Figures 2 and 3 show the stations for the three boring surveys (2007, 2016, and 2017). Stations labeled "S-__" and marked in red were occupied during the 2017 survey conducted as part of this suitability assessment. Stations labeled "B-__" were occupied during borings advanced in 2007 (USACE and NHPDA, 2014). Stations labeled "FD16-__" were occupied during borings advanced in 2016 (GZA, 2016). The green line on Figures 2 and 3 excludes the northeastern area of the proposed dredging site from consideration for providing beach nourishment material because of the presence of unsuitable glacial clay that was observed in the 2007 and 2016 borings. The blue line separates the southern tip because of the presence of gravel throughout Station FD16-10 of the 2016 boring survey. The bathymetric information on Figure 3 was obtained from GZA Geoenvironmental, Inc. (GZA, 2016).

2.1.1 Borings in Piscataqua River in 2007

The USACE advanced eight borings to access sediment characteristics in 2007 (USACE and NHPDA, 2014). In addition to the borings, three probes were driven into the sediment to the depth of refusal, which was assumed to be the bedrock surface elevation. Two of the boring stations (Stations B-1 and B-3) and one probe station (Station P-1) were located outside of the planned dredging area.

Borings were advanced to an elevation of approximately -40 ft MLLW, using a 4-inch-diameter casing and a 4-inch roller bit. A 2-inch split spoon (with an inner diameter [ID] of 1 3/8 inches) was typically used to collect a sediment sample from a 2-ft long depth interval, every 5 ft to the depth of refusal (*i.e.*, 2 ft of split spoon sediment sampling was followed by 3 ft of drilling without sediment sampling). Boring logs are included as Attachment A1.

When the sediment sample recovery was low, a 3-inch split spoon was driven approximately 1 ft to collect a supplementary sediment sample. As stated in the Field Investigations Report (Appendix F of USACE and NHPDA, 2014), the material collected in the 3-inch split spoon was likely scraped from the sides of the existing boring and thus may not have been representative of the sediment in the targeted depth interval. It is not clearly indicated on the boring logs which samples were collected with a 3-inch spoon.

Ten sediment samples collected from the eight borings were analyzed for grain size. Grain size analyses were performed via ASTM D422. The laboratory data sheets are included as Attachment A2.

2.1.2 Grab Sampling and Bottom Photographs in Piscataqua River in 2009

In June 2009, the USACE collected grab samples of surface sediment in a 75-ft grid pattern around Station B-5 (Figure 4) from the 2007 boring survey (USACE and NHPDA, 2014). Samples were collected using a Van Veen grab sampler; the sampler has a surface area of 0.04 m^2 (20 x 20 cm, or 8 x 8 inches) and a sampling depth of 10 cm (4 inches). Samples could not be obtained at six of the 22 occupied stations after 5 attempts because of hard or rocky bottom conditions. Grab samples were analyzed for grain size via ASTM D422; the laboratory data sheets are included as Attachment B.

As part of a survey for eelgrass beds, bottom photographs were taken by the USACE in 2009 (refer to Appendix L in USACE and NHPDA, 2014). Photographs are included in Attachment D of this document.

2.1.3 Borings in Piscataqua River in 2016

In the summer of 2016, GZA performed a geotechnical exploration survey for the USACE in the proposed dredging area (GZA, 2016). This survey consisted of advancing and sampling ten borings (Stations FD16-01 to FD16-10) to elevations of up -54 ft MLLW (Figures 2 and 3). Sediment samples were collected continuously using 24 inch-long split spoon samplers. Visual classification of the soil samples was performed in accordance with the Unified Soil Classification System (ASTM D2488). Boring logs and photographs of the split spoon samples are provided in Attachment C. Laboratory grain size analyses were not performed; however, a sample was retained and archived by the USACE from each split spoon.

Generally, a 2.5 inch ID sampler was used for sediment sampling. Where noted on the boring logs, a 1 3/8 inch ID sampler was used in well-sorted, fine-grained sands, as the sediment recovery rate was found to be greater for these sediments with that sampler than for the 2.5-inch sampler.

2.1.4 Borings in Piscataqua River in 2017

As part of this suitability assessment, Louis Berger advanced borings at 17 stations in the planned dredging area from November 27 to December 4, 2017 (Figures 2 and 3). The objective of the borings was to obtain more detailed information on the physical and chemical characteristics of the sediment to be dredged to assess its suitability for nourishing Nantasket Beach. Coordinates of the boring stations are listed in Table 1.

The survey area excluded the northeastern and southern tip of the dredging area based on findings of unsuitable material from the USACE and GZA boring programs of 2007 and 2016, respectively:

- ***Northeastern Corner:*** Stations B-5 (2007), FD16-04 (2016), and FD16-05 (2016) contained silt and clay in the upper 10-15 ft of the sediment column. This material would be unsuitable (too fine) for placement at Nantasket Beach.

- ***Southern Tip:*** Station FD-16-10 (2016) contained gravel throughout the boring (mean gravel concentration of 50%), based on visual estimates. The material at this station would also be considered unsuitable (too coarse) for beach nourishment at Nantasket Beach.

Cores were collected in continuous 5-ft segments with a core barrel and PVC core liner with an ID of 3 inches. Borings were advanced to a depth of up to -37 ft MLLW, unless refusal was encountered at a shallower depth.

The average percent recovery in the 5-ft long core barrel was 43% (*i.e.*, 2.2 ft of sediment retained in a 5-ft long core barrel upon retrieval). The low recovery rate was at least in part related to the hard-packed sediments present at the site. The recovery rate was similar to the recovery rates experienced during the borings conducted by others in 2007 and 2016 (both 47%). The 2007 survey used a 2-ft-long sampler with an ID of 1 3/8 inches. The 2016 survey used two different 2-ft-long samplers, one with an ID of 2.5 inches and a second one with an ID of 1 3/8 inches. Friction increases with longer core segments, reducing recovery rates; friction decreases with wider IDs, increasing recovery rates. The variety of equipment used during different sediment sampling programs does not seem to have had a measurable impact on sediment sample percent recovery.

Sediments were analyzed for grain size and sediment chemistry. A total of 56 samples from the 17 occupied stations were analyzed for grain size by GeoTesting Express. Samples were analyzed by wet sieve analysis method ASTM D6913. Sieves sizes were the same as those used for the grain size analyses of the 2007 boring samples and 2009 grab samples: 2-inch, 1 ½-inch, 1-inch, ¾-inch, ½-inch, 3/8-inch, #4, #10, #20, #40, #60, and #200.

A total of 19 samples from 12 stations were analyzed for chemical contaminants by TestAmerica. Samples were not obtained from Stations S-04, S-11, S-13, and S-15 because of coarse grain size or refusal, and Station S-17, which was only cored for grain size analysis. Station S-17 was not planned for based on the Sampling and Analysis Plan, but was added in the field to provide additional information.

Most samples submitted for chemical analysis were obtained from the upper 5 ft of the sediment column. Selected samples were also analyzed from deeper 5-ft core segments to assess chemical characteristics at depth. Five samples were analyzed from the 5-10 ft depth interval (Stations S-01, S-02, S-05, S-06, S-12). One sample each was analyzed also from the 10-15 ft and 15-20 ft depth intervals at Station S-12. Laboratory analytical methods and reporting limits (RL) are provided in Table 2. Analyzed parameters consisted of the following:

- *Metals (incl. mercury) and organics (PAHs, PCBs, pesticides, MAEPH):* Analyzed in all 19 samples.
- *VOCs:* VOCs were analyzed in the same samples as the metals and organic compounds listed above, with the exception of Station S-05 (0-5 ft), which was excluded because of coarse grain size (*i.e.*, total of 18 analyzed samples).
- *Hexavalent chromium, PFCs, and dioxins/furans:* Five samples were analyzed from the 0-5 ft segment at the following stations: S-02, S-06, S-08, S-12, and S-16.

Details of the 2017 boring survey including core logs, sample photographs, grain size data sheets, and chemical analyses results are provided in the Field and Laboratory Report in Attachment H.

2.2 Sediment Sampling at Nantasket Beach

In the fall of 2005, Ocean Surveys, Inc. (OSI) conducted an extensive characterization study of Nantasket Beach on behalf of the DCR and USACE (USACE, 2006). The study included the collection of vibracores and ponar grab samples along five beach transects, and subsequent grain size analyses of the collected samples (using ASTM D422). Also included were geotechnical analyses of test pit samples collected during the summer of 2004 by the USACE and DCR. All elevations reported in the study were provided according to the North American Datum of 1983 (NAD83).

2.2.1 Test Pits in 2004

The USACE and DCR excavated 15 test pits extending along the Nantasket peninsula, from across Packard Street in Hull in the north to Berkley Road in the south (Figure 5). The test pits were located approximately at the public access area of the beach and/or the upper intertidal zone. Each test pit constituted one backhoe scoop of sediment, removed and placed on a sheet of plywood (Figures 6 and 7). Thus, the sampling depth was approximately 3 to 4 ft below grade. The excavated sediment was subsampled into two 10-gallon samples for grain size analysis; one set of analyses was performed by the USACE and a second one was performed by the DCR. Laboratory data sheets are included as Attachment E.

2.2.2 Transects in 2005

Five sampling transects were located along the Nantasket peninsula (Figure 8) as follows (from north to south):

- Transect #8: Opposite K Street (northern Hull)
- Transect #1: Opposite Packard Avenue (mid-Hull)
- Transect #3: Opposite Phipps Street (northern end of Nantasket Beach)
- Transect #5: In front of Nantasket Beach Resort (mid-section of Reservation)
- Transect #7: Opposite of Berkley Road.

Transects #3, #5, and #7 were located adjacent to Nantasket Beach. Along these three transects, USACE and DCR sampled a total of 36 stations in the following zones (in a seaward direction); all elevations are relative to mean sea level (MSL):

- *Dune (Transect #3 only)*:
    - Base of dune (+12.3 ft)
    - Mid-berm (+8.2 ft)
    - Berm crest (+6.5 ft).
- *Beach and Intertidal Zone:*
    - Mean high water (MHW; +4.3 ft)
    - +2.0 ft
    - MSL (-0.3 ft)
    - -3.0 ft
    - Mean low water (MLW; -5.3 ft).

- *Subtidal Zone:*
    - -10 ft,
    - -15 ft,
    - -20 ft,
    - -25 ft,
    - -30 ft
    - -35 ft.

Cores upgradient from Station MLW were collected with a portable vibracorer with a 3-inch ID sampling tube. Cores from Station MLW to Station -30 ft were sampled with a boat-based vibracorer with a 4-inch ID sampling tube. Station -35 ft was sampled with a Ponar grab sampler.

Cores were typically 4 ft long, unless penetration was restricted by cobbles, gravel, or debris. Cores were subsampled into an upper sample (typically 0-2 ft) and a lower sample (typically 2-4 ft) for grain size analyses. The laboratory data sheets are included as Attachment F.

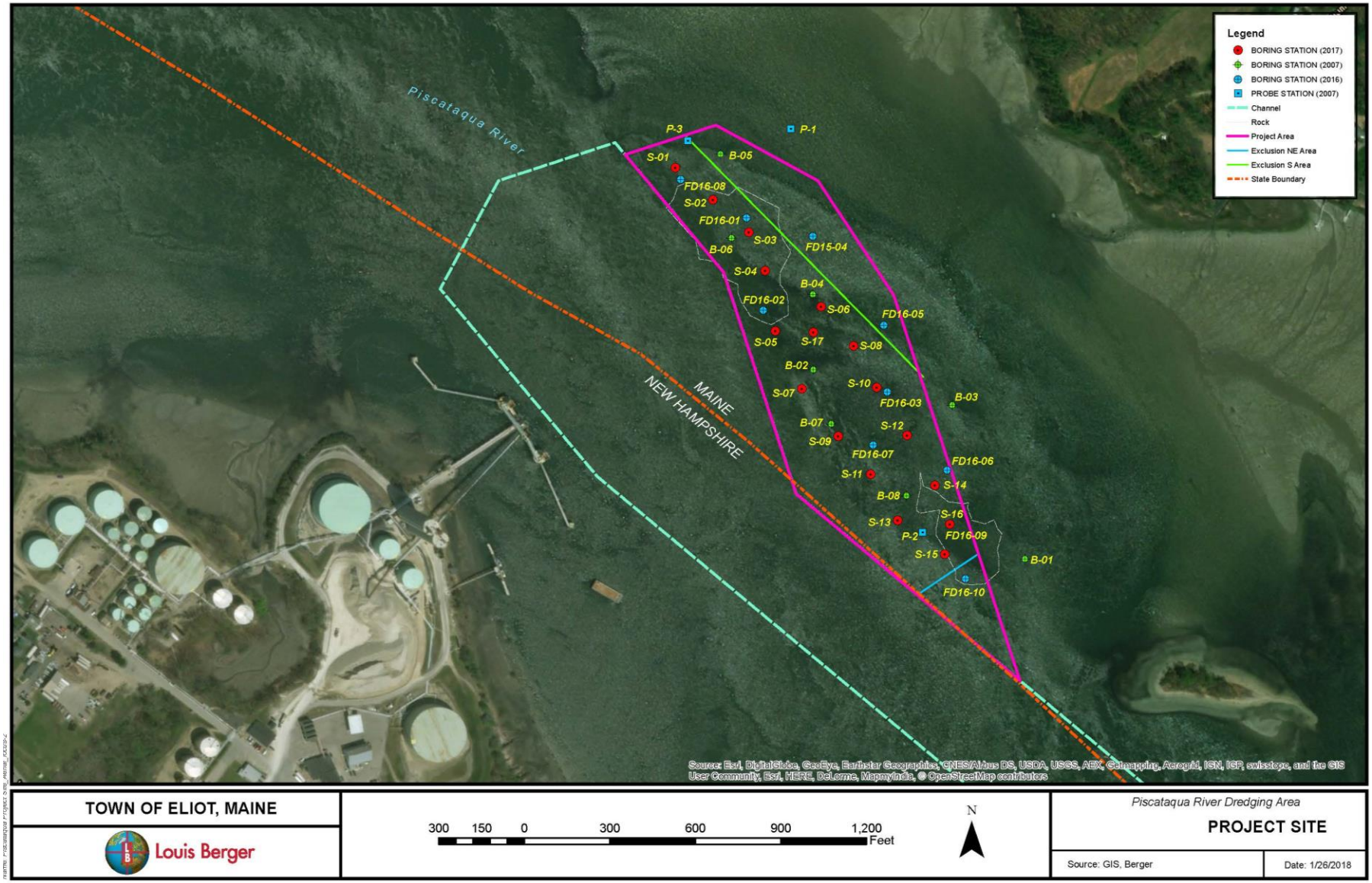

Figure 2. Project site

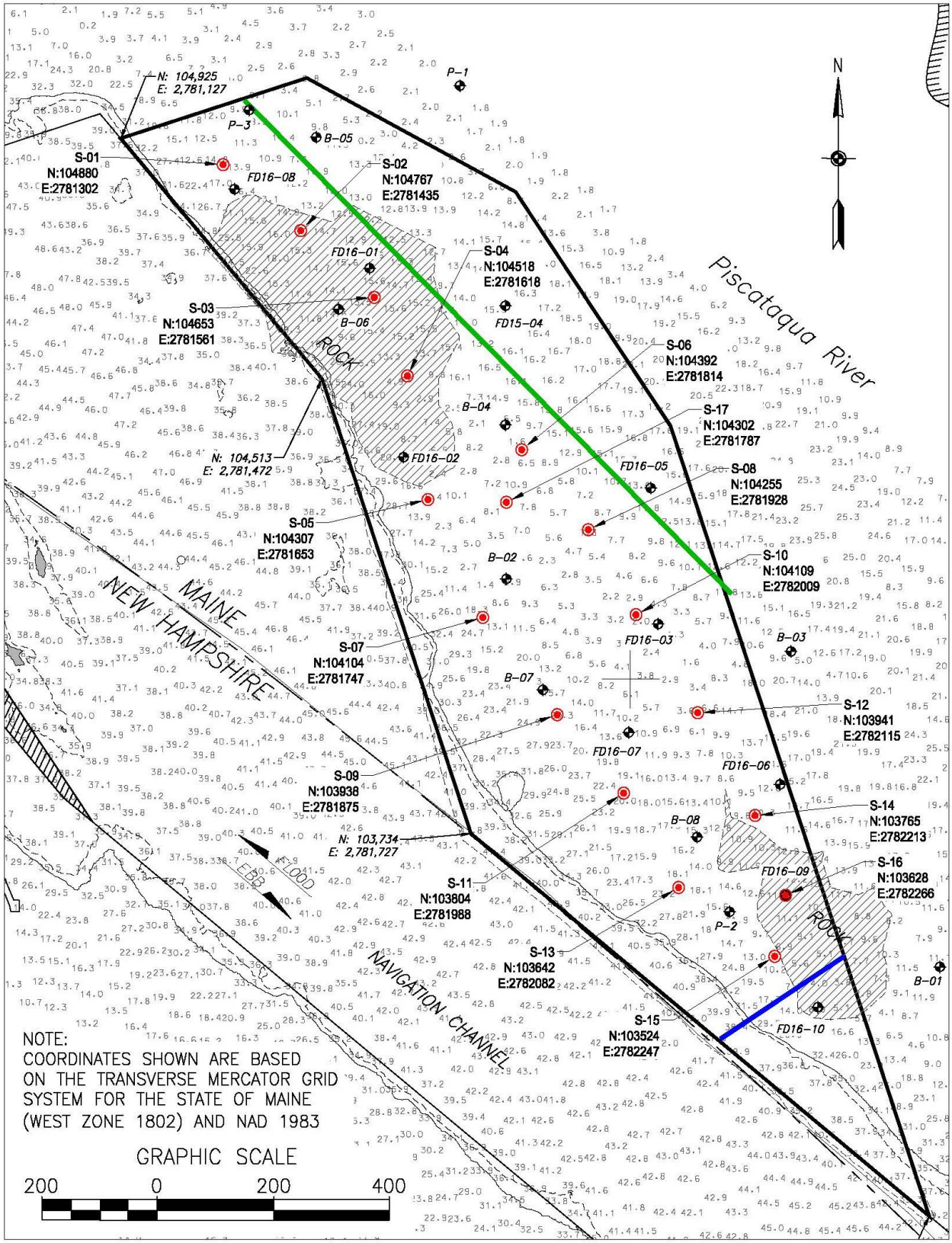

Figure 3. Coring stations within the Piscataqua River dredging area. The stations are superimposed onto a map with bathymetric information from GZA (2016).

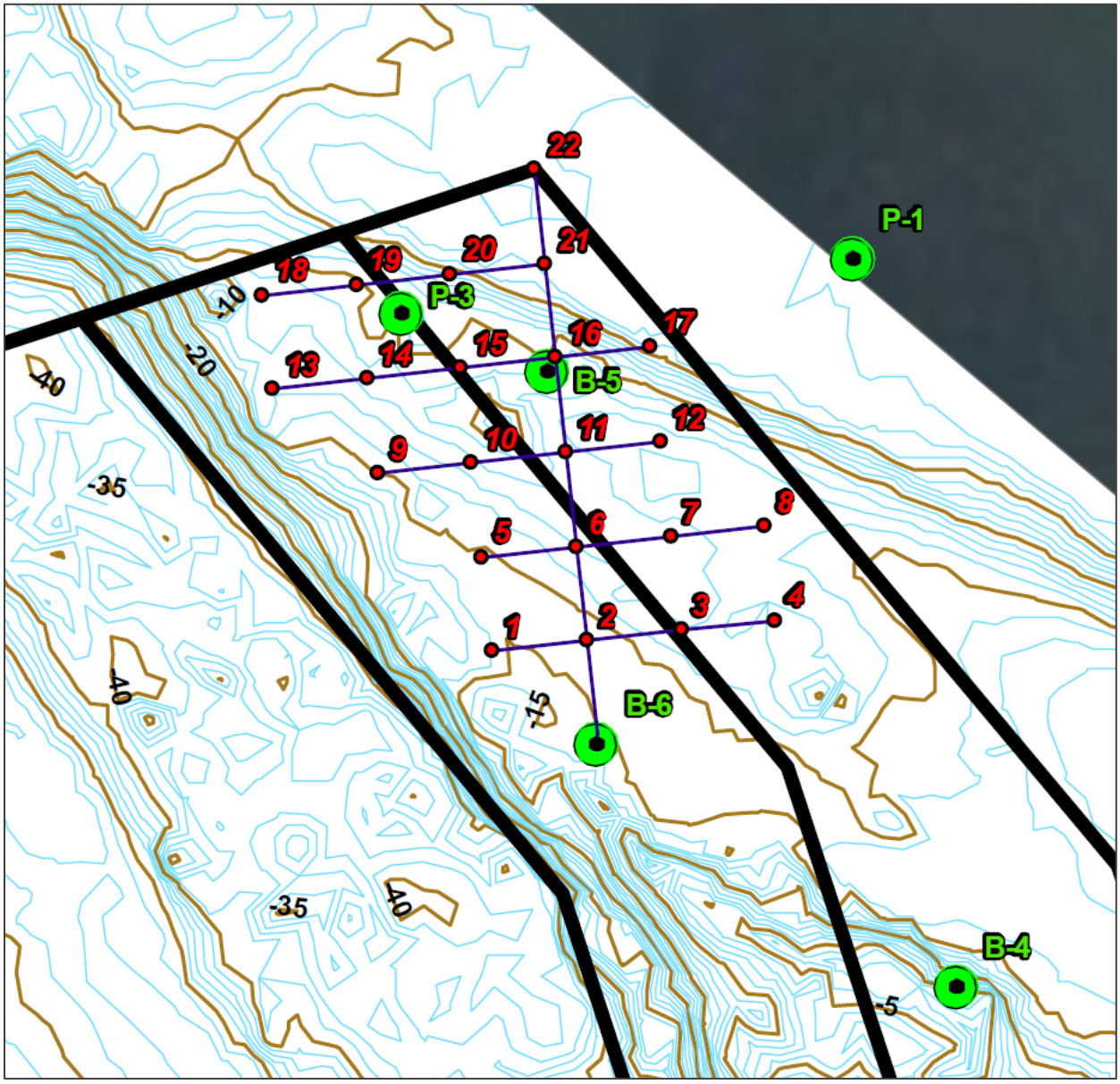

Figure 4. Grab sampling stations *(red numerals)* from the 2009 survey in the northeastern part of the Piscataqua River dredging area. Shown also are the boring stations (B) and probe stations (P) *(in green)* from the 2007 boring survey. Source: USACE and NHPDA (2014)

Table 1. Coordinates and depths of 2017 boring stations, Piscataqua River

Station	Coordinates				Depths		
	State Plane, NAD83 Maine West		WGS84 geodetic datum		Water Depth	Elevation of Base of Boring	Total Length of Boring
	Northing	Easting	Latitude	Longitude	ft MLLW		ft
S-01	104,880.2	2,781,302.0	N43° 07' 9.47"	W70° 48' 31.7"	-14	-24	10
S-02	104,879.2	2,781,406.7	N43° 07' 9.47"	W70° 48' 30.28"	-15	-35	20
S-03	104,652.7	2,781,561.1	N43° 07' 7.24"	W70° 48' 28.18"	-16	-36	20
S-04	104,518.0	2,781,617.9	N43° 07' 5.92"	W70° 48' 27.4"	-11	-14	3
S-05	104,306.5	2,781,653.3	N43° 07' 3.83"	W70° 48' 26.9"	-7	-32	25
S-06	104,391.8	2,781,813.8	N43° 07' 4.69"	W70° 48' 24.75"	-7	-19	12
S-07	104,104.5	2,781,747.1	N43° 07' 1.84"	W70° 48' 25.62"	-25	-35	10
S-08	104,254.8	2,781,927.8	N43° 07' 3.34"	W70° 48' 23.19"	-4	-33	29
S-09	103,937.6	2,781,874.6	N43° 07' 0.21"	W70° 48' 23.88"	-25	-40	15
S-10	104,109.1	2,782,009.4	N43° 07' 1.91"	W70° 48' 22.08"	-2	-27	25
S-11	103,803.5	2,781,988.3	N43° 06' 58.89"	W70° 48' 22.33"	-22	-28	6
S-12	103,941.1	2,782,115.0	N43° 07' 0.26"	W70° 48' 20.64"	-4	-34	30
S-13	103,641.6	2,782,082.5	N43° 06' 57.3"	W70° 48' 21.05"	-20	-26	5.5
S-14	103,764.9	2,782,213.4	N43° 06' 58.53"	W70° 48' 19.29"	-12	-37	25
S-15	103,524.0	2,782,247.1	N43° 06' 56.15"	W70° 48' 18.81"	-10	-16	6
S-16*	103,628.4	2,782,265.6	N43° 06' 57.18"	W70° 48' 18.58"	-13	-38	25
S-17	104,302.0	2,781,787.0	N43° 07' 03.79"	W70° 48' 25.09"	-12	-27	15

* Identical location to 2016 boring station FD16-09.

Table 2. Chemical analyses, with reporting limits, methods, and holding times of 2017 borings

Analyte	**Method**	**Required Reporting Limit** (MassDEP or RIM *[1]*)	**Units** (as dry weight)	**No. of Analyses performed**
Arsenic	6020A	0.5	mg/kg	19
Cadmium	6020A	0.1	mg/kg	19
Chromium	6020A	1.0	mg/kg	19
Copper	6020A	1.0	mg/kg	19
Lead	6020A	1.0	mg/kg	19
Mercury	7174B	0.02	mg/kg	19
Nickel	6020A	1.0	mg/kg	19
Zinc	6020A	1.0	mg/kg	19
PAHs	8270D LL	0.02	mg/kg	19
PCBs (congeners)	8082A	0.01	mg/kg	19
EPH	MAEPH	25	mg/kg	19
VOC	8260C	0.1	mg/kg	18
Percent Water	2540G	1.0	%	19
Additional Analyses				
Pesticides	8081B_LL	0.001 *(2)*	mg/kg	19
Chromium, hexavalent	7196A			5
Dioxins / furans	1613B			5
PFOA / PFOS	537 modified			5

(1) Reporting limit required per MassDEP (2014a) and per RIM (USEPA and USACE, 2004) for pesticides under the additional analyses.
(2) Toxaphene 0.05 mg/kg

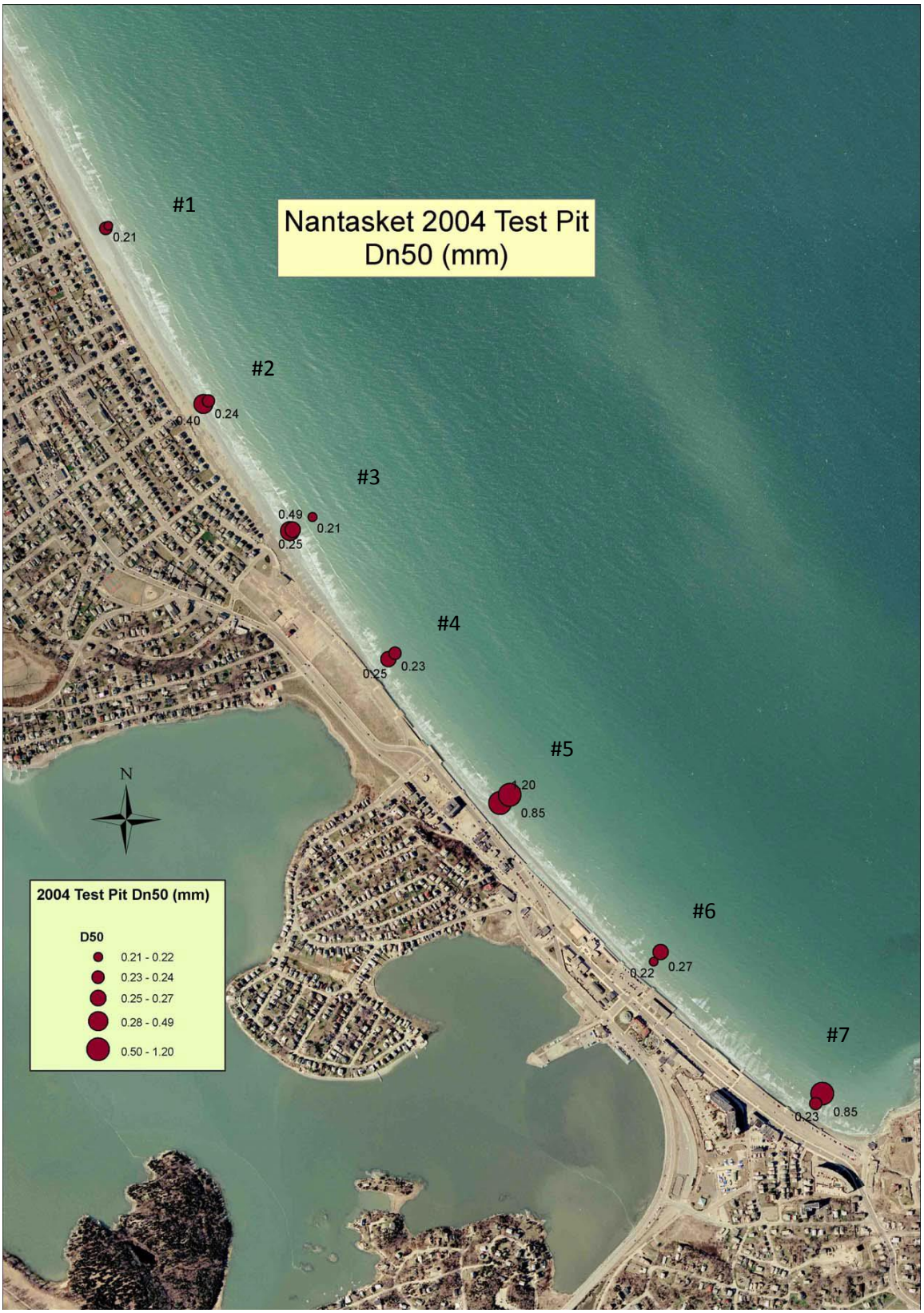

Figure 5. Sediment sampling test pits along Nantasket Beach from 2004. Source: USACE (2006)

Figure 6. Test pit excavated by DCR on June 25, 2004

Figure 7. Test pit, showing coarser sediment at depth

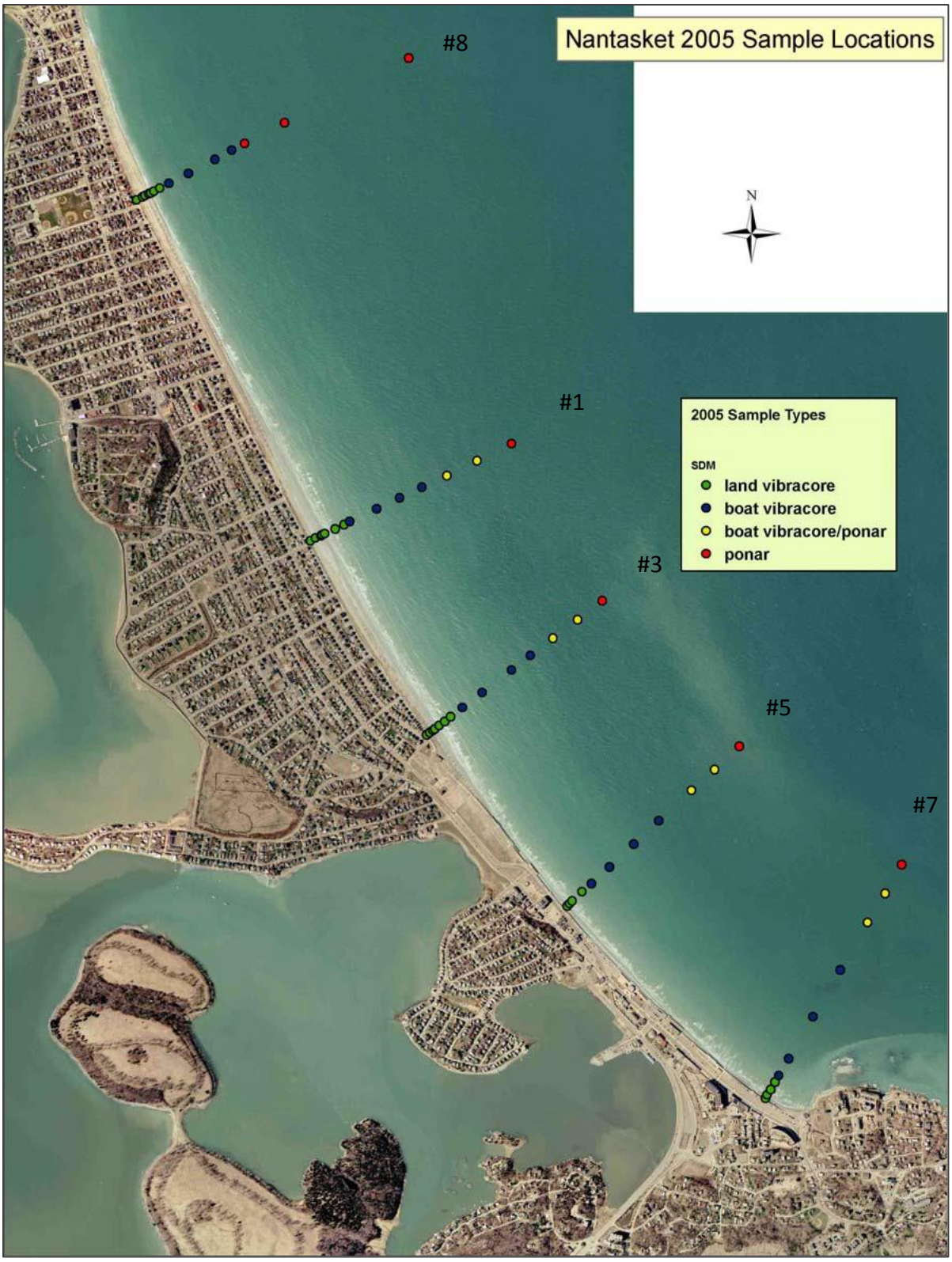

Figure 8. Sediment sampling locations along five transects at Nantasket Beach in 2005.

3. Physical Characteristics of Piscataqua River Sediments

Physical characteristics of primary consideration in evaluating the suitability of the Piscataqua River sediments for Nantasket Beach nourishment are grain size and color. This section summarizes the findings from the various surveys.

3.1 Sediment Grain Size

3.1.1 Borings in 2007

The sediment encountered in the 2007 borings consisted primarily of varying size fractions of sand with gravel (Table 3). Concentrations of fines (silt/clay) were generally low or absent. The exception was Station B-5, which contained high concentrations of silt/clay in the upper 10 ft; this material would not be suitable for beach nourishment. Silt was also encountered in Station B-3 at a depth of 10-12 ft; however, Station B-3 was located outside of the area to be dredged.

The predominant grain size of the 10 samples analyzed by a geotechnical laboratory was sand (Table 4). Because of the small ID of the split spoon sampler (1 3/8 inches), the gravel fraction was likely underrepresented; sediment particles larger than 1 3/8 inches (coarse gravel, cobble) would not have been sampled by this device (likely pushed out of the way of the advancing split spoon without entering the sampler, if encountered). The boring logs indicate that the roller-bit encountered substantial amounts of gravel in layers between samples. USACE and NHPDA (2014, Appendix F) therefore concluded that most of the gravel encountered during the sampling process was pushed aside.

The predominant sand size fraction was fine sand in the size range between 0.15 to 0.42 mm (Table 4). The mean concentration of the fine sand fraction at all stations was 48% of the total sample volume (Figure 9). The mean silt/clay concentration was 20%; without Station B-5, the mean silt/clay content was approximately 10%. The mean concentrations of the medium and coarse sand fractions were 22% and 5%, respectively. The mean concentration of gravel measured in the analyzed samples was 6%.

The probes during the 2007 survey were driven through the sediment to refusal without sampling. Blow counts at probe Station P-1 were interpreted as “consistently deposited” material, suggesting sediment of similar characteristics (Appendix F in USACE and NHPDA, 2014). Blow counts were not recorded at the other probe stations (Stations P-2 and P-3).

3.1.2 Grab Sampling and Bottom Photographs in 2009

Surface sediments in the northern one third of the planned dredging area consisted of poorly-sorted sand, gravel, cobble, and shell fragments with scattered pockets of fine sand and silt. The six stations where a sample could not be obtained likely had a rocky bottom, coarse material, or exposed bedrock that prevented the grab sampler from closing. Gravel was the predominant grain size in five of the 16 successfully collected samples (Table 5). Sand was the predominant grain size in the remaining 11 of the 16 samples. The mean sand concentration in all samples was 61%,

ranging from 17% to 93% in individual samples (Table 5 and Figure 10). The mean gravel concentration was 32% in all 16 samples; the mean silt/clay concentration was 7%.

The predominant sand fraction was also fine sand (mean of 41% of the total sample volume). The mean concentrations of the medium and coarse sand fractions were lower with 14% and 6%, respectively.

The silt/clay concentrations were generally low in the 16 samples, with a mean concentration of 7%, as stated above. Station S-6 contained the highest silt/clay concentration with 31%. Other grab samples (Stations 11, 16, 17, 21, and 22) to the north of 2007 boring station B-6 had the next highest concentrations of silt/clay, ranging from 7% to 19%. These five stations were all located in the northeastern corner of the dredging area.

Bottom photographs taken in 2009 showed that the bottom sediments of the dredging area consisted of sand with cobble, gravel, and shell material (Attachment D). There were several locations with dense kelp beds, but eelgrass was not observed in the surveyed areas. The sediment surface shown in some of the photographs may consist of an armor layer, where currents have eroded the finer-grained sediment, leaving relatively coarser-grained sediment (gravel, cobble) on the surface. This may have been the case at Stations J and M (see map in Attachment D); both stations were located within the dredging area.

3.1.3 Borings in 2016

GZA (2016) identified three strata (from top to bottom) in the 2016 borings in the sediment body to be dredged. The profiles in Figure 11 connect multiple stations from the 2007 and 2016 borings (see Figure 3 for station locations). The three strata were described as follows:

- ***Glaciomarine Clay:*** This stratum was encountered in Station FD16-04 and FD16-05 (neither are shown on Figure 11) in the northeastern part of the dredging area, and identified as the Presumpscot Formation. The Presumpscot Formation is described by Smith and Cameron (1999) as follows:

  > *"Massive to laminated, gray to blue-gray (weathering brown) silt and silty clay. Locally the stratum may contain boulders, sand, and gravel. Occurs as blanket deposit over bedrock and older glacial sediments. Variable thickness from less than 1 m to more than 50 m."*

  At two 2016 boring stations, the sediment consisted of lean clay with sand and gravel, encountered in the upper 12 ft at Station FD16-04 and upper 8 ft at Station FD16-05 (Table 6).

- ***Glaciofluvial/Glaciomarine Outwash:*** Borings at all ten 2016 stations encountered a stratified sand and gravel deposit, ranging in thickness from 16 to 43 ft. The bottom of this stratum was at or below the maximum dredging depth of -37 ft MLLW at about half of the stations in Figure 11. GZA suggested that this stratum may correlate with on-shore units mapped in Maine as "Marine Regressive Sand Deposits", described as massive to stratified

and cross-stratified, well-sorted, brown to gray-brown sand. The predominant sediment type encountered in the 2016 borings consisted of fine to coarse sand. Also encountered within this stratum were occasional zones of sand with gravel, silty sand/silty sand with gravel, and gravel with sand. The variability in the sediment types in the borings at each station indicates substantial spatial variability in grain size within the sediment body.

- ***Glacial Till:*** Seven of the ten 2016 borings encountered approximately 1 to 16 ft of a dense, silty gravel/sand stratum. GZA interpreted this material as glacial till, described as a poorly-sorted mixture of silt, sand, clay, cobbles, and boulders, typically not stratified. The top of this stratum was shallower than the maximum dredging depth of -37 ft MLLW only in Stations FD16-02, FD16-07, and FD16-08 at elevations -28, -36, and -35 ft MLLW, respectively. The predominant sediment type encountered in the Glacial Till was silty sand with gravel to silty gravel with sand, consisting of varying concentrations of sand and gravel and 15% to 30% silt. The lower 1 to 3 ft of this stratum may have contained cobbles or boulders based on observed difficulty advancing the roller bit.

Visual estimates of the grain size distribution in each of the 148 split spoon samples from the 2016 borings are summarized in Table 6. The mean gravel, sand, and silt/clay concentrations of all collected split spoon samples were estimated as 20%, 67%, and 13%, respectively. For only samples from the sediment body to be dredged to a depth of -37 ft MLLW, and not including Stations FD16-04 and FD16-05 in the northeastern corner of the dredging area, the mean gravel, sand, and silt/clay concentrations were estimated as 22%, 69%, and 9%, respectively. Overall, the sand fraction consisted of predominantly fine and medium sand with smaller amounts of coarse sand. Again, it is noted that concentrations and mean values in Table 6 are *based on visual observations* only and not based on quantitative laboratory analyses. Thus, these values should not be used for modeling or further quantitative assessments.

3.1.4 Borings in 2017

Sediment grain size data for the samples collected from the 2017 borings are presented in Tables 7 and 8. The laboratory data sheets are included in Attachment H. The grain size analysis curves of the 56 samples that were analyzed are presented in Figure 12, along with mean and median distributions.

Based on the unweighted mean of the 56 samples, sediments in the area to be dredged consisted predominantly of sand (76%) with smaller fractions of gravel (16%) and silt/clay (8%) (Table 7). The weighted mean grain size distribution (*i.e.*, based on one mean concentration for each of the 17 stations) in the sediment was similar, with 71% sand, 21% gravel, and 8% silt/clay (Table 8; Figure 13).

Based on the weighted means, the predominant sand fraction was fine sand (43% of the total sample), followed by medium sand (22%), and coarse sand (6%) (Table 8). The predominant fine sand fractions were the 0.15-0.25 mm and 0.25-0.42 mm fractions (17% each) followed by the 0.074-0.15 mm fraction (9%) (Table 8; Figure 14).

The coarsest sediments were measured at Stations S-04, S-05, S-11, S-13, and S-15. Most of these stations were located in deeper water along the western side of the dredging area. Station S-15

was located close to the southern tip of the dredging area. Stations S-04 and S-05 were located in the vicinity of the northern rock area (see Figure 3 for location).

3.1.5 Comparison of Grain Size from all Piscataqua River Surveys

Similar to borings in 2007 and 2016, borings in 2017 revealed considerable variability in grain size in the subsurface, consistent with fluvial deposits. The lack of consistent stratification is also shown in Figure 11.

The grain size distributions of the 2007 and 2017 borings were very consistent for the sand fractions (Figure 15). The gravel concentration was higher in the 2017 borings (as a result of wider core tubes). The silt/clay fraction was higher in the 2007 borings (as a result of Station B-05). Without Station B-05, the silt/clay fraction of the 2007 borings (10%) was similar to the silt/clay fraction of the 2017 borings (8.5%).

The grain size distribution of the 2009 grab samples differed from the distribution of the 2007 and 2017 borings. The mean gravel fraction in the grab samples was higher (32%). Bottom photographs suggest that there could be winnowing of the sediment surface as a result of the strong tidal currents at the dredging area, as stated above. Therefore, the grain size data from the 2009 surface grab samples are not considered representative of the sediment body to be dredged.

The grain size distributions observed in the 2007 and 2017 borings were also consistent with observations in the 2016 borings. Sand was the predominant grain size in most of the 2016 cores; the silt/clay fraction was were small. Gravel was observed at 2016 Stations FD16-02 and FD16-10, similar to nearby 2017 Stations S-05 and S-15, respectively. Mean *visual estimates* of all 2016 samples from the sediment body to be dredged (*i.e.*, to a depth of -37 ft MLLW) and without Stations FD16-04 and FD16-05, were 22% gravel, 69% sand, and 9% silt/clay.

Spatially, the coarsest sediment was observed at the southern tip of the dredging area, and on the western side. The western side is deeper and closer to the tidal channel with strong tidal currents. It is conceivable that some of the gravel encountered on the western side was a result of erosion of the sand, perhaps only on the surface. From north to south (2016 and 2017 borings), gravel to -37 ft MLLW was observed in Stations FD16-02, S-05, S-11, B-08, S-13, S-15, and FD16-10. This pattern is not consistent, however; other stations also in deeper water on the western side of the dredging area contained predominantly sand (from north to south: Stations S-07, B-02, B-07, S-09).

3.2 Sediment Color

The color of sediment sampled in the 2007 borings was described as brown in the field logs (Attachment A1). Exceptions were the samples from Stations B-3 and B-5, where the upper 4 inches below the sediment surface were described as black/brown. The laboratory data sheets described the sediments mostly as grayish brown, yellowish brown, or olive brown (Attachment A2).

The color in most of the 2009 grab samples was described as dark olive-brown in the laboratory data sheets (Attachment B). Exceptions were Station 5, where the sample was described as very dark gray, and Station 12, where the sample was described as very dark olive-brown.

The color of the sediment sampled in the 2016 borings was also predominantly described as brown in the field logs, and for some samples as brown/gray, gray, and tan (Attachment C1).

The color of the 2017 boring samples was consistent with colors in samples from previous borings. The sediment in the 2017 cores consisted predominantly of varying shades of brown, based on the color spectrum in the Munsell Chart:

- *Wet sediment:* The color of the wet sediment in the 56 core segments (as observed in the field) was light olive brown (67% of the 56 samples), dark grayish brown (15%), and grayish brown (8%), with the remainder consisting mostly of other shades of brown (see Appendix 8 within Attachment H). Some of the 0-5 ft core segments included dark gray sediment bands that were one to several inches thick. The chemical results and the absence of any sheen or odors indicate that these bands were probably low-oxygen or anoxic horizons in the upper sediment column.

- *Dry sediment:* The color of the dry sediment of the 56 core segments (evaluated after homogenization and grain size analyses by the geotechnical laboratory, which had removed the silt/clay fraction) was light olive brown (66% of the 56 samples), light olive brown (16%), pale brown (7%), grayish brown (5%), light gray (2%), light brownish gray (2%), and gray (2%).

A representative sample (S-12, 20-25 ft) with the predominant colors is shown in Figure 16, both in wet and dry state.

3.3 Physical Characteristics of Piscataqua Sediment - Summary

Based on the collective survey data, the predominant grain size of the sediments in the dredging area is sand (rounded to approximately 70%), with lower concentrations of gravel (20%), and silt/clay (10%). These percentages may vary to some extent because of spatial variability in the sediment body to be dredged. This variability is reflected by the median concentrations that are included in the data tables. The predominant grain size in the 2007 and 2017 borings, as well as in the grab samples, was fine sand, specifically in the 0.15 to 0.42 mm size range. The sediment color was predominantly brown.

The sediment body contains subareas of varying grain size. Borings B-5, FD16-04, and FD16-05 indicate that there is a subarea along the northeastern margin of the dredging area that contains glacial clay to a depth of approximately 10 to 15 ft. Stations FD16-10 and S-15 suggest that the southern tip of the dredging area contains elevated concentrations of gravel. Other borings contain intervals of gravel that are typically a few feet thick; these intervals don’t correlate between individual borings, suggesting that they formed as local deposits. These observations suggest that the following subareas should be excluded (at least partially) as source area for sand for beach nourishment at Nantasket Beach:

- *Northeastern Corner:* In the area surrounding Stations B-5, FD16-04, and FD16-05, the sediment body to be dredged from the sediment surface to a depth of approximately 15 feet does not appear to be suitable for beach nourishment because of the high silt/clay content. Alternatively, depending on the approach used for dredging, the clay zone could be removed separately, and only the deeper sandy sediment could be used; this clay zone constitutes about half of the sediment column to be dredged.

- *Southern Tip:* Station FD16-10 was advanced 40 ft into the sediment and contained much coarser-grained material than other boring stations. Specifically, Station FD16-10 contained 51% gravel, 45% sand, and 4% silt (mean values, based on visual observations). Station S-15 was advanced 5 ft into the sediment and contained 61% gravel. It is noted that this exclusion is based on only these two stations. Therefore, it is possible that other parts of the southern tip may contain suitable sediment for beach nourishment.

Table 3. Grain size, recovery, and sample locations in 2007 borings in Piscataqua River

Depth Interval (from Sediment Surface)	Borings (from North to South)																				
	B-5			B-6			B-4			B-2			B-7			B-3			B-8			B-1		
	Elev.: -14.5 ft			Elev.: -14.5 ft			Elev.: -3 ft			Elev.: -3 ft			Elev.: -19 ft			Elev.: -15 ft			Elev.: -18 ft			Elev.: -13 ft		
	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Sampled	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Analysis?	Sediment	%Recovery	Analysis?
0 - 1		70	●		30			30			25			50	●		20			35	●		35	
1 - 2																								
2 - 3																								
3 - 4																								
4 - 5																								
5 - 6		30			25			45			30			65	●		100			50	●		25	
6 - 7																								
7 - 8																	silt							
8 - 9																								
9 - 10																								
10 - 11		67	●		50						50	●		60	●		60			45			15	
11 - 12																								
12 - 13																								
13 - 14																								
14 - 15																								
15 - 16		55		bedrock				65	●		40			45			35			100			20	
16 - 17																								
17 - 18																								
18 - 19																								
19 - 20																								
20 - 21		60									30			70			20			50			50	●
21 - 22																								
22 - 23													end of boring						end of boring					
23 - 24																								
24 - 25																								
25 - 26		65						55			35						45						45	
26 - 27																								
27 - 28	end of boring															end of boring						end of boring		
28 - 29																								
29 - 30																								
30 - 31											40													
31 - 32																								
32 - 33																								
33 - 34																								
34 - 35																								
35 - 36								70			40													
36 - 37																								
							end of boring			end of boring														
Mean - %Recovery		58			35			53			36			58			47			56			32	
	46.8																							

Key:

- Sandy fine SILT (with/without gravel)
- Silty fine SAND (with/without gravel)
- Fine SAND (with/without gravel)
- Fine to medium SAND (with/without gravel)
- Medium SAND and gravel
- Medium to coarse SAND and gravel
- Coarse SAND AND GRAVEL
- GRAVEL and medium to coarse sand

Table 4. Grain size in 2007 borings of dredging area in Piscataqua River

Boring No. (north to south)	Depth from Sediment Surface (feet)	Sample ID (1)	Grain Size (%) (2)														Particle Size Distribution (mm)						Coefficients	
			Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
			Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0	0.42 - 0.85	0.25 - 0.42	0.15 - 0.25	0.074 - 0.15	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
B-5	0-2	J-1	0.0	5.7	94.3	0.0	1.0	5.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	3.0	0.045	0.013	**0.007**	-	-	-	-	-
	10-12	J-3	13.4	45.1	41.5	7.0	9.0	30.0	0.0	13.0	7.0	5.0	4.0	8.0	10.0	12.0	3.794	0.215	**0.124**	0.037	0.010	0.005	-	-
	Mean		6.7	25.4	67.9	3.5	5.0	17.5	0.0	6.5	3.5	2.5	2.5	4.5	5.5	7.5	1.919	0.114	**0.065**					
B-4	15-17	J-3	1.7	83.8	14.5	2.0	25.0	56.0	0.0	2.0	2.0	8.0	17.0	23.0	23.0	10.0	0.762	0.333	**0.264**	0.166	0.077	0.046	-	-
B-2	10-12	J-3	1.0	90.4	8.6	1.0	46.0	43.0	0.0	1.0	1.0	16.0	30.0	22.0	14.0	7.0	1.008	0.512	**0.405**	0.250	0.141	0.086	5.95	1.42
B-7	0-2	J-1	0.3	89.1	10.6	1.0	8.0	80.0	0.0	0.0	1.0	3.0	5.0	20.0	38.0	22.0	0.363	0.216	**0.189**	0.136	0.086	0.068	3.18	1.26
	5-7	J-2	2.5	84.2	13.3	4.0	25.0	55.0	0.0	3.0	4.0	9.0	16.0	22.0	22.0	11.0	0.969	0.353	**0.276**	0.171	0.083	0.055	-	-
	10-12	J-3	16.2	76.5	7.3	7.0	28.0	42.0	8.0	8.0	7.0	11.0	17.0	17.0	17.0	8.0	6.730	0.675	**0.449**	0.239	0.151	0.097	6.99	0.87
	Mean		6.3	83.3	10.4	4.0	20.3	59.0	2.7	3.7	4.0	7.7	12.7	19.7	25.7	13.7	2.688	0.415	**0.305**	0.182	0.107	0.073	5.09	1.07
B-8	0-2	J-1	13.5	76.5	10.0	7.0	18.0	51.0	0.0	14.0	7.0	8.0	10.0	16.0	19.0	16.0	4.058	0.415	**0.297**	0.169	0.094	0.075	5.52	0.92
	5-7	J-2	19.4	74.9	5.7	30.0	37.0	8.0	0.0	19.0	30.0	25.0	12.0	5.0	2.0	1.0	5.689	2.592	**1.921**	0.971	0.459	0.282	9.19	1.29
	Mean		16.5	75.7	7.9	18.5	27.5	29.5	0.0	16.5	18.5	16.5	11.0	10.5	10.5	8.5	4.874	1.504	**1.109**	0.570	0.276	0.179	7.36	1.10
B-1	20 -22	J-5	1.5	89.9	8.6	0.0	9.0	80.0	0.0	2.0	0.0	2.0	7.0	28.0	34.0	18.0	0.397	0.247	**0.213**	0.158	0.096	0.079	3.12	1.27
Mean (weighted)			**5.6**	**74.7**	**19.6**	**4.8**	**22.1**	**47.5**	**0.4**	**5.3**	**4.8**	**8.8**	**13.4**	**17.9**	**18.8**	**10.8**	**1.941**	**0.521**	**0.393**	**0.265**	**0.139**	**0.093**	**5.38**	**1.22**
Median (weighted)			**4.0**	**83.5**	**9.5**	**2.8**	**22.7**	**49.5**	**0.0**	**2.8**	**2.8**	**7.8**	**11.8**	**20.8**	**18.5**	**9.3**	**1.464**	**0.374**	**0.284**	**0.182**	**0.107**	**0.079**	**5.52**	**1.19**

(1) The laboratory data sheets (included as Attachment A) also use this ID.

(2) Concentrations in individual samples over 30% are color-coded to show dominant concentrations.

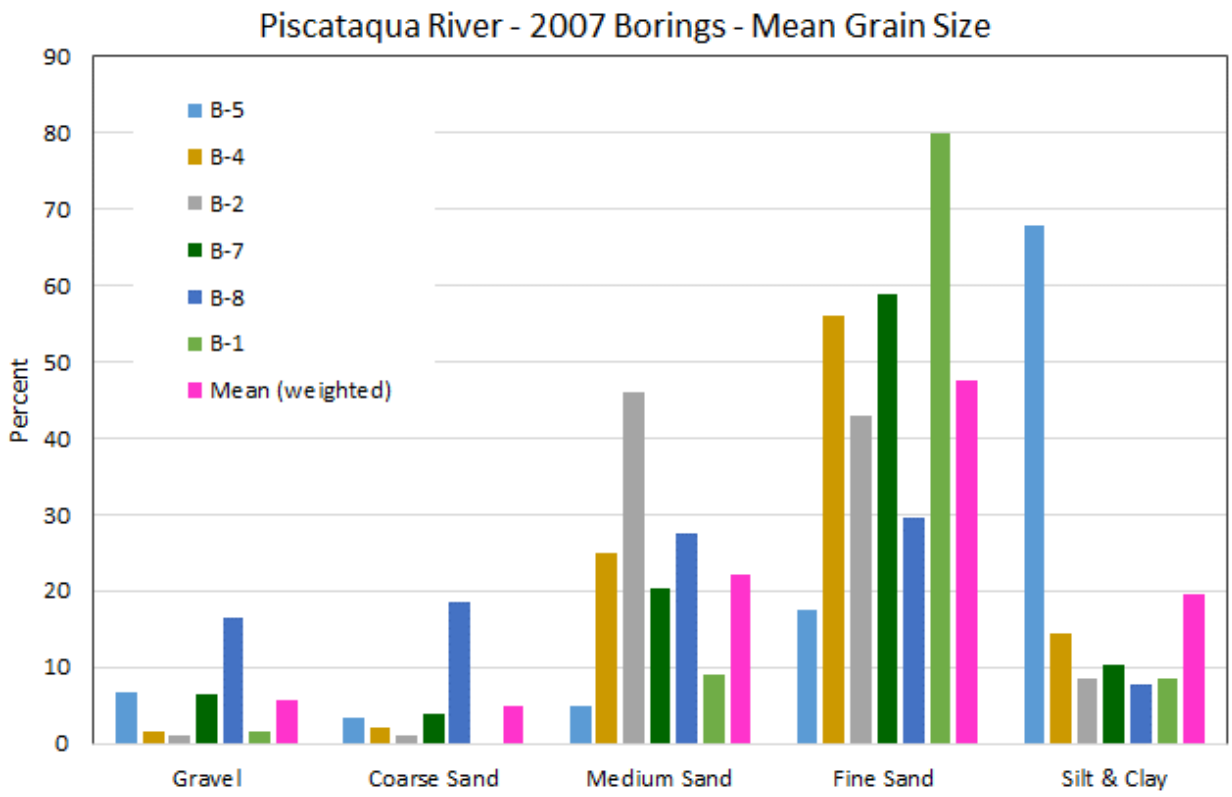

Figure 9. Mean grain size distribution for each 2007 boring station at the Piscataqua River dredging area. Borings are arranged from north (Station B-5) to south (Station B-1).

Table 5. Grain size of 2009 grab samples in northern part of dredging area in Piscataqua River

Station (S-__) (1)	Water depth (ft)	No. of Attempts	Grain Size (%) (2, 3)														Particle Size Distribution (mm)						Coefficients	
			Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
			Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0	0.42 - 0.85	0.25 - 0.42	0.15 - 0.25	0.074 - 0.15	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
3	18	3	78.0	20.7	1.3	6.0	11.0	4.0	36.0	42.0	6.0	5.0	6.0	3.0	0.0	1.0	23.462	17.339	**14.054**	7.935	1.744	0.750	23.12	4.84
5	19	2	45.9	53.3	0.8	12.0	29.0	12.0	8.0	38.0	12.0	13.0	16.0	9.0	3.0	0.0	15.080	6.521	**3.569**	0.923	0.473	0.362	18.02	0.36
6	19	4	1.1	67.6	31.3	0.0	1.0	67.0	0.0	1.0	0.0	*0.5*	*0.5*	*10.0*	*28.5*	*28.5*	0.2397	0.1730	**0.1518**	-	-	-	-	-
7	17	3	14.4	76.9	8.7	2.0	17.0	58.0	6.0	8.0	2.0	4.0	13.0	25.0	25.0	8.0	3.544	0.365	**0.296**	0.196	0.129	0.084	4.36	1.26
9	20	2	57.0	42.1	0.9	11.0	22.0	9.0	43.0	14.0	11.0	10.0	12.0	7.0	2.0	0.0	29.573	19.957	**8.560**	1.625	0.552	0.411	48.60	0.32
10	16	2	41.0	58.1	0.9	17.0	35.0	6.0	3.0	38.0	17.0	28.0	7.0	3.0	3.0	0.0	15.215	5.098	**2.979**	1.376	0.873	0.554	9.21	0.67
11	16	3	0.0	92.9	7.1	0.0	3.0	90.0	0.0	0.0	0.0	0.0	3.0	32.0	45.0	13.0	0.349	0.237	**0.212**	0.169	0.116	0.088	2.69	1.36
12	19	2	67.0	31.0	2.0	6.0	8.0	17.0	23.0	44.0	6.0	3.0	5.0	8.0	7.0	2.0	24.681	14.551	**12.466**	3.036	0.316	0.226	64.36	2.80
14	15	2	11.8	85.4	2.8	8.0	37.0	40.0	6.0	6.0	8.0	12.0	25.0	24.0	13.0	3.0	3.365	0.686	**0.520**	0.319	0.212	0.175	3.92	0.85
15	17	10	82.1	16.9	1.0	1.0	4.0	12.0	40.0	42.0	1.0	1.0	3.0	6.0	5.0	1.0	22.561	19.013	**16.997**	13.570	0.697	0.314	60.63	30.89
16	18	1	0.8	90.2	9.0	1.0	6.0	83.0	0.0	1.0	1.0	1.0	5.0	28.0	47.0	8.0	0.373	0.240	**0.215**	0.173	0.128	0.082	2.92	1.52
17	13	2	5.7	83.4	10.9	4.0	10.0	69.0	0.0	6.0	4.0	4.0	6.0	42.0	24.0	3.0	0.726	0.330	**0.290**	0.210	0.153	0.060	5.46	2.21
18	15	1	36.8	61.5	1.7	10.0	13.0	38.0	0.0	37.0	10.0	3.0	10.0	21.0	15.0	2.0	13.488	3.588	**0.862**	0.330	0.217	0.183	19.63	0.17
19	7	2	60.9	33.5	5.6	19.0	11.0	3.0	28.0	33.0	19.0	8.0	3.0	2.0	1.0	0.0	21.554	9.376	**6.766**	3.174	1.165	0.528	17.77	2.04
21	6	3	3.1	78.4	18.5	1.0	7.0	70.0	0.0	3.0	1.0	2.0	5.0	25.0	32.0	13.0	0.391	0.235	**0.200**	0.134	-	-	-	-
22	8	1	5.5	87.0	7.5	2.0	6.0	79.0	0.0	5.0	2.0	1.0	5.0	37.0	35.0	7.0	0.412	0.289	**0.251**	0.188	0.151	0.096	3.03	1.28
Mean			**31.9**	**61.2**	**6.9**	**6.3**	**13.8**	**41.1**	**12.1**	**19.9**	**6.3**	**6.0**	**7.8**	**17.6**	**17.8**	**5.6**	10.938	6.125	**4.274**	2.224	0.495	0.279	20.26	3.61
Median			**25.6**	**64.6**	**4.2**	**5.0**	**10.5**	**39.0**	**4.5**	**11.0**	**5.0**	**3.5**	**5.5**	**15.5**	**14.0**	**2.5**	8.516	2.137	**0.691**	0.330	0.267	0.204	13.49	1.32
Minimum			*0.0*	*16.9*	*0.8*	*0.0*	*1.0*	*3.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.5*	*2.0*	*0.0*	*0.0*	*0.240*	*0.173*	*0.152*	*0.134*	*0.116*	*0.060*	*2.69*	*0.17*
Maximum			*82.1*	*92.9*	*31.3*	*19.0*	*37.0*	*90.0*	*43.0*	*44.0*	*19.0*	*28.0*	*25.0*	*42.0*	*47.0*	*28.5*	*29.57*	*19.96*	*17.00*	*13.57*	*1.744*	*0.750*	*64.36*	*30.89*

(1) In the grain size analysis report (included as Attachment B); the stations in that report are refered to as S-__.

(2) Concentrations over 30% in individual samples are color-coded to show dominant concentrations.

(3) Entries in field log. Stations without samples had either hard or rocky bottoms.

44 Extrapolated value

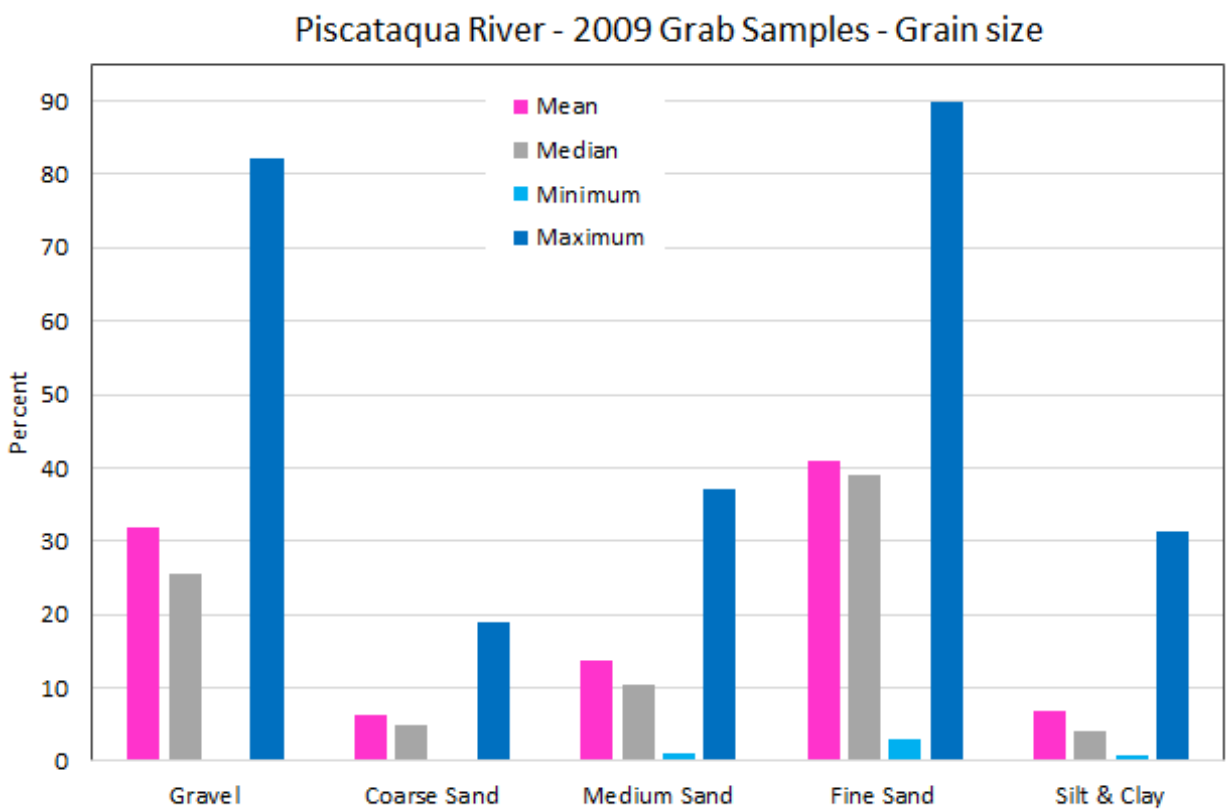

Figure 10. Grain size summary for the 16 grab samples (out of 22 attempts) from the Piscataqua River dredging area, collected in 2009

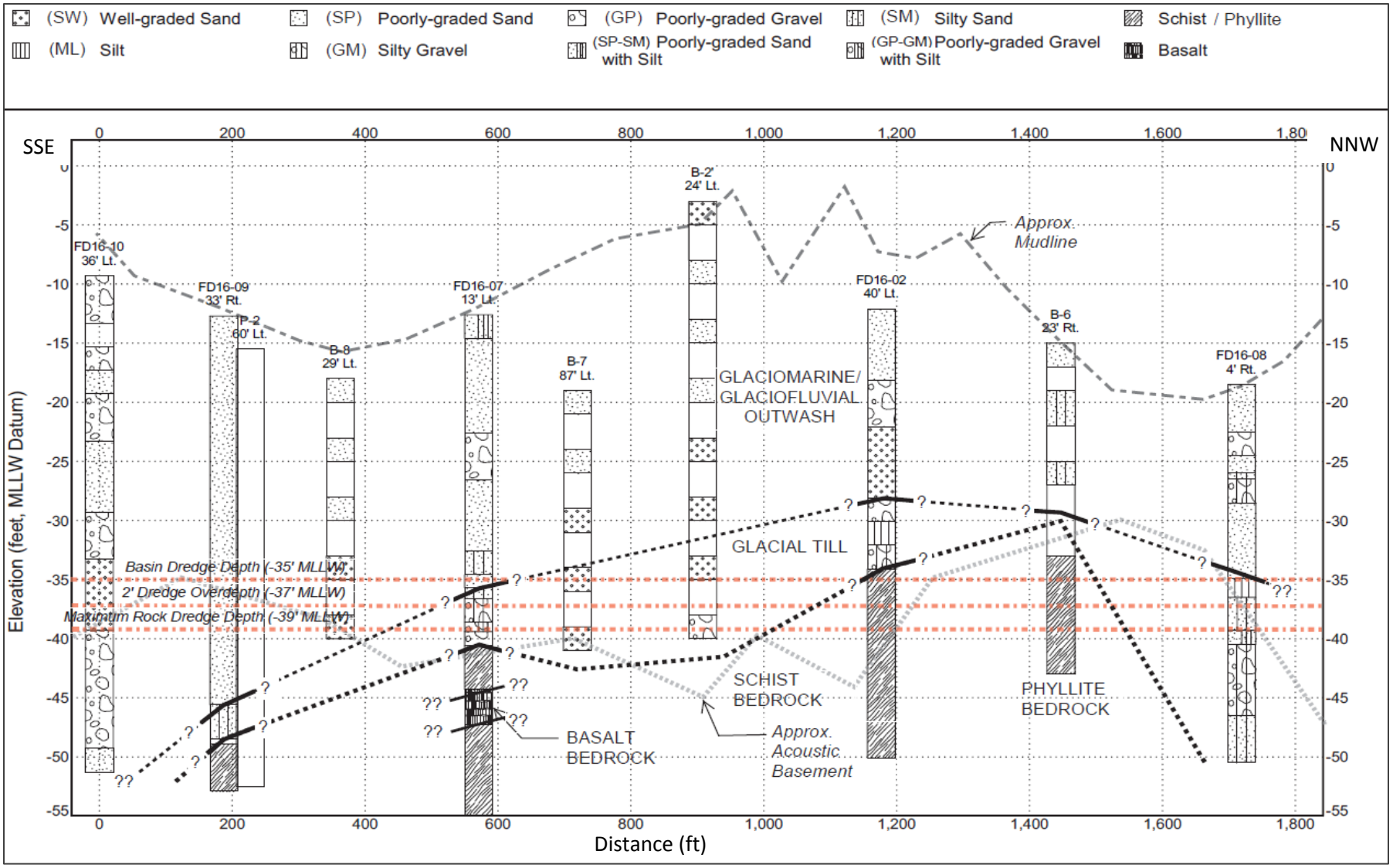

Figure 11. Interpretation of subsurface conditions along a SSE to NNW transect, based on borings in 2007 and 2016. Source: GZA (2016)

Table 6. Sediment type in 2016 borings of dredging area in Piscataqua River (Note: Listed concentrations are based on visual estimates only)

Boring stations in 2016 (from North to South) *(1)*

Depth Interval (from Sediment Surface)	FD16-08 Elev.: -18.5 ft							FD16-01 Elev.: -15.8 ft							FD16-04 Elev.: -18.0 ft							FD16-02 Elev.: -12.1 ft						
	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay
0 - 2	5	90	●	●	●	5		75	20	●	●		5		5	70		●	●	25		40	55	●	●	●	5	
2 - 4	5	90	●	●	●	5		5	90	●	●	●	5			10	●	●	●		90	30	65	●	●	●	5	
4 - 6	80	15	●	●	●	5		10	85		●	●	5			10			●		90	40	55	●	●	●	5	
6 - 8	5	90		●	●	5			95		●	●	5		10	20			●		70	60	35	●	●	●	5	
8 - 10	49	22	●	●	●	29			95		●	●	5			15			●		85	60	35	●	●	●	5	
10 - 12	5	90		●	●	5			95		●	●	5		5	50			●	10	35	10	85	●	●	●	5	
12 - 14	5	90	●	●	●	5			95		●	●	5			90			●	10		20	75	●	●	●	5	
14 - 16	10	85	●	●	●	5			95		●	●	5			90			●	10			95		●	●	5	
16 - 18	14	44	●	●	●	43			95		●	●	5									60	35	●	●	●	5	
18 - 20	25	60	●	●	●	15			95	●	●	●	5			95		●	●	5		10	35	●	●	●	55	
20 - 22	22	65	□	□	●	13			95	●	●	●	5		5	90	●	●	●	5		60	10	●	●	●	30	
22 - 24	60	25	●	●	●	15			95	●	●	●	5		5	90	●	●	●	5		Schist						
24 - 26	60	25	●	●	●	15		13	75	●	●	●	12			95			●	5								
26 - 28	60	25	●	●	●	15		20	65		●	●	15			95			●	5								
28 - 30	30	55	●	●	●	15		25	60	●	●	●	15			95			●	5								
30 - 32	30	55	●	●	●	15		55	30	●	●	●	15			95			●	5								
32 - 34	End of Boring							Cobble, Boulder;							End of Boring													
34 - 36								then bedrock																				
36 - 38																												
38 - 40																												
40 - 42																												
42 - 44																												
44 - 46																												
46 - 48																												
Mean	29	58	●	●	●	13		13	80	□	●	●	7		2	67		□	●	6	25	35	53	●	●	●	12	
Mean	87					13		93					7		69					31		88					12	

Depth Interval (from Sediment Surface)	FD16-05 Elev.: -16.7 ft							FD16-03 *(2)* Elev.: -3.4 ft							FD16-07 Elev.: -12.6 ft							FD16-06 Elev.: -14.2 ft						
	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay
0 - 2	10	20			●		70	40	50	●	●	●	10		15	75	●	●	●	10		5	80			●	15	
2 - 4		22			●		78	18	70	●	●	●	12		25	70	●	●	●	5		5	80			●	15	
4 - 6		70			●	30		15	75			●	10		25	70	●	●	●	5			95		●	●	5	
6 - 8	7	40			●	13	40	15	65	●	●	●	20		40	55	●	●	●	5			95		●	●	5	
8 - 10	5	75			●	20		20	60		●	●	20		40	55	●	●	●	5			95		●	●	5	
10 - 12	10	75			●	15		20	60	●	●	●	20		60	35	●	●	●	5			95		●	●	5	
12 - 14	17	70	□	□	●	13		20	60	●	●	●	20		60	35	●	●	●	5			95		●	●	5	
14 - 16	20	70	●	●	●	10		16	35	●	●	●	4	45	25	70	●	●	●	5			95		●	●	5	
16 - 18	15	75	□	●	●	10		25	55		●	●		20	25	70	●	●	●	5			95		●	●	5	
18 - 20	10	85	□	●	●	5		25	55		●	●		20	10	85	●	●	●	5			95		●	●	5	
20 - 22								35	25		●	●	40		15	65		●	●	20			95		●	●	5	
22 - 24								60	25	●	●		15		12	70	□	●	●	18			95		●	●	5	
24 - 26		95		●	●	5		15	80	●	●	●	5		60	20	●	●	●	20		10	85		●	●	5	
26 - 28		95	●	●	●	5			95	●	●	●	5		80	10	●	●	●	10			95		●	●	5	
28 - 30		95	●	●	●	5		5	90	●	●	●	5		Schist								95	●	●	●	5	
30 - 32									95	●	●	●	5									5	90	●	●	●	5	
32 - 34		95	●	●	●	5			95	●	●	●	5									10	85	●	●	●	5	
34 - 36	End of Boring								95		●	●	5									40	50	●	●	●	10	
36 - 38									95		●	●	5									End of Boring						
38 - 40									95	●	●	●	5															
40 - 42									95	●	●	●	5															
42 - 44								15	50			●	35															
44 - 46								27	63	●	●	●	10															
46 - 48																												
Mean	7	70	□	□	●	10	13	16	69	●	●	●	11	4	35	56	●	●	●	9		4	89	□	●	●	6	
Mean	77					23		85					15		91					9		94					6	

Depth Interval (from Sediment Surface)	FD16-09 Elev.: -12.7 ft							FD16-10 Elev.: -9.3 ft							Depth Interval (from Sediment Surface)
	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	Gravel	Sand	Coarse	Medium	Fine	Silt	Clay	
0 - 2	15	80	●	●	●	5		80	15	●	●	●	5		0 - 2
2 - 4	5	90		●	●	5		60	35	●	●	●	5		2 - 4
4 - 6	5	90		●	●	5									4 - 6
6 - 8	5	90	●	●	●	5		60	35	●	●	●	5		6 - 8
8 - 10	5	90	●	●	●	5		35	60	●	●	●	5		8 - 10
10 - 12	5	90	●	●	●	5		60	35				5		10 - 12
12 - 14	5	90	●	●	●	5		55	40	●	●	●	5		12 - 14
14 - 16	15	80	□	●	●	5		25	70	●	●	●	5		14 - 16
16 - 18	30	65				5		30	70	●	●	●			16 - 18
18 - 20	30	65	●	●	●	5		40	60	●	●	●			18 - 20
20 - 22	20	75	●	●	●	5		70	30	●	●	●			20 - 22
22 - 24	10	85	●	●	●	5		60	40	●	●	●			22 - 24
24 - 26	10	85	●	●	●	5		30	65	●	●	●	5		24 - 26
26 - 28	5	90	●	●	●	5		25	70	●	●	●	5		26 - 28
28 - 30	5	90	●	●	●	5		15	80	●	●	●	5		28 - 30
30 - 32	5	90	●	●	●	5		70	25	●	●	●	5		30 - 32
32 - 34	7	78		●	●	15		70	25	●	●	●	5		32 - 34
34 - 36	30	55		●	●	15		70	25	●	●	●	5		34 - 36
36 - 38	Bedrock							60	35	●	●	●	5		36 - 38
38 - 40								70	25	●	●	●	5		38 - 40
40 - 42								30	65	●	●	●	5		40 - 42
42 - 44								End of Boring							42 - 44
44 - 46															44 - 46
46 - 48															46 - 48
Mean	12	82	□	●	●	6		51	45	●	●	●	4		Mean
Mean	94					6		96					4		Mean

Mean of all samples (based on mean of each boring)	
Gravel	20 %
Sand	67 %
Silt	9 %
Clay	4 %

Mean of all samples from sediment body to be dredged (i.e., to El. -37 ft MLLW)	
Gravel	19 %
Sand	67 %
Silt	8 %
Clay	6 %

Mean of samples from sediment body to be dredged (without Stations FD16-04 and FD16-05)	
Gravel	22 %
Sand	69 %
Silt	8 %
Clay	1 %

Sand Code:

- ● Dominant concentration
- ● Partial concentration
- ■ Not present (individual sample), or comparatively infrequent (used for mean)

Zones:

- Boundary between the strata "Glaciomarine Clay" above and "Glaciofluvial/Glaciomarine Outwash" below.
- Boundary between the strata "Glaciofluvial/Glaciomarine Outwash" above and "Glacial Till" below.
- Bottom of zone to be dredged (i.e., approximate elevation of -37 ft MLLW)

Notes:

(1) Concentrations over 30% in individual samples are color-coded to show dominant concentrations.

(2) Station FD16-03: Depth below 20 ft is 1 ft deeper (i.e., 20-22 ft listed here was 21-23 ft in the field). The shift is due to boulder encountered in the field.

(3) Weighted Mean: Based on the mean values for each station

Source: GZA, 2016

Table 7. Grain size in 2017 borings of dredging area in Piscataqua River (Stations S-01 to S-07)

Station	Sample No.	Grain Size (%)														Particle Size Distribution (mm)						Coefficients	
		Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Confor-mity	C_c Curva-ture
S- 01	0-5 ft	8.5	87.0	4.5	4.0	25.0	58.5	0.0	8.0	4.0	7.0	18.0	29.0	22.0	7.5	1.345	0.404	**0.336**	0.229	0.162	0.127	3.19	1.03
	5-10 ft	12.8	84.7	2.5	6.0	26.0	52.5	7.0	6.0	6.0	9.0	17.0	32.0	18.0	2.5	3.416	0.518	**0.390**	0.282	0.199	0.172	3.02	0.89
S- 02	0-5 ft	9.3	82.8	7.9	2.0	9.0	72.1	2.0	7.0	2.0	2.0	7.0	25.0	35.0	12.1	0.696	0.279	**0.233**	0.174	0.112	0.084	3.31	1.28
	5-10 ft	7.5	89.1	3.4	1.0	17.0	70.6	5.0	3.0	1.0	2.0	15.0	31.0	30.0	9.6	0.713	0.335	**0.283**	0.201	0.156	0.123	2.72	0.98
	10-15 ft	20.5	76.8	2.7	6.0	48.0	23.3	0.0	20.0	6.0	19.0	29.0	14.0	6.0	3.3	6.120	1.074	**0.755**	0.465	0.279	0.209	5.14	0.97
S- 03	0-5 ft	11.5	79.7	8.8	6.0	26.0	48.2	2.0	9.0	6.0	9.0	17.0	14.0	21.0	13.2	2.813	0.473	**0.325**	0.183	0.105	0.080	5.92	0.89
	5-10 ft	0.6	84.1	15.3	0.0	11.0	73.0	1.0	0.0	0.0	2.0	9.0	17.0	34.0	22.0	0.390	0.212	**0.182**	0.120	--	--	--	--
	10-15 ft	9.4	83.3	7.3	2.0	20.0	61.7	4.0	5.0	2.0	5.0	15.0	27.0	24.0	10.7	0.989	0.359	**0.295**	0.195	0.124	0.089	4.01	1.18
	15-20 ft	9.2	84.9	5.9	6.0	45.0	34.1	0.0	9.0	6.0	16.0	29.0	20.0	10.0	4.1	2.115	0.685	**0.537**	0.324	0.195	0.153	4.48	1.00
S- 04	0-3 ft	40.8	38.3	20.9	7.0	14.0	17.0	26.0	15.0	7.0	7.0	7.0	7.0	6.0	4.0	34.203	5.158	**1.578**	0.227	--	--	--	--
S- 05	0-5 ft	29.5	62.2	8.3	8.0	17.0	37.7	13.0	16.0	8.0	8.0	9.0	10.0	16.0	11.7	15.852	1.436	**0.582**	0.206	0.112	0.083	17.30	0.36
	5-10 ft	66.7	27.0	6.3	6.0	10.0	10.7	42.0	25.0	6.0	5.0	5.0	4.0	4.0	2.7	43.700	22.712	**12.024**	2.938	0.316	0.166	137.23	2.30
	10-15 ft	49.7	44.2	6.1	13.0	19.0	11.9	22.0	28.0	13.0	10.0	9.0	6.0	3.0	2.9	41.750	6.913	**4.671**	1.127	0.324	0.185	37.39	0.99
	15-20 ft	42.9	50.5	6.6	10.0	24.0	16.4	6.0	37.0	10.0	13.0	11.0	7.0	5.0	4.4	8.828	5.060	**2.655**	0.656	0.225	0.135	37.56	0.63
	20-25 ft	29.1	62.8	8.1	16.0	31.0	15.9	8.0	21.0	16.0	18.0	13.0	8.0	5.0	2.9	10.443	2.644	**1.588**	0.589	0.216	0.110	23.95	1.19
S- 06	0-5 ft	10.0	36.9	53.1	5.0	8.0	24.0	2.0	8.0	5.0	6.0	2.0	1.0	1.0	22.0	2.054	0.094	--	--	--	--	--	--
	5-10 ft	14.7	69.4	15.9	1.0	4.0	64.0	3.0	12.0	1.0	2.0	2.0	10.0	31.0	23.0	3.879	0.212	**0.180**	0.115	--	--	--	--
	10-12 ft	38.6	38.1	23.3	8.0	12.0	18.0	17.0	22.0	8.0	6.0	6.0	5.0	7.0	6.0	22.716	4.123	**1.306**	0.165	--	--	--	--
S- 07	0-5 ft	11.3	84.9	3.8	2.0	25.0	58.2	8.0	3.0	2.0	6.0	19.0	27.0	23.0	8.2	1.473	0.406	**0.334**	0.223	0.160	0.125	3.25	0.98
	5-10 ft	5.4	89.3	5.3	2.0	27.0	60.7	3.0	2.0	2.0	7.0	20.0	31.0	23.0	6.7	0.810	0.384	**0.323**	0.223	0.159	0.119	3.23	1.09

Table 7 *(cont.)*. **Grain size in 2017 borings of dredging area in Piscataqua River** (Stations S-08 to S-12)

Station	Sample No.	Grain Size (%)														Particle Size Distribution (mm)						Coefficients	
		Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
S- 08	0-5 ft	12.6	80.1	7.3	2.0	11.0	66.7	4.0	9.0	2.0	3.0	8.0	16.0	35.0	15.7	1.790	0.268	**0.222**	0.166	0.105	0.084	3.17	1.21
	5-10 ft	4.7	87.0	8.3	0.0	8.0	78.7	2.0	3.0	0.0	1.0	7.0	17.0	41.0	20.7	0.405	0.221	**0.195**	0.152	0.094	0.080	2.78	1.32
	10-15 ft	0.8	92.1	7.1	0.0	14.0	77.9	0.0	1.0	0.0	3.0	11.0	26.0	37.0	14.9	0.425	0.226	**0.221**	0.168	0.109	0.086	2.98	1.28
	15-20 ft	0.6	92.1	7.3	0.0	4.0	87.7	0.0	1.0	0.0	1.0	3.0	18.0	48.0	21.7	0.314	0.208	**0.187**	0.151	0.096	0.082	2.55	1.35
	20-25 ft	0.3	90.2	9.5	1.0	8.0	81.5	0.0	0.0	1.0	2.0	6.0	21.0	39.0	21.5	0.364	0.218	**0.191**	0.143	0.089	0.076	2.86	1.24
	25-29 ft	4.6	76.2	19.2	3.0	8.0	65.0	1.0	4.0	3.0	4.0	4.0	6.0	30.0	29.0	0.521	0.184	**0.155**	0.097	--	--	--	--
S- 09	0-5 ft	18.8	74.5	6.7	5.0	17.0	52.3	7.0	12.0	5.0	6.0	11.0	21.0	20.0	11.3	7.690	0.455	**0.339**	0.204	0.126	0.092	4.94	0.99
	5-10 ft	21.5	74.0	4.5	9.0	29.0	35.5	5.0	17.0	9.0	14.0	15.0	15.0	12.0	8.5	7.374	1.144	**0.675**	0.297	0.164	0.119	9.60	0.65
	10-15 ft	38.3	55.5	6.2	13.0	28.0	14.8	3.0	35.0	13.0	14.0	14.0	8.0	4.0	2.8	8.666	4.222	**2.173**	0.653	0.282	0.172	24.62	0.59
S- 10	0-5 ft	10.5	83.5	6.0	5.0	35.0	43.0	7.0	4.0	5.0	15.0	20.0	20.0	17.0	6.0	2.270	0.622	**0.436**	0.257	0.162	0.115	5.39	0.92
	5-10 ft	22.3	71.6	6.1	18.0	38.0	15.9	4.0	18.0	18.0	23.0	15.0	8.0	5.0	2.9	6.641	1.974	**1.373**	0.621	0.266	0.162	12.17	1.21
	10-15 ft	5.1	83.5	11.4	1.0	14.0	69.0	1.0	4.0	1.0	2.0	12.0	29.0	28.0	12.0	0.574	0.293	**0.243**	0.170	0.092	--	--	--
	15-20 ft	28.0	67.1	4.9	3.0	16.0	48.1	10.0	18.0	3.0	4.0	12.0	23.0	17.0	8.1	14.337	0.649	**0.397**	0.247	0.161	0.119	5.46	0.79
	20-25 ft	12.3	81.3	6.4	5.0	22.0	54.6	4.0	8.0	5.0	6.0	16.0	25.0	20.0	9.6	2.772	0.413	**0.334**	0.213	0.139	0.097	4.26	1.14
S- 11	0-5 ft	32.8	63.0	4.2	14.0	33.0	15.8	3.0	30.0	14.0	16.0	17.0	9.0	4.0	2.8	11.311	3.028	**1.670**	0.633	0.312	0.217	13.96	0.61
S- 12	0-5 ft	21.6	73.4	5.0	5.0	19.0	49.0	0.0	22.0	5.0	6.0	13.0	22.0	20.0	7.0	7.093	0.576	**0.385**	0.237	0.160	0.120	4.82	0.82
	5-10 ft	4.2	91.7	4.1	2.0	6.0	83.9	0.0	4.0	2.0	1.0	5.0	26.0	41.0	16.9	0.401	0.244	**0.215**	0.168	0.117	0.096	2.56	1.21
	10-15 ft	1.4	94.1	4.5	1.0	10.0	83.5	0.0	1.0	1.0	1.0	9.0	28.0	39.0	16.5	0.401	0.250	**0.219**	0.168	0.115	0.094	2.66	1.20
	15-20 ft	1.6	93.5	4.9	0.0	20.0	73.1	0.0	2.0	0.0	3.0	17.0	32.0	30.0	11.1	0.562	0.315	**0.268**	0.191	0.141	0.103	3.05	1.12
	20-25 ft	0.7	92.0	7.3	1.0	18.0	72.7	0.0	1.0	1.0	3.0	15.0	29.0	29.0	14.7	0.533	0.294	**0.245**	0.173	0.109	0.085	3.45	1.20
	25-30 ft	10.0	82.0	8.0	4.0	29.0	49.0	6.0	4.0	4.0	7.0	22.0	25.0	16.0	8.0	1.797	0.474	**0.369**	0.236	0.140	0.089	5.30	1.32

Table 7 *(cont.)*. **Grain size in 2017 borings of dredging area in Piscataqua River** (Stations S-13 to S-17, and summary statistics)

Station	Sample No.	Grain Size (%)														Particle Size Distribution (mm)						Coefficients	
		Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Confor-mity	C_c Curva-ture
S- 13	0-5 ft	42.5	50.3	7.2	10.0	28.0	12.8	12.0	30.0	10.0	13.0	15.0	6.0	4.0	2.8	17.047	5.366	**2.381**	0.683	0.281	0.151	35.51	0.58
S- 14	0-5 ft	6.0	77.0	17.0	2.0	10.0	65.0	4.0	2.0	2.0	2.0	8.0	22.0	25.0	18.0	0.548	0.250	**0.204**	0.124	--	--	--	--
	5-10 ft	2.1	92.2	5.7	3.0	34.0	55.3	1.0	1.0	3.0	12.0	22.0	22.0	20.0	13.3	0.981	0.415	**0.325**	0.199	0.123	0.094	4.41	1.01
	10-15 ft	3.7	93.2	3.1	10.0	18.0	64.9	0.0	4.0	10.0	10.0	8.0	20.0	32.0	12.9	1.823	0.345	**0.265**	0.188	0.142	0.108	3.18	0.94
	15-20 ft	2.7	92.9	4.4	3.0	47.0	42.6	0.0	3.0	3.0	15.0	32.0	24.0	14.0	4.6	1.213	0.564	**0.453**	0.291	0.185	0.154	3.66	0.97
	20-25 ft	5.3	90.7	4.0	9.0	48.0	34.0	0.0	5.0	9.0	15.0	33.0	21.0	9.0	4.0	1.865	0.674	**0.549**	0.350	0.225	0.172	3.92	1.06
S- 15	0-5 ft	61.2	34.5	4.3	5.0	10.0	19.7	39.0	22.0	5.0	4.0	6.0	13.0	5.0	1.7	40.175	17.220	**9.000**	0.851	0.292	0.220	78.20	0.19
S- 16	0-5 ft	5.5	84.8	9.7	4.0	17.0	63.3	1.0	5.0	4.0	6.0	11.0	20.0	27.0	16.3	0.959	0.303	**0.236**	0.161	0.094	0.076	3.98	1.13
	5-10 ft	13.3	82.1	4.6	4.0	3.0	75.4	1.0	12.0	4.0	1.0	2.0	13.0	45.0	17.4	3.339	0.231	**0.206**	0.164	0.114	0.093	2.47	1.26
	10-15 ft	5.5	91.2	3.3	6.0	44.0	41.7	0.0	5.0	6.0	15.0	29.0	24.0	14.0	3.7	1.560	0.605	**0.476**	0.305	0.203	0.169	3.57	0.91
	15-20 ft	12.2	78.5	9.3	10.0	31.0	37.7	2.0	10.0	10.0	14.0	17.0	13.0	14.0	10.7	3.687	0.718	**0.472**	0.218	0.107	0.078	9.18	0.85
	20-25 ft	8.6	86.4	5.0	9.0	60.0	17.0	1.0	8.0	9.0	29.0	31.0	11.0	4.0	2.0	2.685	1.044	**0.792**	0.505	0.304	0.229	4.57	1.07
S- 17	0-5 ft	1.0	90.2	8.8	1.0	13.0	76.2	0.0	1.0	1.0	3.0	10.0	20.0	33.0	23.2	0.428	0.230	**0.197**	0.142	0.090	0.078	2.96	1.12
	5-10 ft	2.7	91.7	5.6	1.0	14.0	76.4	0.0	3.0	1.0	2.0	12.0	30.0	34.0	12.4	0.502	0.286	**0.241**	0.180	0.128	0.096	2.98	1.17
	10-15 ft	25.8	69.1	5.1	4.0	13.0	51.9	13.0	13.0	4.0	4.0	9.0	18.0	25.0	8.9	16.769	0.550	**0.348**	0.208	0.153	0.109	5.03	0.72

Statistics (all 56 samples)

Mean	**15.7**	**76.1**	**8.3**	**5.1**	**21.3**	**49.6**	**5.4**	**10.3**	**5.1**	**7.8**	**13.5**	**18.3**	**20.7**	**10.6**
Median	**10.0**	**82.5**	**6.3**	**4.0**	**18.0**	**52.4**	**2.0**	**7.5**	**4.0**	**6.0**	**12.0**	**20.0**	**20.0**	**9.6**
Minimum	0.3	27.0	2.5	0.0	3.0	10.7	0.0	0.0	0.0	1.0	2.0	1.0	1.0	1.7
Maximum	66.7	94.1	53.1	18.0	60.0	87.7	42.0	37.0	18.0	29.0	33.0	32.0	48.0	29.0

(1) Concentrations over 30% in individual samples are color-coded to show dominant concentrations.

Table 8. Grain size in 2017 borings of dredging area in Piscataqua River (weighted means per station)

Station	Number of 5-ft core sections	Grain Size (%)														Particle Size Distribution (mm)						Coefficients	
		Sum			Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
S-01	2	10.7	85.9	3.5	5.0	25.5	55.5	3.5	7.0	5.0	8.0	17.5	30.5	20.0	5.0	2.38	0.46	0.36	0.26	0.18	0.15	3.10	0.96
S-02	3	12.4	82.9	4.7	3.0	24.7	55.3	2.3	10.0	3.0	7.7	17.0	23.3	23.7	8.3	2.51	0.56	0.42	0.28	0.18	0.14	3.72	1.08
S-03	4	7.7	83.0	9.3	3.5	25.5	54.3	1.8	5.8	3.5	8.0	17.5	19.5	22.3	12.5	1.58	0.43	0.33	0.21	0.14	0.11	4.80	1.03
S-04	1	40.8	38.3	20.9	7.0	14.0	17.0	26.0	15.0	7.0	7.0	7.0	7.0	6.0	4.0	34.20	5.16	1.58	0.23				
S-05	5	43.6	49.3	7.1	10.6	20.2	18.5	18.2	25.4	10.6	10.8	9.4	7.0	6.6	4.9	24.11	7.75	4.30	1.10	0.24	0.14	50.68	1.09
S-06	3	21.1	48.1	30.8	4.7	8.0	35.3	7.3	14.0	4.7	4.7	3.3	5.3	13.0	17.0	9.55	1.48	0.74	0.14				
S-07	2	8.4	87.1	4.6	2.0	26.0	59.5	5.5	2.5	2.0	6.5	19.5	29.0	23.0	7.5	1.14	0.39	0.33	0.22	0.16	0.12	3.24	1.04
S-08	6	3.9	86.3	9.8	1.0	8.8	76.3	1.2	3.0	1.0	2.3	6.5	17.3	38.3	20.6	0.64	0.22	0.20	0.15	0.10	0.08	2.87	1.28
S-09	3	26.2	68.0	5.8	9.0	24.7	34.2	5.0	21.3	9.0	11.3	13.3	14.7	12.0	7.5	7.91	1.94	1.06	0.38	0.19	0.13	13.05	0.74
S-10	5	15.6	77.4	7.0	6.4	25.0	46.1	5.2	10.4	6.4	10.0	15.0	21.0	17.4	7.7	5.32	0.79	0.56	0.30	0.16	0.12	6.82	1.01
S-11	1	32.8	63.0	4.2	14.0	33.0	15.8	3.0	30.0	14.0	16.0	17.0	9.0	4.0	2.8	11.31	3.03	1.67	0.63	0.31	0.22	13.96	0.61
S-12	6	6.6	87.8	5.6	2.2	17.0	68.5	1.0	5.7	2.2	3.5	13.5	27.0	29.2	12.4	1.80	0.36	0.28	0.20	0.13	0.10	3.64	1.14
S-13	1	42.5	50.3	7.2	10.0	28.0	12.8	12.0	30.0	10.0	13.0	15.0	6.0	4.0	2.8	17.05	5.37	2.38	0.68	0.28	0.15	35.51	0.58
S-14	5	4.0	89.2	6.8	5.4	31.4	52.4	1.0	3.0	5.4	10.8	20.6	21.8	20.0	10.6	1.29	0.45	0.36	0.23	0.17	0.13	3.79	1.00
S-15	1	61.2	34.5	4.3	5.0	10.0	19.7	39.0	22.0	5.0	4.0	6.0	13.0	5.0	1.7	40.18	17.22	9.00	0.85	0.29	0.22	78.20	0.19
S-16	5	9.0	84.6	6.4	6.6	31.0	47.0	1.0	8.0	6.6	13.0	18.0	16.2	20.8	10.0	2.45	0.58	0.44	0.27	0.16	0.13	4.75	1.04
S-17	3	9.8	83.7	6.5	2.0	13.3	68.2	4.3	5.7	2.0	3.0	10.3	22.7	30.7	14.8	5.90	0.36	0.26	0.18	0.12	0.09	3.65	1.00
Mean		**21.0**	**70.6**	**8.5**	**5.7**	**21.5**	**43.3**	**8.1**	**12.9**	**5.7**	**8.2**	**13.3**	**17.1**	**17.4**	**8.8**	**9.96**	**2.74**	**1.43**	**0.37**	**0.19**	**0.14**	**15.45**	**0.92**
Median		**12.4**	**82.9**	**6.5**	**5.0**	**24.7**	**47.0**	**4.3**	**10.0**	**5.0**	**8.0**	**15.0**	**17.3**	**20.0**	**7.7** #	**5.32**	**0.58**	**0.44**	**0.26**	**0.17**	**0.13**	**4.75**	**1.01**
Minimum		3.9	34.5	3.5	1.0	8.0	12.8	1.0	2.5	1.0	2.3	3.3	5.3	4.0	1.7	0.64	0.22	0.20	0.14	0.10	0.08	2.87	0.19
Maximum		61.2	89.2	30.8	14.0	33.0	76.3	39.0	30.0	14.0	16.0	20.6	30.5	38.3	20.6	40.18	17.22	9.00	1.10	0.31	0.22	78.20	1.28

(1) Concentrations over 30% in individual samples are color-coded to show dominant concentrations.

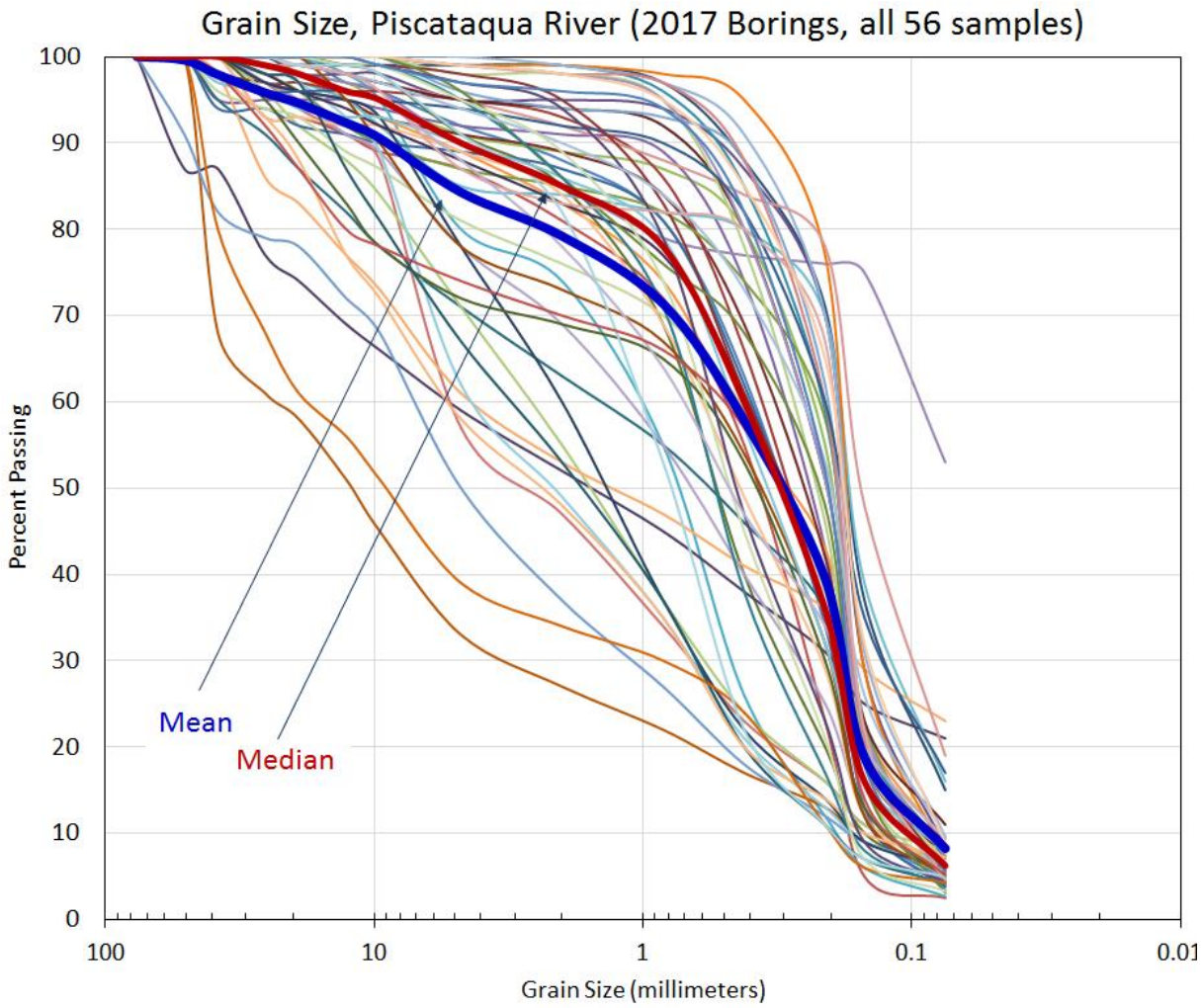

Figure 12. Grain size analysis curves for the 56 samples from the 2017 borings in the Piscataqua River, including mean and median concentrations

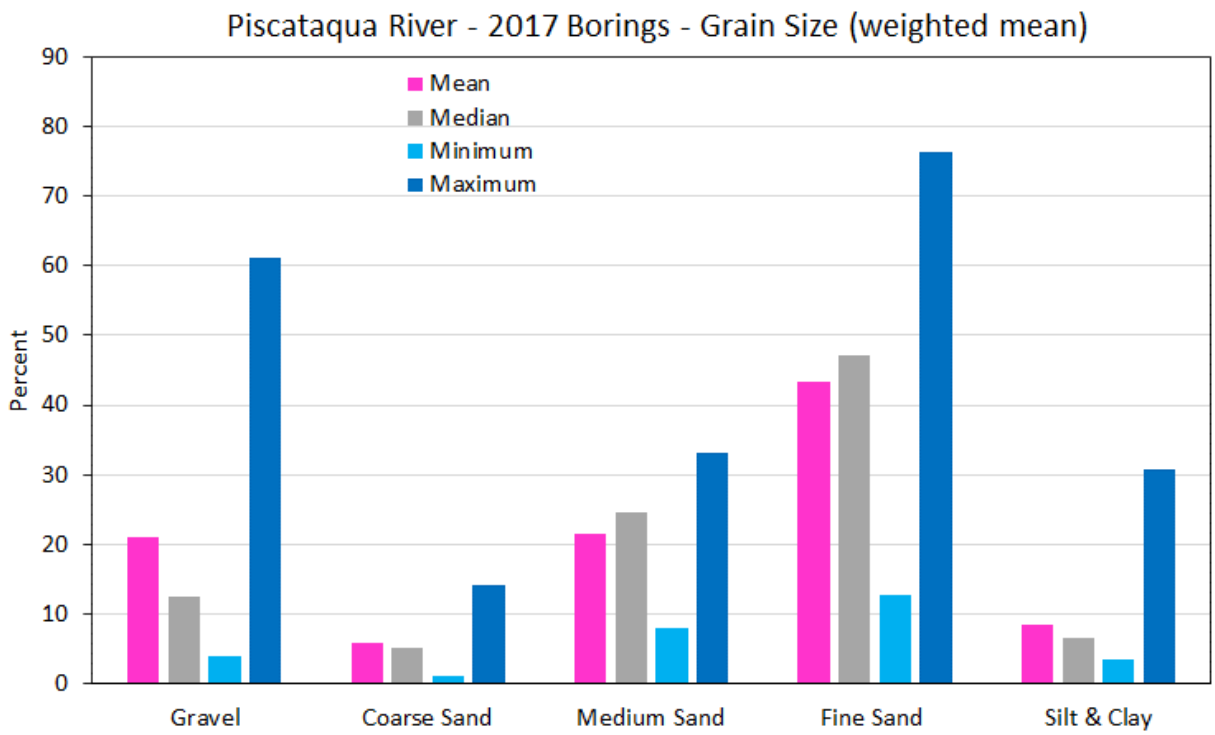

Figure 13. Summary statistics of mean concentrations of the 17 stations of the 2017 borings at the Piscataqua River dredging area

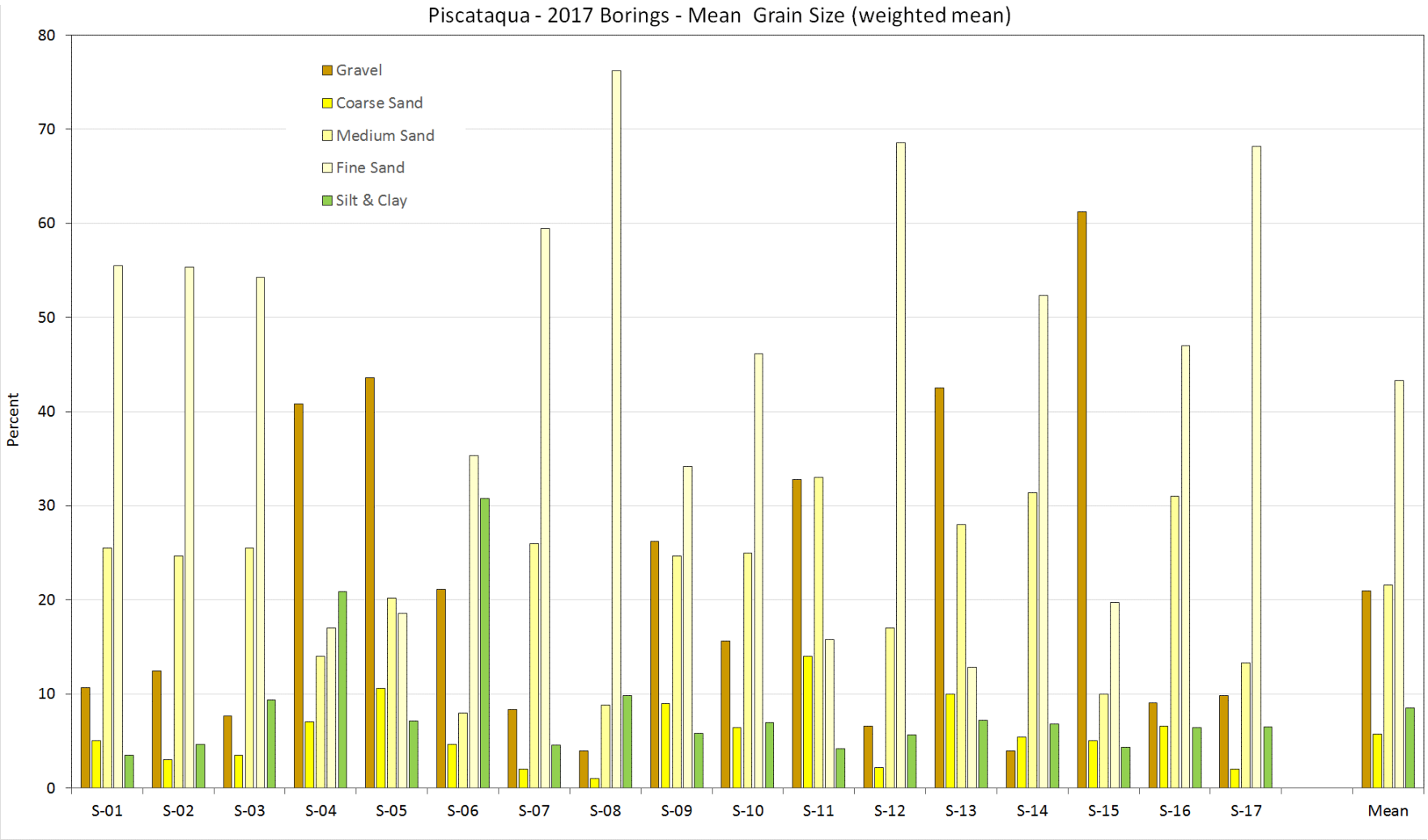

Figure 14. Mean grain size concentration (weighted means) for 2017 boring stations at the Piscataqua River dredging area, as well as weighted mean concentration of all 17 stations

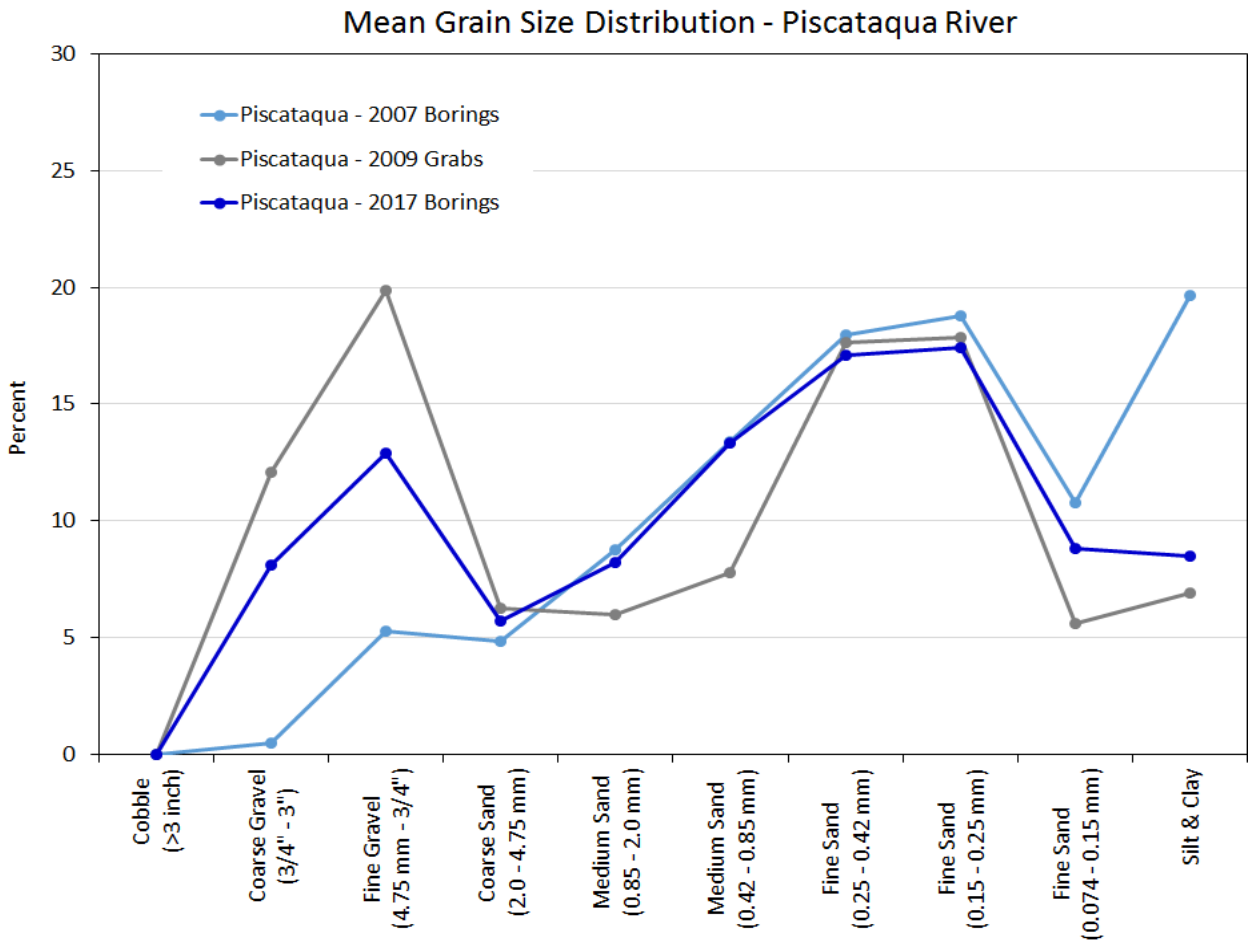

Figure 15. Mean grain size distributions of 2007 and 2017 borings and 2009 grab samples at the Piscataqua River dredging area

s

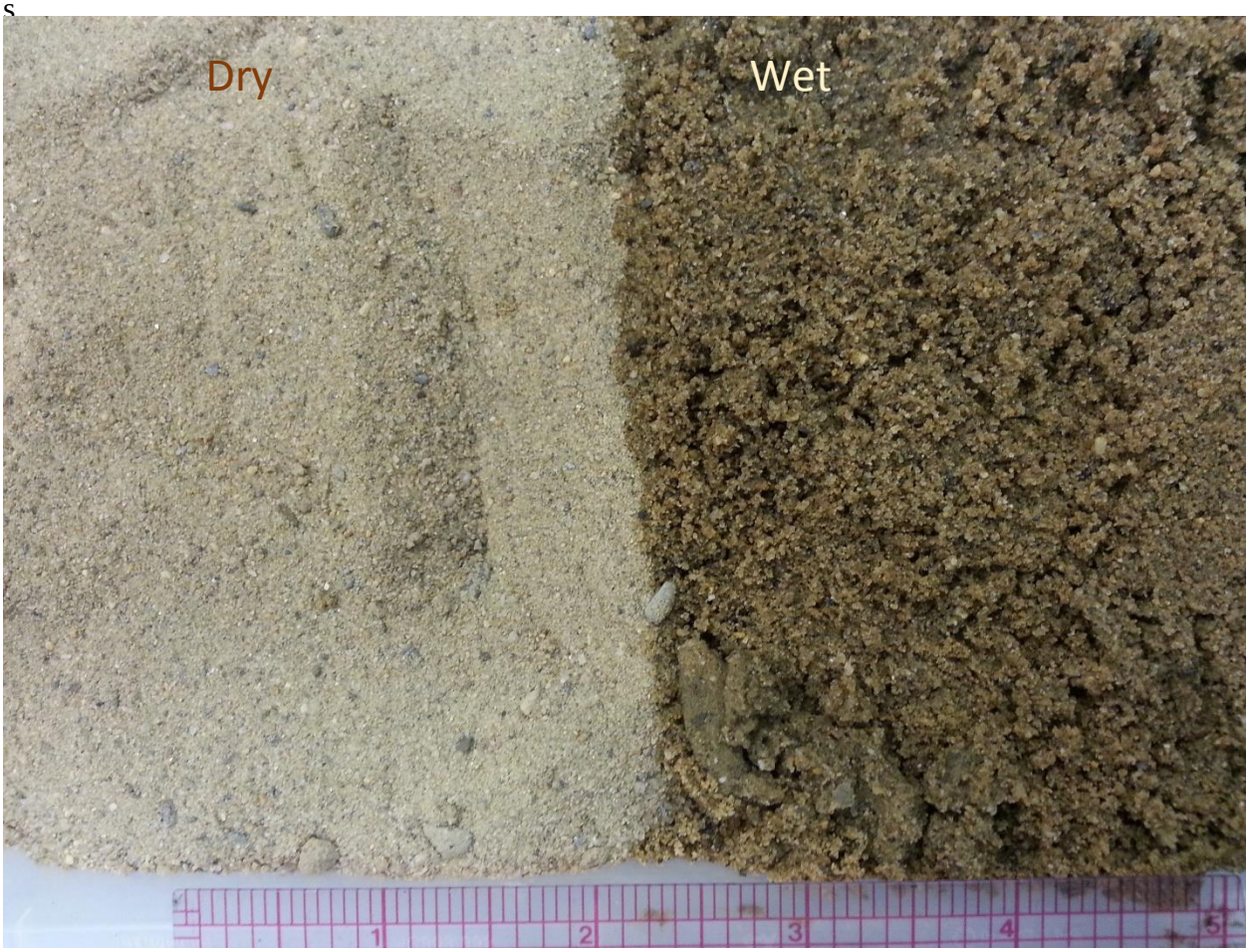

Figure 16. Color of Sample S-12, 20-25 ft (in wet and dry state) from the Piscataqua River site. This sample is considered representative of most of the sediment samples.

4. Physical Characteristics of Nantasket Beach Sediments

This section describes the physical characteristics of the sediment at Nantasket Beach, sampled in 2004 and 2005 from test pits, as well as cores and grab samples collected along transects (USACE, 2006).

4.1 Grain Size

Grain size data for the test pits are presented in Table 9. Grain size data for coring and grab sampling stations of Transects 3, 5 and 7 are presented in Tables 10 to 12, respectively; these data are summarized for each zone in Table 13 for mean values and in Table 14 for median values.

- ***Test Pits:*** Sediment in the test pits consisted of 1.6% cobble, 22.3% gravel, 75.6% sand, and 0.5% silt/clay (mean concentrations of 14 sample analyses from the seven pits) (Table 9). Most of the sand consisted of fine sand (66%), with the fine sand size fraction of 0.15 to 0.25 mm representing 41% of the total sample and the fine sand fraction of 0.25 to 0.42 mm representing 21% of the total sample (Figure 17). Gravel concentrations in test pit samples ranged from 3% to 44%, reflecting the dynamic nature of the beach's sediment environment. Cobble was only found in three of the pit samples. The highest cobble concentration was measured in Sample 7B with 16%, although the second sample from Test Pit #7 (Sample 7A) contained only 1% cobble.

- ***Transects:*** Along the beach and intertidal zone, the sediment consisted predominantly of sand (Tables 10 to 14; Figures 18 to 20). The mean sand, gravel, and silt/clay concentrations were 86%, 13%, and 1%, respectively for the combined beach and intertidal zone (Table 13). The upper 2 ft of the sediment column was generally finer-grained (mean sand and gravel concentrations of 93% and 7%, respectively) than the deeper (2-4 ft) samples (mean sand and gravel concentrations of 79% and 20%, respectively); this is also reflected in Figure 19. The predominant sand fraction was fine sand (mean of 77% in the beach and intertidal zone), specifically the size range of 0.15 to 0.25 mm (mean of 48% in the beach and intertidal zone).

  In the subtidal zone, the grain size distribution was generally similar to the beach and intertidal zone, although the sediment was slightly finer-grained (Figure 21). This was reflected by the higher concentration of the fine sand size fraction of 0.074 to 0.15 mm in the subtidal zone.

4.2 Color

Sediment samples in the test pits were described as gray-brown in the laboratory data sheets; the sediments along the transects were described predominantly as gray, with same samples described as olive-brown to yellow-brown (Attachment E).

Figure 22 is a representative example of the color of the sediment along Nantasket Beach (photographed in February 2018). Using the color scheme of the Munsell Chart, the color of the dry sand (from the beach) is gray; the color of the wet sand (from the intertidal zone is dark gray.

4.3 Physical Suitability of Piscataqua River Sediments for Nantasket Beach - Discussion

This section evaluates the suitability of the Piscataqua River sediment for beach nourishment at Nantasket Beach based on physical characteristics. Mean grain size distributions from surveys at the Piscataqua River site and at Nantasket Beach are shown in Figure 23. Figure 24 shows the most applicable data sets for this suitability assessment, namely the grain size distributions from the beach and intertidal zone and test pits at Nantasket Beach and the 2017 borings at the Piscataqua River site. Grain sizes for the Piscataqua River site and Nantasket Beach by individual size fractions are presented in Figure 25. Considering that the 2007 borings undersampled gravel, the data were also normalized to only the sand and silt/clay fraction; these data (without considering Station B-5) are shown in Figure 26. Main grain size fractions are summarized in Figure 27. The following conclusions can be drawn:

- ***Sand:*** The Piscataqua River sediments are more poorly-sorted than the Nantasket Beach sediments; however, the predominant grain size in the sediments from both sites is fine sand, particularly in the size fraction 0.15 to 0.25 mm. Total concentrations of this fine sand fraction are not as high at the Piscataqua River dredging area as they are at Nantasket Beach; instead, the medium and coarse sand fractions are higher at the Piscataqua River site. The smallest fine sand fraction (0.074 to 0.15 mm) was slightly higher in the Piscataqua River sediments than in the Nantasket Beach test pit sediment samples, but lower than in the beach, intertidal zone, and subtidal zone sediment core and grab samples from Nantasket Beach. Overall, while the predominant sand fraction at both locations is fine sand, the sand in the Piscataqua River sediment is coarser and not as well-sorted as the Nantasket Beach sediments.

- ***Silt/clay:*** The mean silt/clay concentration in the Piscataqua River sediment from 2007 was 20% (Figures 23 and 25), but only 10% without Station B-5 (Figures 24 and 26). A concentration of 10% was also measured in the 2009 grab samples and the 2017 borings. By comparison, the Nantasket Beach samples contained only low concentrations of silt/clay, with only 0.5% in the test pit samples, 1.6% in the beach and intertidal zone samples, and 2.8% in the subtidal zone samples. Therefore, it is likely that Piscataqua River sediment placed on Nantasket Beach would gradually lose much of this size fraction when exposed to wave action and resultant resuspension. A portion of this size fraction would settle in the subtidal zone while the remainder would remain suspended in the water column longer and likely be transported further out to sea. Overall, the difference in silt/clay content between the Piscataqua River sediment and the Nantasket Beach sediment is small. Silt/clay that is resuspended and transported offshore would be accounted for in the placement design by appropriate overfill to reach the target nourishment volumes.

- ***Gravel:*** The mean gravel content observed in the Nantasket Beach sediments was 22% in the test pit samples, 13% in the beach and intertidal zone core samples, and 11% in the subtidal zone core and grab samples. These concentrations are comparable to the mean gravel concentration of 16% found in the 56 Piscataqua River samples from the 2017 borings. Weighted mean gravel concentrations (averaging one mean gravel concentration per boring station) at the Piscataqua River site were 21%.

Similar observations apply for median gravel concentrations. The median gravel concentrations in the Nantasket Beach sediments were 19% in the test pit samples, 9.5% in the beach and intertidal zone core samples, and 3% in the subtidal zone core and grab samples. Median concentrations in the 56 Piscataqua River samples from the 2017 borings were 10%; weighted mean gravel concentrations were 12%.

Generally, the split between fine gravel and coarse gravel was similar as well. Approximately two thirds of the gravel in the 2017 Piscataqua River sediments was fine gravel; the remainder was coarse gravel. The same split was observed in the beach and intertidal zone sediment sampled at Nantasket Beach; the split in the subtidal zone sediments and the pit samples was closer to 50/50.

- ***Cobble:*** Although cobbles accumulate along the seawall at Nantasket Beach, the large test pit samples show that cobble is not abundant on the beach (mean concentration of 1.6% in 14 test pit samples). The amount of cobble in the Piscataqua River sediments is not known. Bottom photographs from 2009 (Attachment D) show that some cobble and rocks can be expected, although the comparatively uniform grain size distribution in many borings suggest that the cobble content in the Piscataqua River sediments is small to minimal. A high cobble concentration in the sediment body to be dredged would probably also have resulted in a higher frequency of refusal during the borings.

- ***Color:*** Dry Piscataqua River sediments are predominantly yellowish brown; wet sediment are predominantly light olive brown. Dry Nantasket Beach sediments are predominantly gray; wet sediments are predominantly dark gray. Overall, the sediments from the Piscataqua River site are more yellowish than the Nantasket River sediments (Figure 28). Over time, gradual bleaching of the Piscataqua River sediment placed at Nantasket Beach would likely change the color to more closely resemble native conditions. Sediment color is determined by chemistry and mineralogy, and bleaching (color change and rate) is determined by chemistry, light, and physical mixing. As these sediments are both of glacial origin and seemingly abundant in quartz and feldspars, it is reasonable to assume that the iron staining would weather from the placed sediment. The combination of exposure to a new chemical environment, light, and physical mixing on a moderate energy beach would lighten the sediment to the natural color of the minerals that make up the sand grains. It is possible that noticeable lightening of the sand would occur in the first year. Lightening would also include dark gray sediment observed during the 2017 borings in the 0-5 ft segment of several stations at the Piscataqua River site. In addition, the placed sediment would mix with native sediment over time, particularly during large storms, further changing the color at the beach back toward native conditions.

In summary, the Piscataqua River sediment is considered suitable for nourishment of Nantasket Beach. The slightly coarser sand size of the Piscataqua River sediments would have the benefit of extending the life expectancy of the nourishment.

Table 9. Grain size of pit samples along Nantasket Beach

Station (#__)	Location	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
		Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0	0.42 - 0.85	0.25 - 0.42	0.15 - 0.25	0.074 - 0.15	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Confor-mity	C_c Curva-ture
1A	Packard Ave	0.0	14.0	86.0	0.0	1.0	4.0	81.0	6.0	8.0	1.0	1.0	3.0	23.0	53.0	5.0	2.000	0.256	**0.231**	0.195	0.170	0.161	0.92	1.59
1B		0.0	8.0	92.0	0.0	0.0	2.0	90.0	2.0	6.0	0.0	1.0	1.0	19.0	64.0	7.0	0.305	0.288	**0.212**	0.184	0.164	0.156	0.96	1.46
Mean for #1		0.0	11.0	89.0	0.0	0.5	3.0	85.5	4.0	7.0	0.5	1.0	2.0	21.0	58.5	6.0	1.153	0.272	**0.222**	0.190	0.167	0.159	0.94	1.53
2A	Revere	0.0	32.0	68.0	0.0	4.0	10.0	54.0	19.0	13.0	4.0	3.0	7.0	32.0	20.0	2.0	23.200	0.746	**0.399**	0.288	0.218	0.195	0.57	3.82
2B	Street	0.0	16.0	84.0	0.0	4.0	4.0	76.0	4.0	12.0	4.0	2.0	2.0	20.0	52.0	4.0	5.430	0.262	**0.235**	0.197	0.172	0.163	0.91	1.61
Mean for #2		0.0	24.0	76.0	0.0	4.0	7.0	65.0	11.5	12.5	4.0	2.5	4.5	26.0	36.0	3.0	14.315	0.504	**0.317**	0.243	0.195	0.179	0.74	2.72
3A	Phipps Street	0.0	39.0	61.0	0.0	2.0	14.0	45.0	20.0	19.0	2.0	3.0	11.0	29.0	14.0	2.0	22.700	3.190	**0.491**	0.321	0.245	0.216	0.15	14.79
3B		0.0	20.0	80.0	0.0	5.0	7.0	68.0	8.0	12.0	4.0	6.0	2.0	19.0	45.0	4.0	10.500	0.300	**0.253**	0.204	0.175	0.165	0.84	1.82
3C		0.0	3.0	96.0	1.0	3.0	9.0	84.0	1.0	2.0	3.0	4.0	5.0	15.0	54.0	15.0	0.425	0.225	**0.205**	0.173	0.148	0.137	0.97	1.64
Mean for #3 (2)		0.0	29.5	70.5	0.0	3.5	10.5	56.5	14.0	15.5	3.0	4.5	6.5	24.0	29.5	3.0	16.600	1.745	**0.372**	0.263	0.210	0.191	0.50	8.31
4A	Mid HRA lot	5.0	7.0	87.0	1.0	1.0	5.0	81.0	6.0	1.0	1.0	1.0	4.0	30.0	47.0	4.0	0.677	0.276	**0.245**	0.201	0.173	0.163	0.90	1.70
4B		0.0	10.0	89.0	1.0	3.0	8.0	78.0	3.0	7.0	3.0	3.0	5.0	21.0	51.0	6.0	1.100	0.256	**0.230**	0.192	0.167	0.157	0.92	1.63
Mean for #4		2.5	8.5	88.0	1.0	2.0	6.5	79.5	4.5	4.0	2.0	2.0	4.5	25.5	49.0	5.0	0.889	0.266	**0.238**	0.197	0.170	0.160	0.91	1.67
5A	Beach Resort	0.0	42.0	58.0	0.0	6.0	15.0	37.0	20.0	22.0	6.0	4.0	11.0	19.0	16.0	2.0	24.200	5.730	**1.200**	0.342	0.232	0.202	0.10	28.31
5B		0.0	44.0	55.0	1.0	4.0	7.0	44.0	23.0	21.0	4.0	2.0	5.0	17.0	22.0	5.0	29.300	6.290	**0.850**	0.262	0.190	0.169	0.06	37.34
Mean for #5		0.0	43.0	56.5	0.5	5.0	11.0	40.5	21.5	21.5	5.0	3.0	8.0	18.0	19.0	3.5	26.750	6.010	**1.025**	0.302	0.211	0.186	0.08	32.83
6A	Wharf Ave	0.0	3.0	96.0	1.0	0.0	4.0	92.0	1.0	2.0	0.0	1.0	3.0	25.0	63.0	4.0	0.312	0.234	**0.217**	0.189	0.168	0.160	0.95	1.46
6B		0.0	27.0	72.0	1.0	3.0	10.0	59.0	13.0	14.0	3.0	4.0	6.0	15.0	38.0	6.0	15.900	0.425	**0.274**	0.206	0.171	0.159	0.63	2.68
Mean for #6		0.0	15.0	84.0	1.0	1.5	7.0	75.5	7.0	8.0	1.5	2.5	4.5	20.0	50.5	5.0	8.106	0.330	**0.246**	0.198	0.170	0.160	0.79	2.07
7A	Berkley Road	1.0	18.0	80.0	1.0	2.0	3.0	75.0	9.0	9.0	2.0	1.0	2.0	18.0	52.0	5.0	10.900	0.256	**0.230**	0.194	0.169	0.159	0.92	1.61
7B		16.0	32.0	51.0	1.0	2.0	1.0	48.0	20.0	12.0	2.0	0.0	1.0	11.0	32.0	5.0	86.800	12.400	**0.850**	0.219	0.177	0.163	0.02	76.12
Mean for #7		8.5	25.0	65.5	1.0	2.0	2.0	61.5	14.5	10.5	2.0	0.5	1.5	14.5	42.0	5.0	48.850	6.328	**0.540**	0.207	0.173	0.161	0.47	38.87
Mean (all 7 pits)		**1.6**	**22.3**	**75.6**	**0.5**	**2.6**	**6.7**	**66.3**	**11.0**	**11.3**	**2.6**	**2.3**	**4.5**	**21.3**	**40.6**	**4.4**	16.666	2.208	**0.423**	0.228	0.185	0.171	0.63	12.57
Median (all 7 pits)		**0.0**	**19.0**	**80.0**	**0.5**	**2.5**	**6.0**	**71.5**	**8.5**	**12.0**	**2.5**	**2.0**	**3.5**	**19.5**	**46.0**	**4.5**	10.700	0.294	**0.249**	0.203	0.173	0.163	0.87	1.76

(1) Concentrations over 30% are color-coded to show dominant concentrations

(2) Samples 3A and 3B only.

Source: USACE, 2006

Table 10. Grain size of sediment samples from Transect #3 along Nantasket Beach

Transect (T-__)	Station	Depth in Sample (feet)	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
			Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
			Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
3	Base of dune	0-1.5	0.0	36.0	63.0	1.0	2.0	21.0	40.0	21.0	15.0	2.0	3.0	18.0	21.0	16.0	3.0	26.900	1.100	**0.575**	0.319	0.220	0.190	0.49	5.77
3		1.8-3.8	0.0	3.0	96.0	1.0	0.0	14.0	82.0	3.0	0.0	0.0	1.0	13.0	42.0	34.0	6.0	0.442	0.311	**0.277**	0.219	0.177	0.161	0.96	1.93
3	Mid berm	0-1.5	0.0	43.0	56.0	1.0	1.0	11.0	44.0	21.0	22.0	1.0	2.0	9.0	19.0	22.0	3.0	29.000	9.520	**0.553**	0.273	0.201	0.180	0.04	52.96
3		1.8-3.3	0.0	22.0	77.0	1.0	3.0	13.0	61.0	10.0	12.0	3.0	3.0	10.0	37.0	21.0	3.0	13.400	0.414	**0.361**	0.271	0.207	0.184	0.96	2.24
3	Berm crest	0.0-1.1	0.0	21.0	78.0	1.0	1.0	4.0	73.0	8.0	13.0	1.0	1.0	3.0	18.0	50.0	5.0	11.700	0.263	**0.234**	0.195	0.169	0.159	0.91	1.65
3		1.3-2.4	0.0	23.0	76.0	1.0	7.0	15.0	54.0	1.0	22.0	7.0	6.0	10.0	25.0	25.0	3.0	8.540	0.523	**0.372**	0.254	0.196	0.177	0.70	2.95
3	MHW	0.0-0.9	0.0	1.0	98.0	1.0	0.0	0.0	98.0	1.0	0.0	0.0	0.0	0.0	11.0	73.0	14.0	0.246	0.211	**0.198**	0.172	0.150	0.140	1.00	1.51
3		1.1-2.1	0.0	33.0	66.0	1.0	6.0	10.0	50.0	12.0	21.0	6.0	4.0	6.0	16.0	29.0	5.0	16.200	1.660	**0.400**	0.229	0.180	0.164	0.19	10.07
3	+2	0.0-2.2	0.0	10.0	89.0	1.0	3.0	5.0	81.0	6.0	4.0	3.0	2.0	3.0	14.0	58.0	9.0	0.850	0.236	**0.219**	0.186	0.161	0.150	0.98	1.57
3																									
3	MSL	0.0-2.2	0.0	3.0	97.0	0.0	2.0	10.0	85.0	0.0	3.0	2.0	4.0	6.0	20.0	52.0	13.0	0.425	0.237	**0.215**	0.180	0.154	0.143	0.95	1.65
3		2.7-4.9	0.0	1.0	98.0	1.0	1.0	4.0	93.0	0.0	1.0	1.0	2.0	2.0	10.0	58.0	25.0	0.260	0.204	**0.188**	0.156	0.133	0.124	0.96	1.65
3	-3	0.0-2.0	0.0	1.0	99.0	0.0	1.0	8.0	90.0	0.0	1.0	1.0	3.0	5.0	10.0	63.0	17.0	0.315	0.217	**0.202**	0.172	0.146	0.135	1.01	1.61
3		2.6-4.6	0.0	6.0	93.0	1.0	2.0	5.0	86.0	4.0	2.0	2.0	2.0	3.0	7.0	49.0	30.0	0.353	0.203	**0.183**	0.148	0.126	0.118	0.92	1.72
3	MLW	0.0-1.0	0.0	0.0	99.0	1.0	1.0	3.0	95.0	0.0	0.0	1.0	1.0	2.0	9.0	60.0	26.0	0.246	0.201	**0.185**	0.154	0.132	0.123	0.96	1.63
3		1.2-2.2	0.0	6.0	93.0	1.0	1.0	2.0	90.0	6.0	0.0	1.0	1.0	1.0	5.0	57.0	28.0	0.248	0.200	**0.183**	0.152	0.128	0.119	0.96	1.68
3	-10	0.0-2.0	0.0	1.0	98.0	1.0	1.0	5.0	92.0	0.0	1.0	1.0	2.0	3.0	8.0	51.0	33.0	0.250	0.193	**0.175**	0.145	0.125	0.118	0.92	1.64
3		2.3-4.3	0.0	5.0	94.0	1.0	1.0	4.0	89.0	3.0	2.0	1.0	2.0	2.0	7.0	55.0	27.0	0.282	0.204	**0.187**	0.153	0.128	0.118	0.97	1.73
3	-15	0.0-1.9	0.0	1.0	98.0	1.0	1.0	4.0	93.0	1.0	0.0	1.0	2.0	2.0	9.0	61.0	23.0	0.250	0.206	**0.190**	0.160	0.134	0.125	0.99	1.66
3		2.1-4.1	0.0	9.0	89.0	2.0	3.0	4.0	82.0	2.0	7.0	3.0	2.0	2.0	3.0	51.0	28.0	0.550	0.204	**0.185**	0.150	0.125	0.115	0.96	1.77
3	-20	0.0-1.8	0.0	0.0	99.0	1.0	0.0	1.0	98.0	0.0	0.0	0.0	1.0	0.0	2.0	47.0	49.0	0.213	0.163	**0.150**	0.130	0.116	0.111	0.94	1.47
3		2.2-4.0	0.0	15.0	83.0	2.0	4.0	3.0	76.0	5.0	10.0	4.0	2.0	1.0	1.0	33.0	42.0	4.750	0.184	**0.160**	0.131	0.113	0.106	0.89	1.73
3	-25	0.0-1.6	0.0	0.0	98.0	2.0	0.0	1.0	97.0	0.0	0.0	0.0	0.0	1.0	1.0	59.0	37.0	0.224	0.181	**0.166**	0.138	0.118	0.110	0.96	1.65
3		1.9	0.0	0.0	97.0	3.0	1.0	1.0	95.0	0.0	0.0	1.0	1.0	0.0	3.0	17.0	75.0	0.177	0.138	**0.131**	0.117	0.105	0.099	1.01	1.39
3	-30	0.0-1.8	0.0	1.0	97.0	2.0	1.0	2.0	94.0	0.0	1.0	1.0	1.0	1.0	2.0	49.0	43.0	0.225	0.172	**0.157**	0.132	0.114	0.108	0.94	1.60
3		2.1-3.9	0.0	24.0	72.0	4.0	5.0	6.0	61.0	15.0	9.0	5.0	4.0	2.0	4.0	14.0	43.0	19.000	0.204	**0.156**	0.127	0.110	0.097	0.82	2.10
3	-35	Ponar	0.0	0.0	97.0	3.0	0.0	0.0	97.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0	58.0	0.192	0.149	**0.139**	0.121	0.107	0.101	0.98	1.48
3																									

(1) Concentrations over 30% are color-coded to show dominant concentrations

Table 11. Grain size of sediment samples from Transect #5 along Nantasket Beach

Transect (T-__)	Station	Depth in Sample (feet)	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
			Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
			Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
5	MHW	0.0-1.6	0.0	0.0	100.0	0.0	1.0	8.0	91.0	0.0	0.0	1.0	6.0	2.0	21.0	63.0	7.0	0.308	0.230	**0.213**	0.185	0.164	0.156	0.96	1.47
5		1.9-3.5	0.0	41.0	58.0	1.0	4.0	5.0	49.0	5.0	36.0	4.0	2.0	3.0	8.0	30.0	11.0	14.000	5.670	**0.425**	0.201	0.158	0.144	0.05	39.33
5	+2	0.0-1.8	0.0	19.0	81.0	0.0	7.0	10.0	64.0	0.0	19.0	7.0	4.0	6.0	13.0	40.0	11.0	6.180	0.311	**0.246**	0.192	0.160	0.147	0.80	2.11
5		2.1-4.0	0.0	29.0	70.0	1.0	4.0	5.0	61.0	12.0	17.0	4.0	2.0	3.0	14.0	33.0	14.0	15.900	0.365	**0.260**	0.189	0.150	0.136	0.72	2.68
5	MSL	0.0-1.8	0.0	27.0	73.0	0.0	4.0	6.0	63.0	0.0	27.0	4.0	3.0	3.0	9.0	45.0	9.0	11.800	0.342	**0.241**	0.198	0.165	0.153	0.75	2.24
5		2.2-4.0	0.0	34.0	65.0	1.0	1.0	4.0	60.0	9.0	25.0	1.0	2.0	2.0	11.0	35.0	14.0	15.000	0.364	**0.250**	0.185	0.150	0.137	0.69	2.65
5	-3	0.0-1.0	0.0	2.0	97.0	1.0	2.0	7.0	88.0	0.0	2.0	2.0	2.0	5.0	15.0	57.0	16.0	0.305	0.218	**0.201**	0.170	0.146	0.136	0.98	1.60
5		1.3-1.9	0.0	50.0	49.0	1.0	3.0	3.0	43.0	29.0	21.0	3.0	1.0	2.0	4.0	23.0	16.0	38.100	13.30	**4.750**	0.198	0.144	0.131	0.02	101.7
5	MLW	0.0-1.9	0.0	5.0	95.0	0.0	2.0	6.0	87.0	0.0	5.0	2.0	2.0	4.0	18.0	55.0	14.0	0.354	0.228	**0.209**	0.176	0.152	0.142	0.96	1.61
5		2.2-4.1	0.0	23.0	76.0	1.0	2.0	5.0	69.0	4.0	19.0	2.0	3.0	2.0	9.0	38.0	22.0	11.800	0.245	**0.209**	0.163	0.135	0.125	0.87	1.95
5	-10	0.0-1.8	0.0	14.0	85.0	1.0	2.0	5.0	78.0	1.0	13.0	2.0	2.0	3.0	9.0	47.0	22.0	3.250	0.226	**0.204**	0.164	0.134	0.123	0.97	1.84
5		1.8-3.9	0.0	19.0	80.0	1.0	2.0	5.0	73.0	3.0	16.0	2.0	2.0	3.0	10.0	42.0	21.0	10.600	0.234	**0.206**	0.165	0.136	0.126	0.92	1.87
5	-15	0.0-1.8	0.0	0.0	99.0	1.0	1.0	2.0	96.0	0.0	0.0	1.0	1.0	1.0	2.0	64.0	30.0	0.234	0.193	**0.178**	0.149	0.126	0.117	0.98	1.65
5		2.3-4.2	0.0	36.0	62.0	2.0	1.0	1.0	60.0	15.0	21.0	1.0	1.0	0.0	2.0	26.0	32.0	19.000	0.250	**0.192**	0.143	0.123	0.116	0.71	2.16
5	-20	0.0-1.9	0.0	0.0	99.0	1.0	0.0	0.0	99.0	0.0	0.0	0.0	0.0	0.0	2.0	49.0	48.0	0.213	0.165	**0.151**	0.130	0.115	0.109	0.94	1.51
5		2.2-4.1	0.0	4.0	94.0	2.0	0.0	1.0	93.0	1.0	3.0	0.0	0.0	1.0	2.0	45.0	46.0	0.223	0.166	**0.152**	0.131	0.117	0.111	0.93	1.50
5	-25	0.0-1.7	0.0	6.0	92.0	2.0	1.0	2.0	89.0	1.0	5.0	1.0	0.0	2.0	5.0	35.0	49.0	0.242	0.163	**0.149**	0.127	0.111	0.105	0.94	1.56
5		2.1-3.8	0.0	16.0	82.0	2.0	1.0	1.0	80.0	6.0	10.0	1.0	0.0	1.0	2.0	26.0	52.0	9.520	0.158	**0.146**	0.127	0.115	0.110	0.93	1.43
5	-30	0.0-2.0	0.0	17.0	81.0	2.0	3.0	6.0	72.0	1.0	16.0	3.0	3.0	3.0	4.0	16.0	52.0	7.620	0.161	**0.144**	0.123	0.107	0.100	0.93	1.61
5		2.4-4.4	0.0	34.0	64.0	2.0	5.0	7.0	52.0	6.0	28.0	5.0	4.0	3.0	3.0	9.0	40.0	15.300	1.690	**0.231**	0.136	0.118	0.111	0.10	15.26
5	-35	Ponar	42.0	56.0	2.0	0.0	1.0	1.0	0.0	53.0	3.0	1.0	1.0	0.0	0.0	0.0	0.0	93.30	77.90	**55.90**	43.20	35.50	28.50	0.84	2.73
5																									

Table 12. Grain size of sediment samples from Transect #7 along Nantasket Beach

Transect (T-__)	Station	Depth in Sample (feet)	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
			Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
			Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
7	MHW	0.0-1.9	0.0	0.0	99.0	1.0	0.0	1.0	98.0	0.0	0.0	0.0	0.0	1.0	25.0	61.0	12.0	0.286	0.222	**0.205**	0.177	0.154	0.144	0.98	1.54
7		1.1-2.0	0.0	17.0	82.0	1.0	3.0	33.0	46.0	4.0	13.0	3.0	8.0	25.0	26.0	18.0	2.0	8.630	0.576	**0.454**	0.301	0.219	0.193	0.81	2.98
7	+2	0.0-1.7	0.0	3.0	97.0	0.0	2.0	3.0	92.0	0.0	3.0	2.0	1.0	2.0	20.0	58.0	14.0	0.304	0.223	**0.206**	0.175	0.152	0.142	0.97	1.57
7		2.1-3.8	0.0	19.0	80.0	1.0	0.0	2.0	78.0	10.0	9.0	0.0	1.0	1.0	8.0	48.0	22.0	11.700	0.224	**0.202**	0.163	0.135	0.124	0.96	1.80
7	MSL	0.0-2.0	0.0	8.0	91.0	1.0	2.0	4.0	85.0	2.0	6.0	2.0	2.0	2.0	20.0	53.0	12.0	0.389	0.234	**0.214**	0.179	0.154	0.143	3.96	1.63
7		2.5-4.5	0.0	28.0	71.0	1.0	4.0	6.0	61.0	24.0	4.0	4.0	3.0	3.0	8.0	37.0	16.0	61.300	0.300	**0.233**	0.178	0.145	0.133	0.80	2.25
7	-3	0.0-1.9	0.0	11.0	88.0	1.0	10.0	19.0	59.0	5.0	6.0	10.0	10.0	9.0	12.0	34.0	13.0	3.310	0.425	**0.261**	0.189	0.153	0.139	0.61	3.05
7		2.3-4.2	0.0	3.0	95.0	2.0	2.0	5.0	88.0	1.0	2.0	2.0	3.0	2.0	4.0	46.0	38.0	0.247	0.183	**0.165**	0.137	0.120	0.114	0.91	1.61
7	MLW	0.0-1.8	0.0	11.0	86.0	3.0	2.0	2.0	82.0	5.0	6.0	2.0	2.0	0.0	3.0	35.0	44.0	0.425	0.170	**0.154**	0.132	0.118	0.112	0.91	1.52
7		2.2-4.0	0.0	2.0	97.0	1.0	2.0	4.0	91.0	1.0	1.0	2.0	2.0	2.0	4.0	68.0	19.0	0.245	0.208	**0.194**	0.166	0.141	0.130	1.02	1.60
7	-10	0.0-1.2	0.0	3.0	95.0	2.0	2.0	2.0	91.0	1.0	2.0	2.0	1.0	1.0	4.0	55.0	32.0	0.241	0.191	**0.174**	0.144	0.124	0.117	0.94	1.63
7		1.5-2.7	0.0	21.0	73.0	6.0	3.0	3.0	67.0	16.0	5.0	3.0	1.0	2.0	4.0	45.0	18.0	31.600	0.228	**0.205**	0.163	0.129	0.114	1.02	2.00
7	-15	0.0-1.8	0.0	1.0	97.0	2.0	1.0	2.0	94.0	0.0	1.0	1.0	1.0	1.0	2.0	55.0	37.0	0.229	0.181	**0.165**	0.139	0.122	0.115	0.93	1.57
7		2.2-4.0	0.0	9.0	86.0	5.0	2.0	2.0	82.0	3.0	6.0	2.0	1.0	1.0	2.0	60.0	20.0	0.250	0.207	**0.191**	0.159	0.130	0.117	1.04	1.77
7	-20	0.0-1.5	0.0	0.0	97.0	3.0	0.0	2.0	95.0	0.0	0.0	0.0	0.0	2.0	4.0	41.0	50.0	0.211	0.158	**0.147**	0.129	0.117	0.113	0.94	1.41
7		1.9-3.4	0.0	3.0	95.0	2.0	1.0	3.0	91.0	2.0	1.0	1.0	1.0	2.0	7.0	48.0	36.0	0.247	0.187	**0.169**	0.139	0.119	0.111	0.92	1.68
7	-25	Ponar	0.0	25.0	74.0	1.0	0.0	4.0	70.0	23.0	2.0	0.0	1.0	3.0	7.0	43.0	20.0	46.300	0.239	**0.213**	0.168	0.138	0.127	0.93	1.88
7																									

(1) Concentrations over 30% are color-coded to show dominant concentrations

Table 13. Mean grain size of multiple sediment cores along three transects at Nantasket Beach

Transect / Zone	Sample Position in Core	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
		Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
Transect 3 - Dune and Berm	Upper	0.0	33.3	65.7	1.0	1.3	12.0	52.3	16.7	16.7	1.3	2.0	10.0	19.3	29.3	3.7	22.533	3.628	0.454	0.262	0.197	0.176	0.48	20.13
	Lower	0.0	16.0	83.0	1.0	3.3	14.0	65.7	4.7	11.3	3.3	3.3	11.0	34.7	26.7	4.0	7.461	0.416	0.337	0.248	0.193	0.174	0.87	2.37
	Both	**0.0**	**24.7**	**74.3**	**1.0**	**2.3**	**13.0**	**59.0**	**10.7**	**14.0**	**2.3**	**2.7**	**10.5**	**27.0**	**28.0**	**3.8**	14.997	2.022	**0.395**	0.255	0.195	0.175	0.68	11.25
Transect 3 - Beach and Intertidal	Upper	0.0	3.0	96.4	0.6	1.4	5.2	89.8	1.4	1.6	1.4	2.0	3.2	12.8	61.2	15.8	0.416	0.220	0.204	0.173	0.149	0.138	0.98	1.59
	Lower	0.0	11.5	87.5	1.0	2.5	5.3	79.8	5.5	6.0	2.5	2.3	3.0	9.5	48.3	22.0	4.265	0.567	0.239	0.171	0.142	0.131	0.76	3.78
	Both	**0.0**	**6.8**	**92.4**	**0.8**	**1.9**	**5.2**	**85.3**	**3.2**	**3.6**	**1.9**	**2.1**	**3.1**	**11.3**	**55.4**	**18.6**	2.127	0.374	**0.219**	0.172	0.146	0.135	0.88	2.57
Transect 3 - Subtidal	Upper	0.0	0.5	97.8	1.7	0.5	2.2	95.2	0.2	0.3	0.5	1.0	1.2	3.7	51.0	40.5	0.226	0.177	0.163	0.138	0.119	0.112	0.96	1.58
	Lower	0.0	10.6	87.0	2.4	2.8	3.6	80.6	5.0	5.6	2.8	2.2	1.4	3.6	34.0	43.0	4.952	0.187	0.164	0.136	0.116	0.107	0.93	1.74
	Both	**0.0**	**5.1**	**92.9**	**2.0**	**1.5**	**2.8**	**88.5**	**2.4**	**2.7**	**1.5**	**1.5**	**1.3**	**3.6**	**43.3**	**41.6**	2.374	0.182	**0.163**	0.137	0.118	0.110	0.94	1.66
Transect 5 - Beach and Intertidal	Upper	0.0	10.6	89.2	0.2	3.2	7.4	78.6	0.0	10.6	3.2	3.4	4.0	15.2	52.0	11.4	3.789	0.266	0.222	0.184	0.157	0.147	0.89	1.81
	Lower	0.0	35.4	63.6	1.0	2.8	4.4	56.4	11.8	23.6	2.8	2.0	2.4	9.2	31.8	15.4	18.960	3.989	1.179	0.187	0.147	0.135	0.47	29.66
	Both	**0.0**	**23.0**	**76.4**	**0.6**	**3.0**	**5.9**	**67.5**	**5.9**	**17.1**	**3.0**	**2.7**	**3.2**	**12.2**	**41.9**	**13.4**	11.375	2.127	**0.700**	0.186	0.152	0.141	0.68	15.73
Transect 5 - Subtidal	Upper	7.0	15.5	76.3	1.2	1.3	2.7	72.3	9.3	6.2	1.3	1.2	1.5	3.7	35.2	33.5	17.477	13.135	9.454	7.316	6.016	4.842	0.93	1.82
	Lower	0.0	21.8	76.4	1.8	1.8	3.0	71.6	6.2	15.6	1.8	1.4	1.6	3.8	29.6	38.2	10.929	0.500	0.185	0.140	0.122	0.115	0.72	4.44
	Both	**3.8**	**18.4**	**76.4**	**1.5**	**1.5**	**2.8**	**72.0**	**7.9**	**10.5**	**1.5**	**1.3**	**1.5**	**3.7**	**32.6**	**35.6**	14.500	7.391	**5.241**	4.054	3.337	2.693	0.84	3.01
Transect 7 - Beach and Intertidal	Upper	0.0	6.6	92.2	1.2	3.2	5.8	83.2	2.4	4.2	3.2	3.0	2.8	16.0	48.2	19.0	0.943	0.255	0.208	0.170	0.146	0.136	1.49	1.86
	Lower	0.0	13.8	85.0	1.2	2.2	10.0	72.8	8.0	5.8	2.2	3.4	6.6	10.0	43.4	19.4	16.424	0.298	0.250	0.189	0.152	0.139	0.90	2.05
	Both	**0.0**	**10.2**	**88.6**	**1.2**	**2.7**	**7.9**	**78.0**	**5.2**	**5.0**	**2.7**	**3.2**	**4.7**	**13.0**	**45.8**	**19.2**	8.684	0.277	**0.229**	0.180	0.149	0.137	1.19	1.96
Transect 7 - Subtidal	Upper	0.0	7.3	90.8	2.0	0.8	2.5	87.5	6.0	1.3	0.8	0.8	1.8	4.3	48.5	34.8	11.745	0.192	0.175	0.145	0.125	0.118	0.94	1.62
	Lower	0.0	11.0	84.7	4.3	2.0	2.7	80.0	7.0	4.0	2.0	1.0	1.7	4.3	51.0	24.7	10.699	0.207	0.188	0.154	0.126	0.114	0.99	1.82
	Both	**0.0**	**8.9**	**88.1**	**3.0**	**1.3**	**2.6**	**84.3**	**6.4**	**2.4**	**1.3**	**0.9**	**1.7**	**4.3**	**49.6**	**30.4**	11.297	0.199	**0.181**	0.149	0.126	0.116	0.96	1.71
All 3 Transects - Beach and Intertidal	Upper	0.0	6.7	92.6	0.7	2.6	6.1	83.9	1.3	5.5	2.6	2.8	3.3	14.7	53.8	15.4	1.716	0.247	0.211	0.176	0.151	0.140	1.12	1.75
	Lower	0.0	20.2	78.7	1.1	2.5	6.6	69.7	8.4	11.8	2.5	2.6	4.0	9.6	41.2	18.9	13.217	1.618	0.556	0.182	0.147	0.135	0.71	11.83
	Both	**0.0**	**13.3**	**85.8**	**0.9**	**2.5**	**6.3**	**76.9**	**4.8**	**8.6**	**2.5**	**2.7**	**3.7**	**12.2**	**47.7**	**17.1**	7.395	0.926	**0.383**	0.179	0.149	0.138	0.92	6.75
All 3 Transects - Subtidal	Upper	2.3	7.8	88.3	1.6	0.9	2.4	85.0	5.2	2.6	0.9	1.0	1.5	3.9	44.9	36.3	9.816	4.501	3.264	2.533	2.087	1.691	0.94	1.67
	Lower	0.0	14.5	82.7	2.8	2.2	3.1	77.4	6.1	8.4	2.2	1.5	1.6	3.9	38.2	35.3	8.860	0.298	0.179	0.143	0.121	0.112	0.88	2.67
	Both	**1.3**	**10.8**	**85.8**	**2.2**	**1.5**	**2.7**	**81.6**	**5.6**	**5.2**	**1.5**	**1.2**	**1.5**	**3.9**	**41.8**	**35.9**	9.390	2.591	**1.862**	1.447	1.193	0.973	0.91	2.12

(1) Concentrations over 30% are color-coded to show dominant concentrations

Source: USACE, 2006

Table 14. Median grain size of multiple sediment cores along three transects at Nantasket Beach

Transect / Zone	Sample Position in Core	Grain Size (%) (1)															Particle Size Distribution (mm)						Coefficients	
		Sum				Sand by Main Fraction			Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand		Fine Sand										
		Cobble (>3 inch)	Gravel	Sand	Silt & Clay	Coarse Sand	Medium Sand	Fine Sand	3/4" - 3"	4.75 mm - 3/4"	2.0 - 4.75 mm	0.85 - 2.0 mm	0.42 - 0.85 mm	0.25 - 0.42 mm	0.15 - 0.25 mm	0.074 - 0.15 mm	D_{85}	D_{60}	D_{50} Median	D_{30}	D_{15}	D_{10}	C_u Conformity	C_c Curvature
Transect 3 - Dune and Berm	Upper	0.0	36.0	63.0	1.0	2.0	13.0	44.0	21.0	15.0	2.0	3.0	10.0	21.0	21.0	3.0	26.900	1.100	0.553	0.273	0.207	0.184	0.49	5.77
	Lower	0.0	21.0	78.0	1.0	1.0	13.0	73.0	8.0	12.0	1.0	1.0	10.0	37.0	34.0	5.0	11.700	0.311	0.277	0.219	0.177	0.161	0.96	1.93
	Both	**0.0**	**22.5**	**76.5**	**1.0**	**1.5**	**13.5**	**57.5**	**9.0**	**14.0**	**1.5**	**2.5**	**10.0**	**23.0**	**23.5**	**3.0**	12.550	0.469	**0.367**	0.263	0.199	0.179	0.81	2.60
Transect 3 - Beach and Intertidal	Upper	0.0	1.0	98.0	1.0	1.0	5.0	90.0	0.0	1.0	1.0	2.0	3.0	11.0	60.0	14.0	0.315	0.217	0.202	0.172	0.150	0.140	0.98	1.61
	Lower	0.0	6.0	93.0	1.0	1.5	4.5	88.0	5.0	1.5	1.5	2.0	2.5	8.5	53.0	26.5	0.307	0.204	0.186	0.154	0.131	0.122	0.94	1.70
	Both	**0.0**	**3.0**	**97.0**	**1.0**	**1.0**	**5.0**	**90.0**	**1.0**	**1.0**	**1.0**	**2.0**	**3.0**	**10.0**	**58.0**	**17.0**	0.315	0.211	**0.198**	0.172	0.146	0.135	0.96	1.65
Transect 3 - Subtidal	Upper	0.0	0.5	98.0	1.5	0.5	1.5	95.5	0.0	0.0	0.5	1.0	1.0	2.0	50.0	40.0	0.225	0.177	0.162	0.135	0.117	0.111	0.95	1.62
	Lower	0.0	12.0	86.0	2.5	3.5	3.5	79.0	3.5	8.0	3.5	2.0	1.5	3.0	25.0	42.5	2.650	0.194	0.158	0.129	0.112	0.103	0.93	1.75
	Both	**0.0**	**1.0**	**97.0**	**2.0**	**1.0**	**3.0**	**93.0**	**0.0**	**1.0**	**1.0**	**2.0**	**1.0**	**3.0**	**49.0**	**42.0**	0.250	0.184	**0.160**	0.132	0.116	0.110	0.96	1.65
Transect 5 - Beach and Intertidal	Upper	0.0	5.0	95.0	0.0	2.0	7.0	87.0	0.0	5.0	2.0	3.0	4.0	15.0	55.0	11.0	0.354	0.230	0.213	0.185	0.160	0.147	0.96	1.61
	Lower	0.0	34.0	65.0	1.0	3.0	5.0	60.0	9.0	21.0	3.0	2.0	2.0	9.0	33.0	14.0	15.000	0.365	0.260	0.189	0.150	0.136	0.69	2.68
	Both	**0.0**	**25.0**	**74.5**	**1.0**	**2.5**	**5.5**	**63.5**	**2.0**	**19.0**	**2.5**	**2.0**	**3.0**	**12.0**	**39.0**	**14.0**	11.800	0.327	**0.244**	0.187	0.151	0.140	0.78	2.18
Transect 5 - Subtidal	Upper	0.0	10.0	88.5	1.0	1.0	2.0	83.5	1.0	4.0	1.0	1.0	1.5	3.0	41.0	39.0	1.746	0.179	0.165	0.140	0.121	0.113	0.94	1.63
	Lower	0.0	19.0	80.0	2.0	1.0	1.0	73.0	6.0	16.0	1.0	1.0	1.0	2.0	26.0	40.0	10.600	0.234	0.192	0.136	0.118	0.111	0.92	1.87
	Both	**0.0**	**16.0**	**82.0**	**2.0**	**1.0**	**2.0**	**78.0**	**1.0**	**10.0**	**1.0**	**1.0**	**1.0**	**2.0**	**35.0**	**40.0**	7.620	0.193	**0.178**	0.136	0.118	0.111	0.93	1.65
Transect 7 - Beach and Intertidal	Upper	0.0	8.0	91.0	1.0	2.0	3.0	85.0	2.0	6.0	2.0	2.0	2.0	20.0	53.0	13.0	0.389	0.223	0.206	0.177	0.153	0.142	0.97	1.57
	Lower	0.0	17.0	82.0	1.0	2.0	5.0	78.0	4.0	4.0	2.0	3.0	2.0	8.0	46.0	19.0	8.630	0.224	0.202	0.166	0.141	0.130	0.91	1.80
	Both	**0.0**	**9.5**	**89.5**	**1.0**	**2.0**	**4.0**	**83.5**	**3.0**	**5.0**	**2.0**	**2.0**	**2.0**	**10.0**	**47.0**	**15.0**	0.407	0.224	**0.206**	0.176	0.149	0.136	0.94	1.62
Transect 7 - Subtidal	Upper	0.0	2.0	96.0	2.0	0.5	2.0	92.5	0.5	1.5	0.5	1.0	1.5	4.0	49.0	34.5	0.235	0.186	0.170	0.142	0.123	0.116	0.94	1.60
	Lower	0.0	9.0	86.0	5.0	2.0	3.0	82.0	3.0	5.0	2.0	1.0	2.0	4.0	48.0	20.0	0.250	0.207	0.191	0.159	0.129	0.114	1.02	1.77
	Both	**0.0**	**3.0**	**95.0**	**2.0**	**1.0**	**2.0**	**91.0**	**2.0**	**2.0**	**1.0**	**1.0**	**2.0**	**4.0**	**48.0**	**32.0**	0.247	0.191	**0.174**	0.144	0.124	0.115	0.94	1.68
All 3 Transects - Beach and Intertidal	Upper	0.0	5.0	95.0	1.0	2.0	5.0	87.0	0.0	5.0	2.0	2.0	3.0	15.0	55.0	13.0	0.354	0.223	0.206	0.177	0.153	0.142	0.97	1.61
	Lower	0.0	17.0	82.0	1.0	2.0	5.0	78.0	5.0	4.0	2.0	2.0	2.0	8.5	46.0	19.0	8.630	0.224	0.202	0.166	0.141	0.130	0.91	1.80
	Both	**0.0**	**9.5**	**89.5**	**1.0**	**2.0**	**5.0**	**83.5**	**2.0**	**5.0**	**2.0**	**2.0**	**3.0**	**10.0**	**47.0**	**15.0**	0.407	0.224	**0.206**	0.176	0.149	0.136	0.94	1.65
All 3 Transects - Subtidal	Upper	0.0	2.0	96.0	1.5	0.5	2.0	92.5	0.5	1.5	0.5	1.0	1.5	3.0	49.0	39.0	0.235	0.179	0.165	0.140	0.121	0.113	0.94	1.62
	Lower	0.0	12.0	86.0	2.5	2.0	3.0	79.0	3.5	8.0	2.0	1.0	1.5	3.0	26.0	40.0	2.650	0.207	0.191	0.136	0.118	0.111	0.93	1.77
	Both	**0.0**	**3.0**	**95.0**	**2.0**	**1.0**	**2.0**	**91.0**	**1.0**	**2.0**	**1.0**	**1.0**	**1.0**	**3.0**	**48.0**	**40.0**	0.250	0.191	**0.174**	0.136	0.118	0.111	0.94	1.65

(1) Concentrations over 30% are color-coded to show dominant concentrations

Source: USACE, 2006

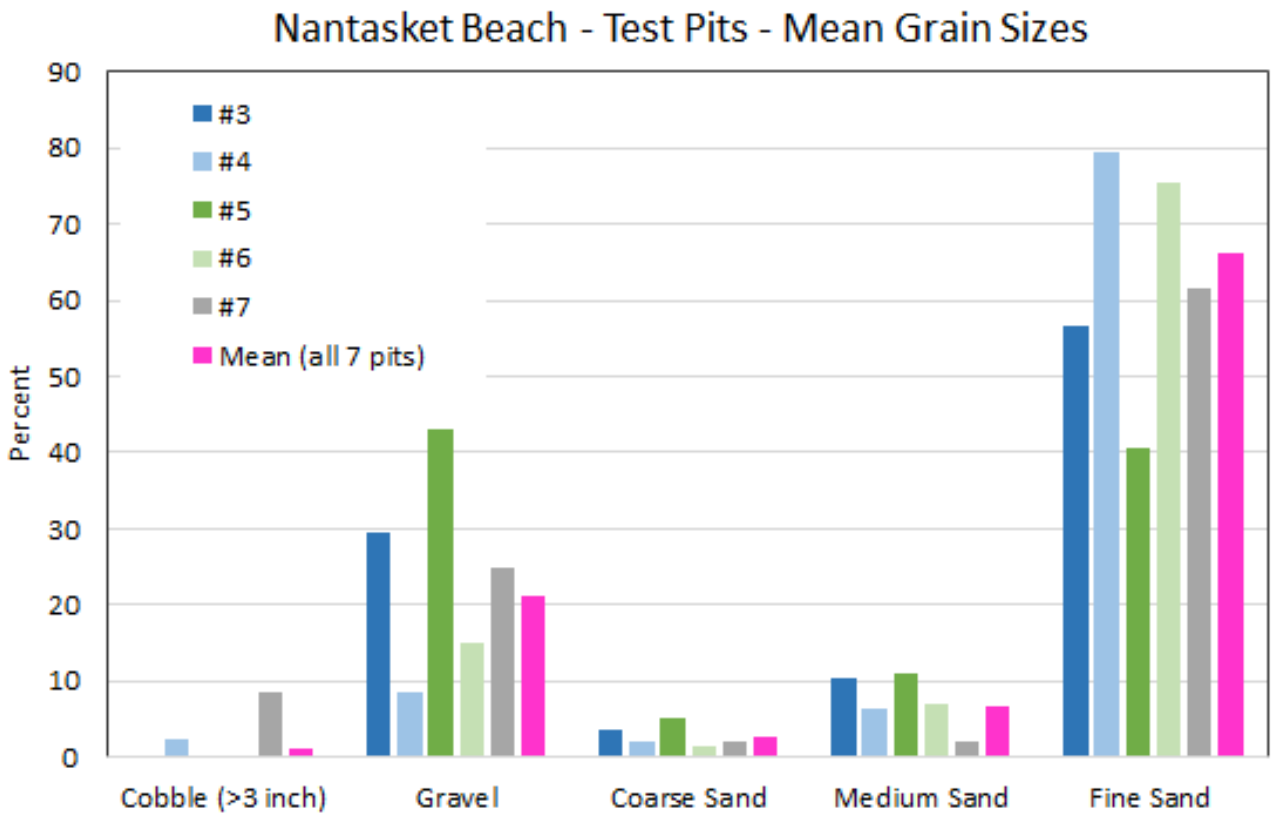

Figure 17. Mean grain size for each test pit along Nantasket Beach. Test pits are arranged on this graph from north (Station #3 on the left) to south (Station #7 on the right)

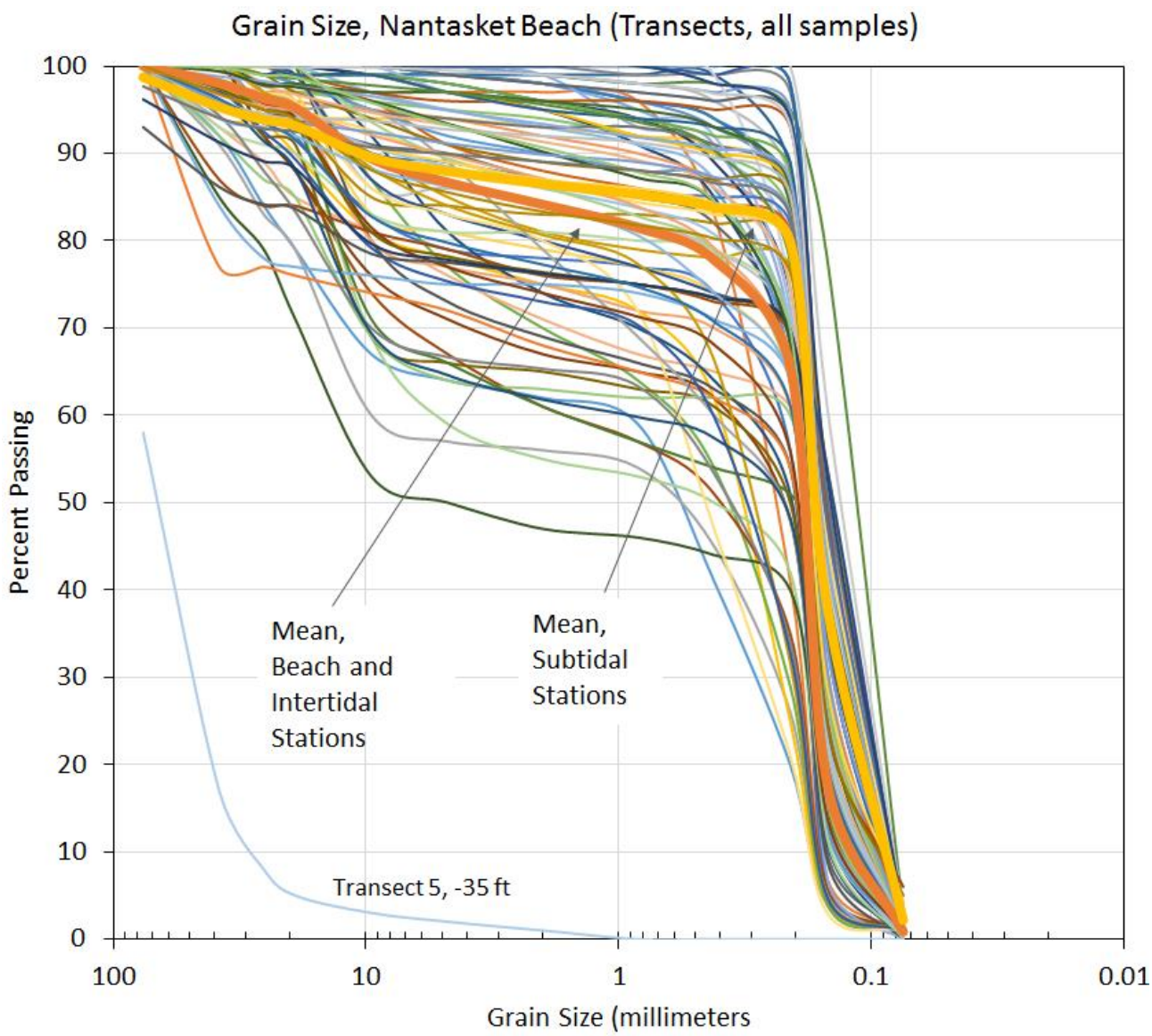

Figure 18. Grain size analysis curves for all samples from the 2005 transects at Nantasket Beach, including mean concentrations for the beach and intertidal zone, and the subtidal zone

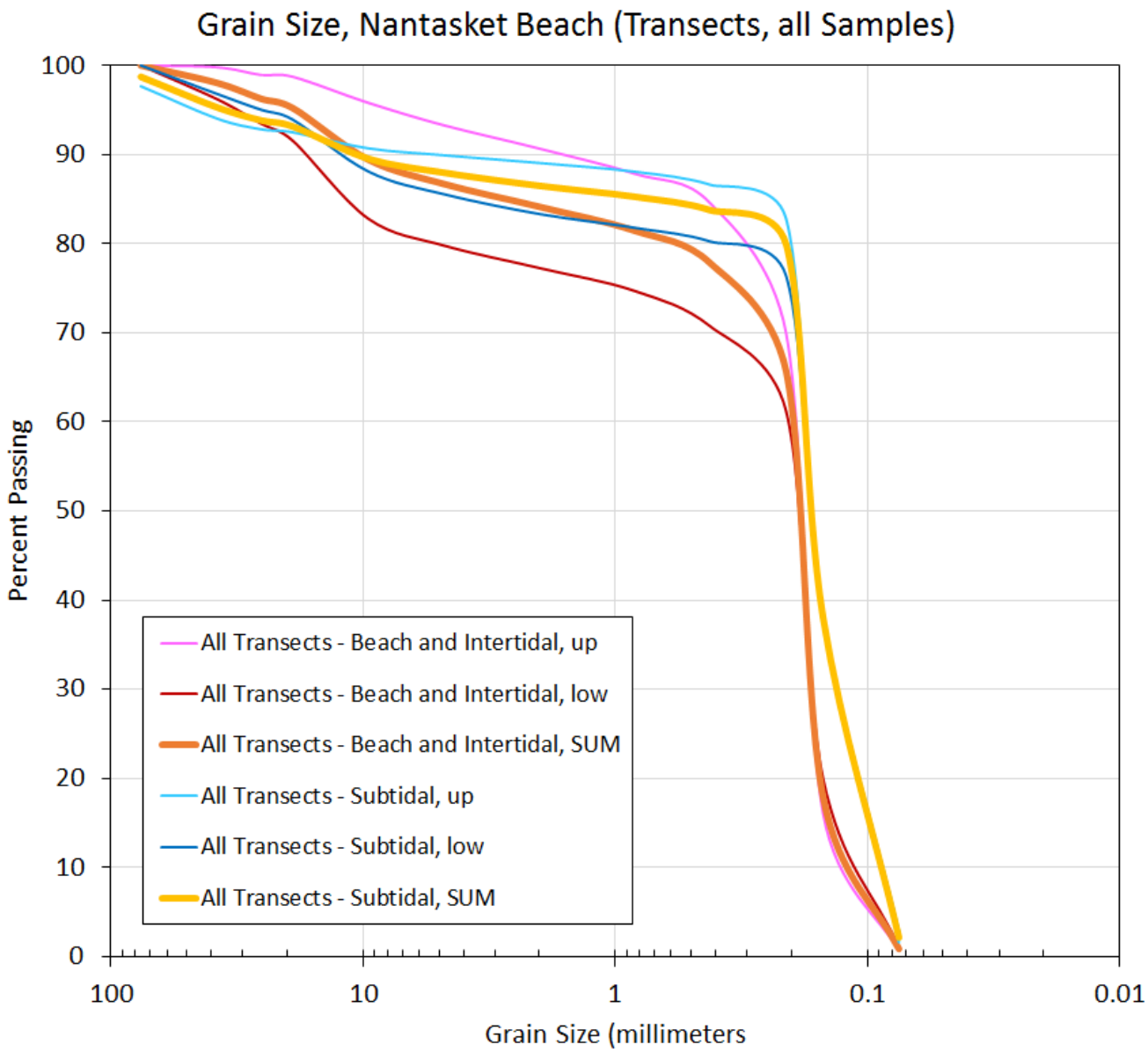

Figure 19. Mean grain size distributions for all samples from the 2005 transects at Nantasket Beach for the beach and intertidal zone, and the subtidal zone (upper sample, lower sample, and both samples combined)

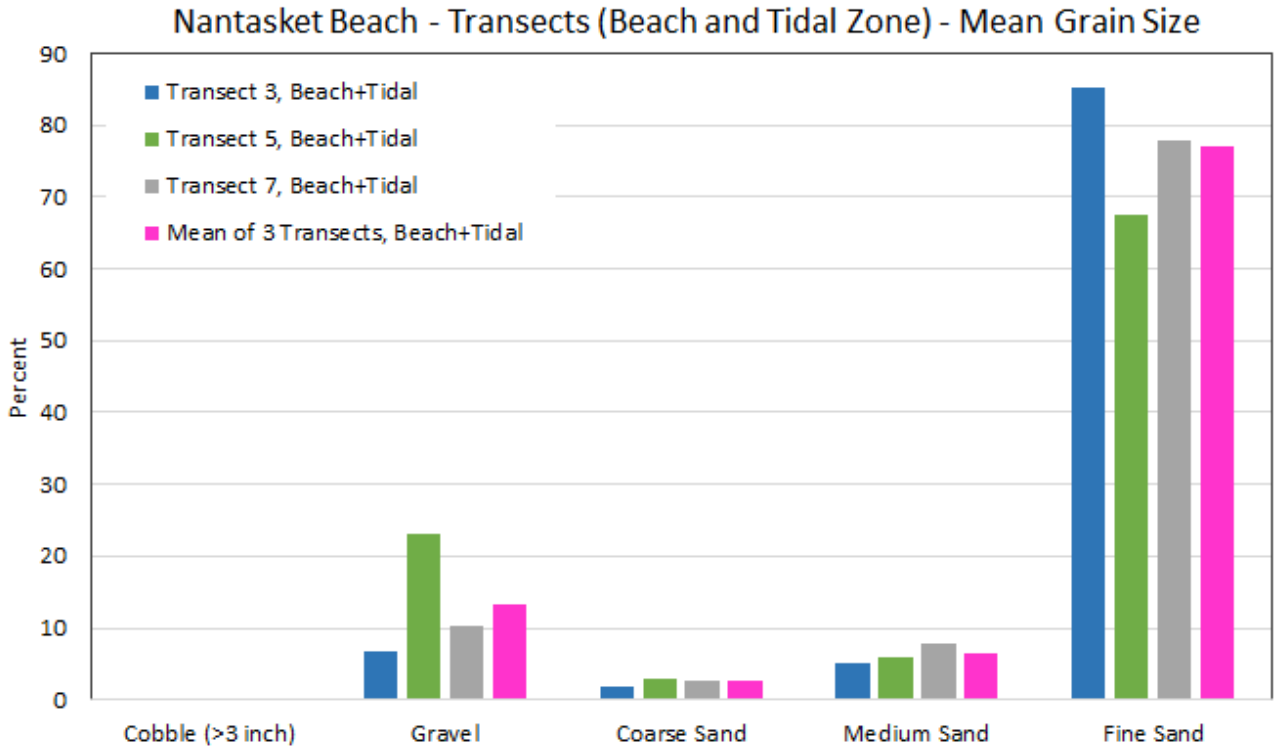

Figure 20. Mean grain size along transects on Nantasket Beach for the beach and intertidal zone. Transects are arranged from north (Transect #3 on the left) to south (Transect #7 on the right)

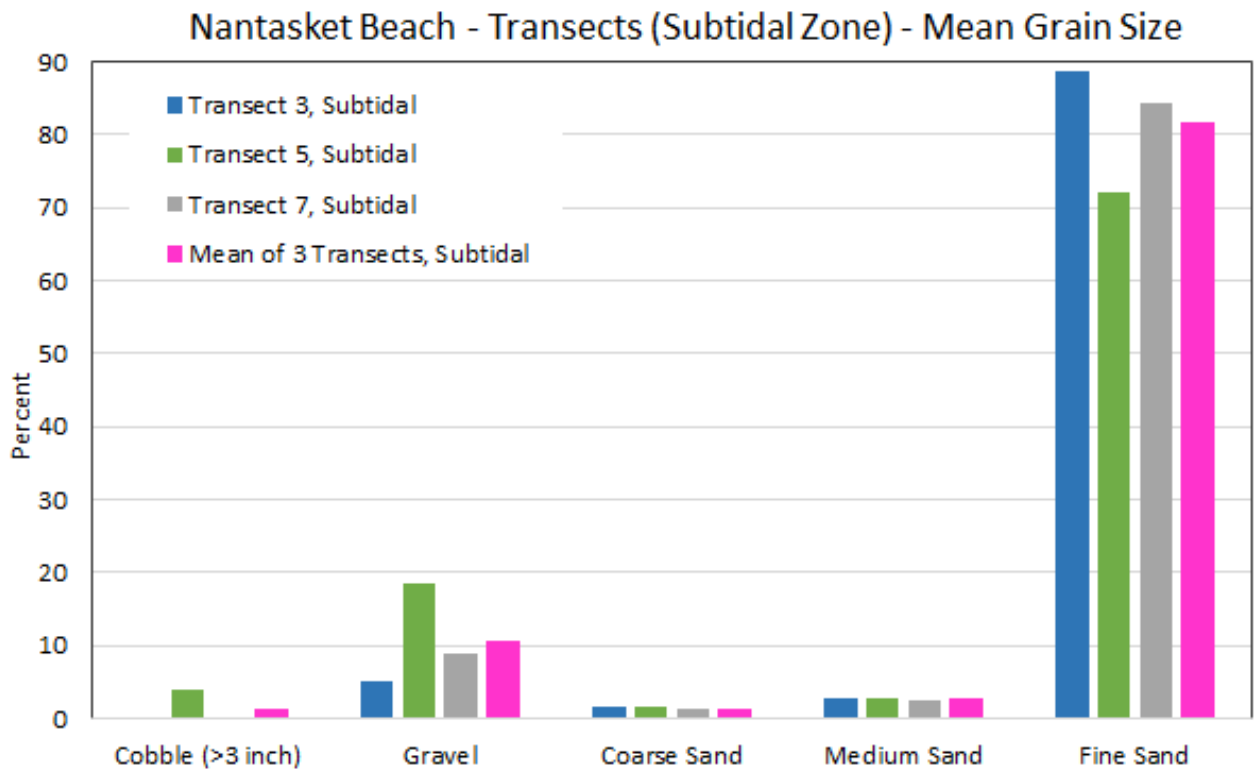

Figure 21. Mean grain size along transects on Nantasket Beach for the subtidal zone. Transects are arranged from north (Transect #3 on the left) to south (Transect #7 on the right)

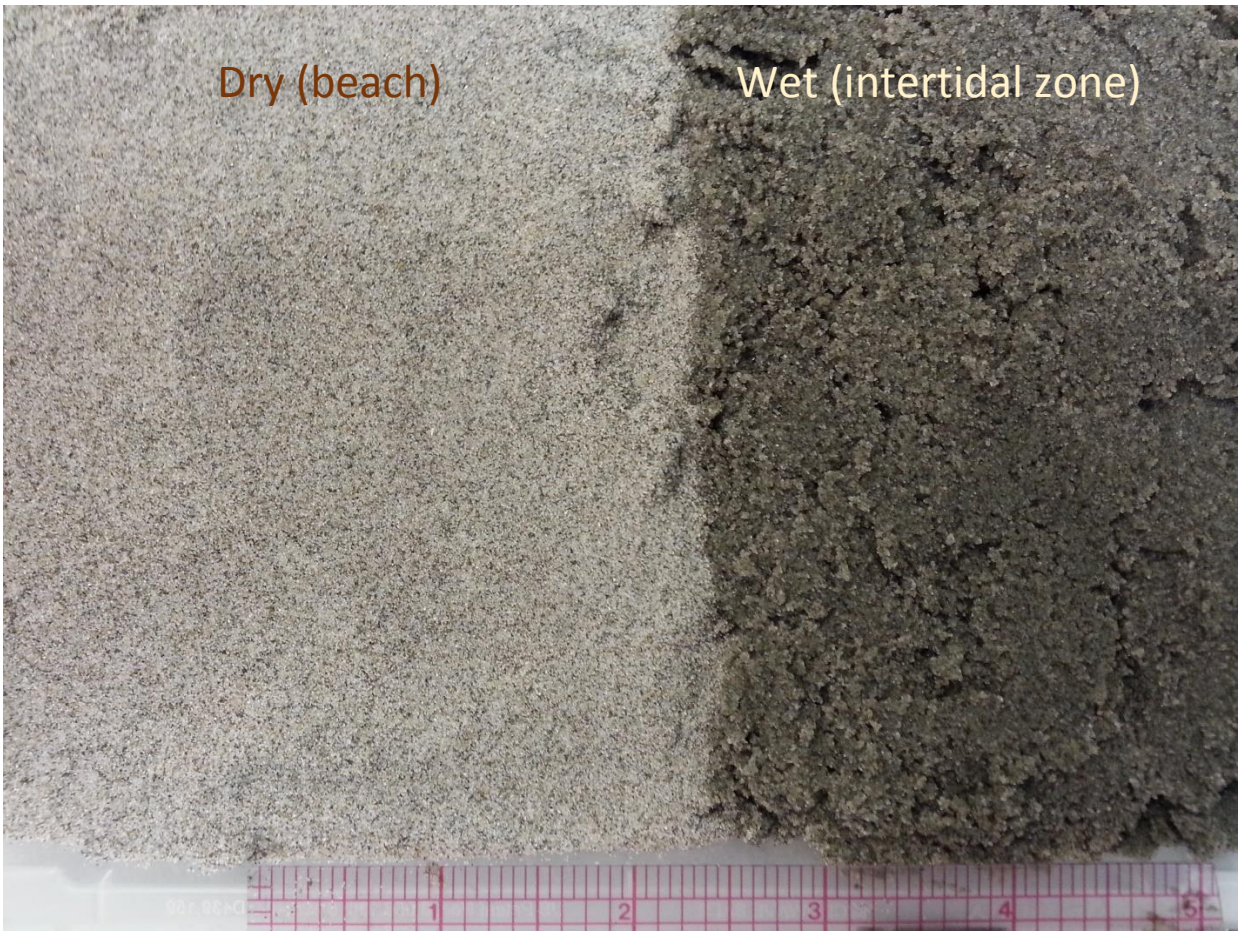

Figure 22. Color of the sand from the mid-section of Nantasket Beach (in wet and dry state). The color in this photograph is considered representative of the sand along Nantasket Beach.

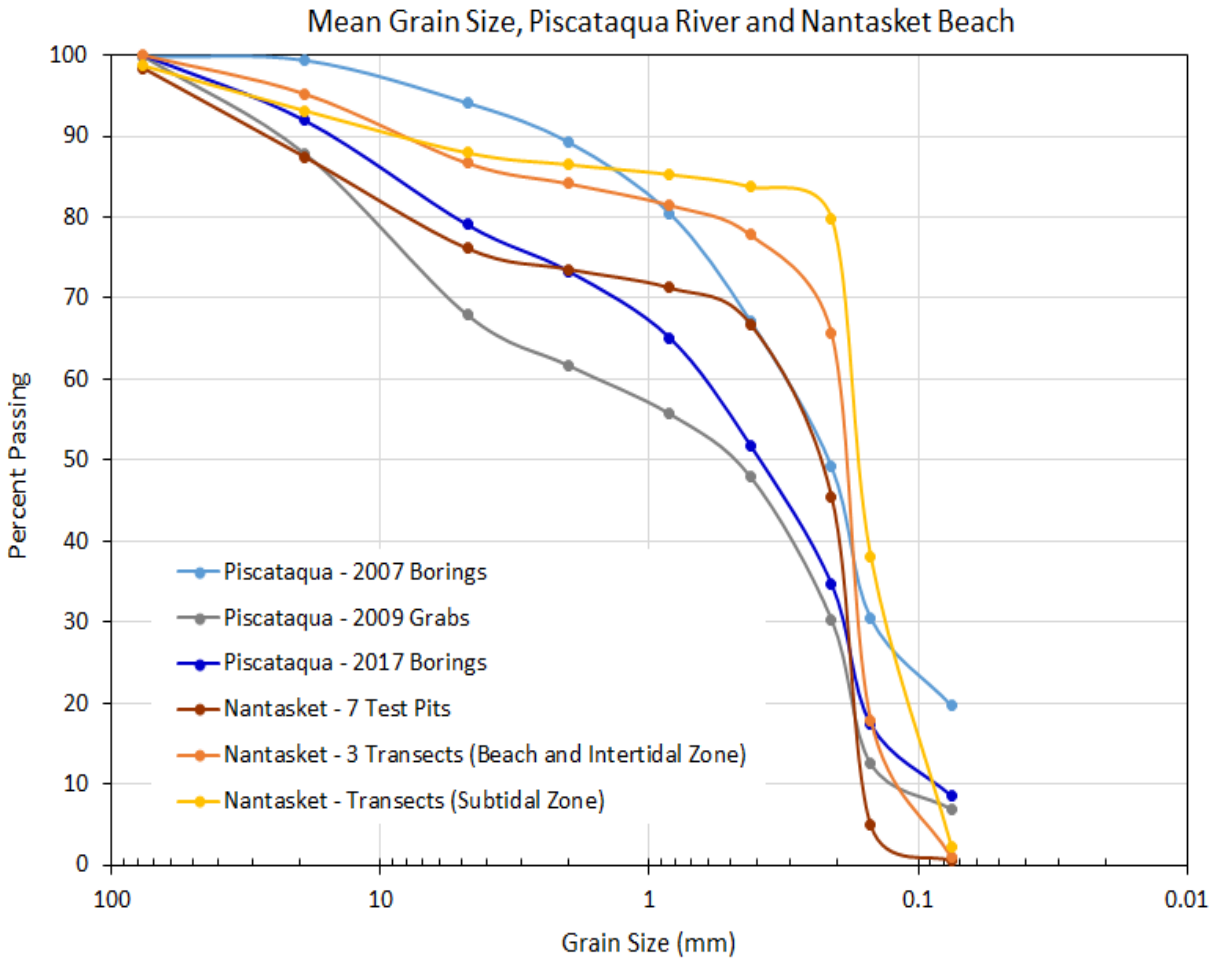

Figure 23. Mean grain size distribution (in percent passing) at the Piscataqua River site and at Nantasket Beach, combining all surveys

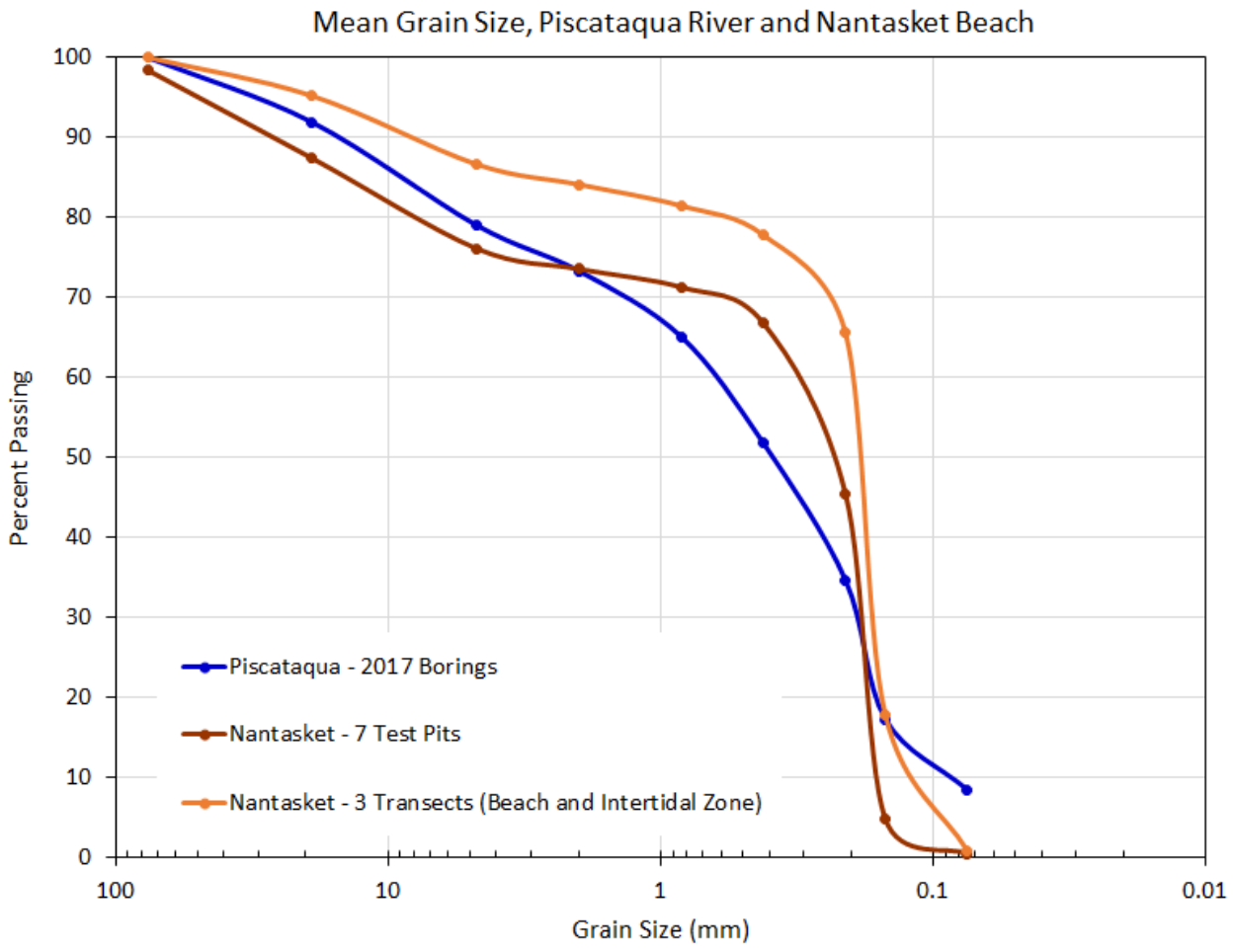

Figure 24. Mean grain size distributions (in percent passing) comparing the most applicable data for Nantasket Beach (from test pits and the beach and intertidal zone transect portion; 2004 and 2005) and the Piscataqua River site (2017 borings).

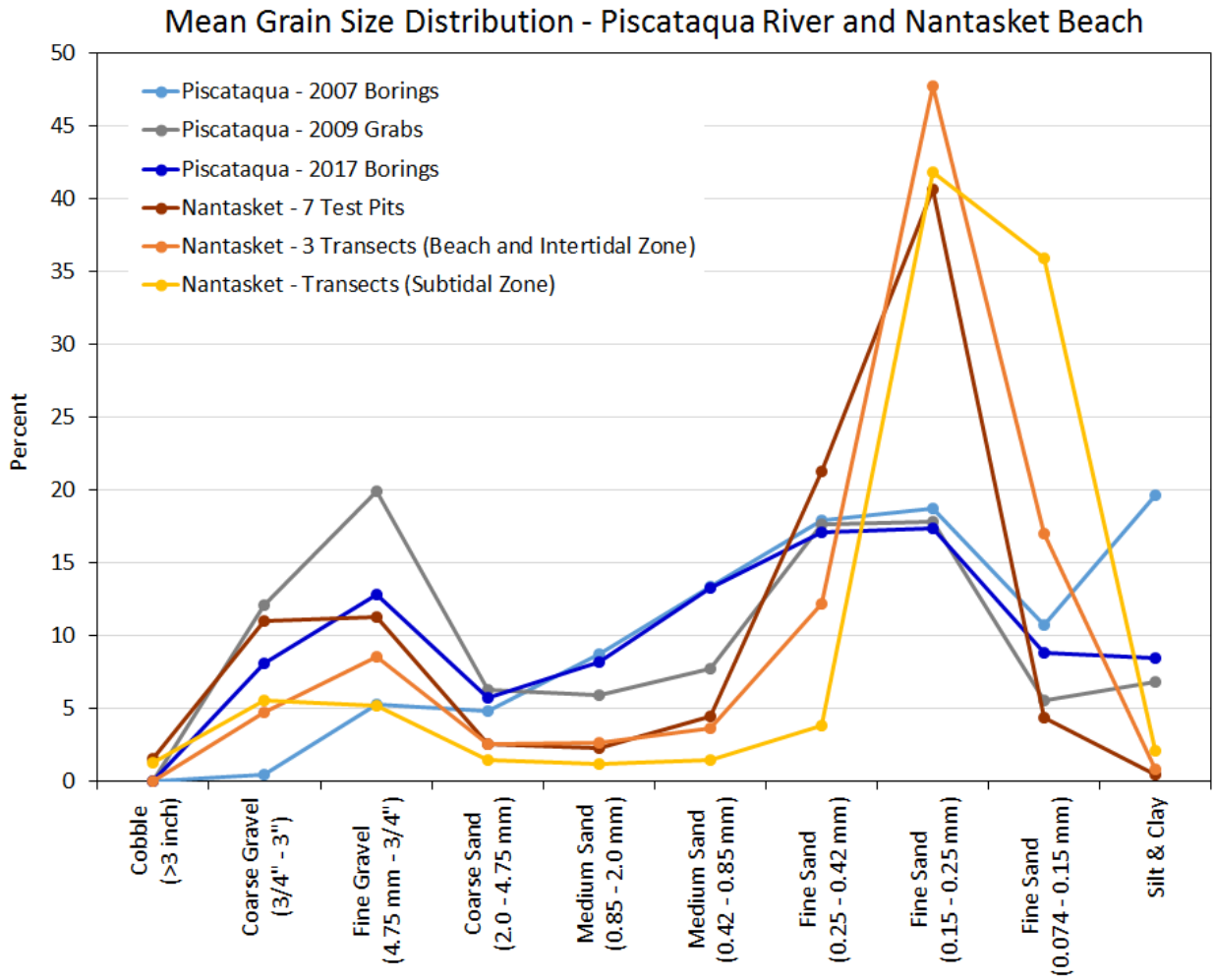

Figure 25. Mean grain size distribution by size fraction (in percent) for sediment samples from the Piscataqua River and Nantasket Beach

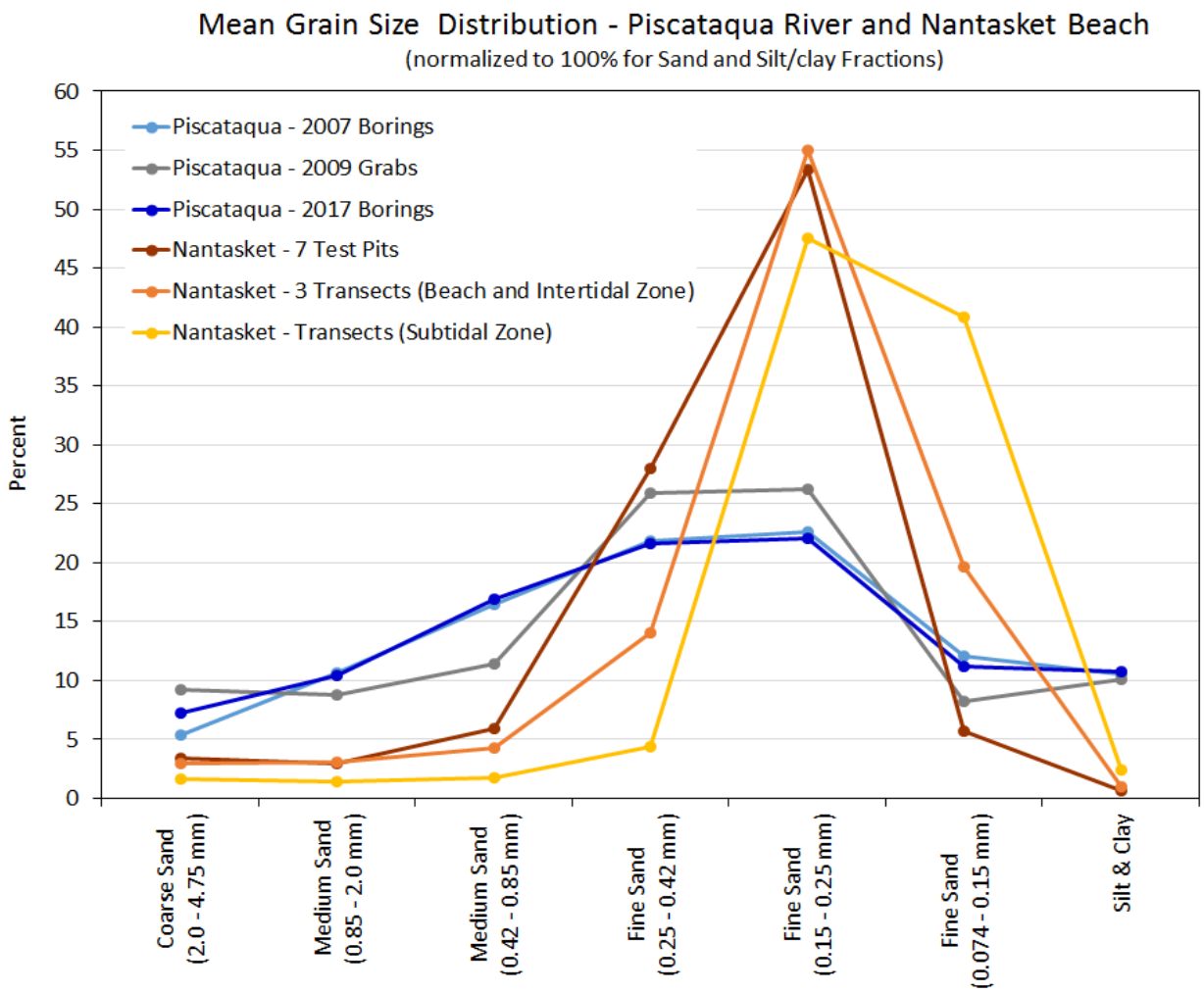

Figure 26. Mean grain size distribution by size fraction (in percent) for sediment samples from the Piscataqua River and Nantasket Beach, normalized to 100% for the sand and silt/clay size classes only, and without the two grain size samples from Station B-5 of the 2007 borings.

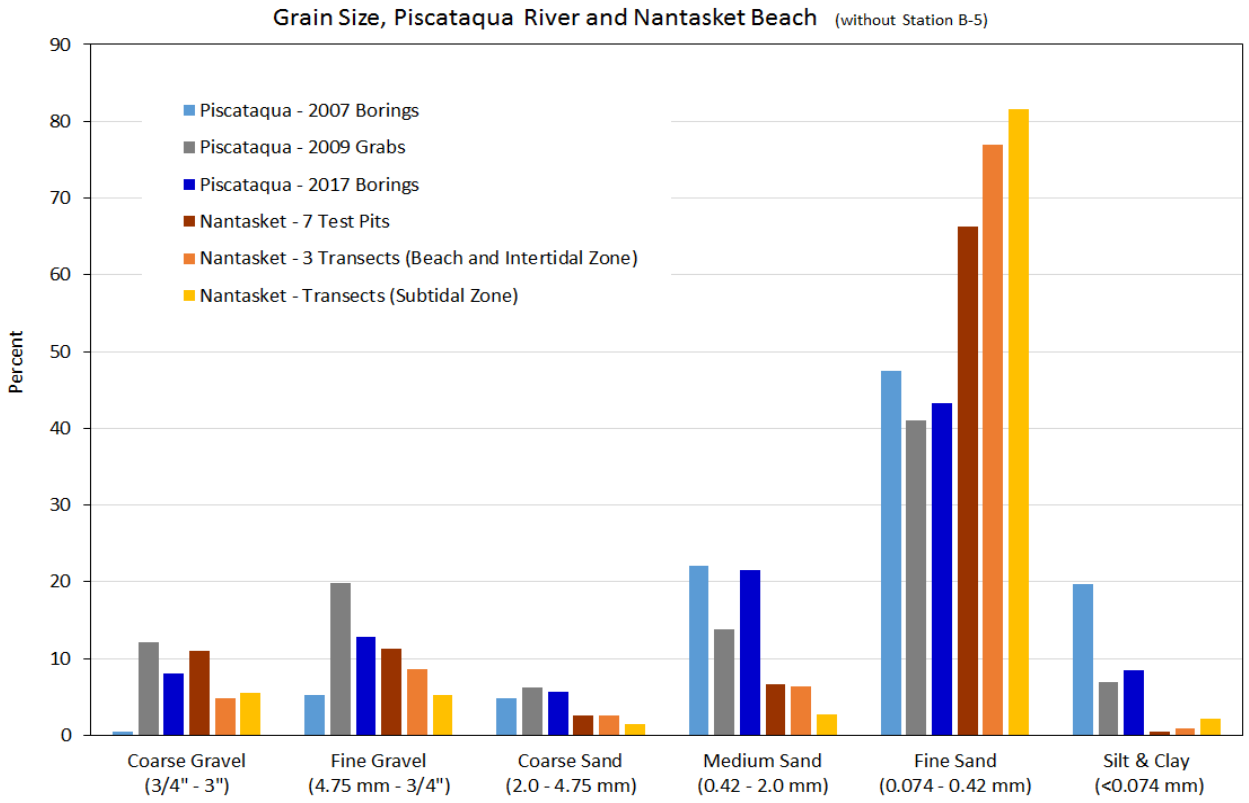

Figure 27. Summary of mean grain size distribution by major size fractions for sediment samples from the Piscataqua River and Nantasket Beach, without the two grain size samples from Station B-5 of the 2007 borings

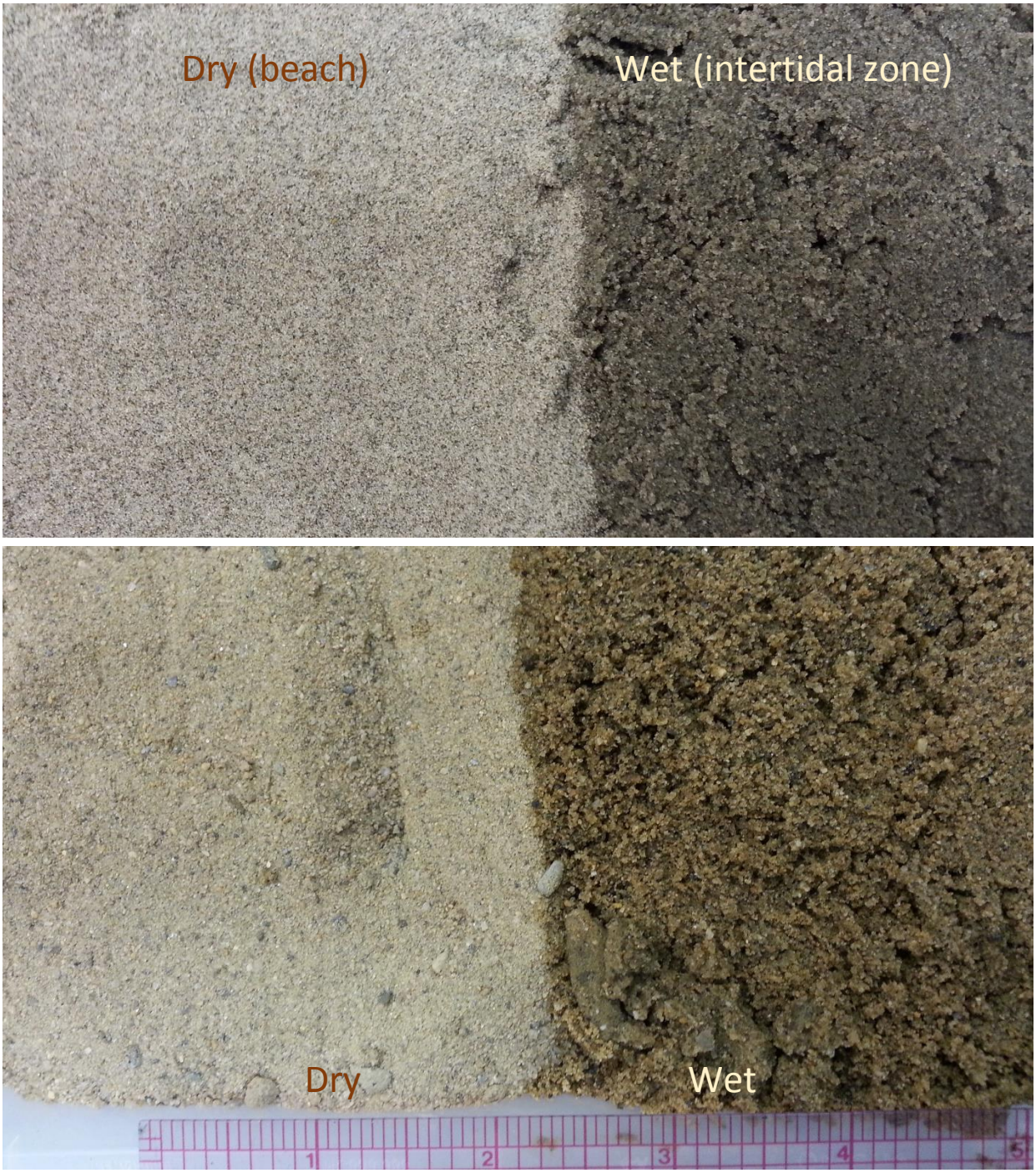

Figure 28. Side-by-side comparison of the color of sediment from Nantasket Beach (top) and the Piscataqua River site (bottom)

5. Chemical Characteristics of Piscataqua River Sediments

This section describes the Piscataqua River watershed, presents the results of the sediment chemistry analyses from the 2017 sediment boring samples and compares the data to pertinent criteria, and assesses the potential for ecological and human health risks caused by placing the dredged sediment on Nantasket Beach.

5.1 Watershed

The Piscataqua River watershed drains 1,495 square miles (Seacoast, 2017) Subwatersheds to the estuary include the Great Works, Salmon Falls, Cocheco, Bellamy, Winnicutt, Squamscott, Lamprey, Oyster, and Exeter Rivers, as well as Spruce Creek. The main stem of the Piscataqua River is relatively short, flowing just over 12 miles; it forms at the confluence between the Salmon Falls River and the Cocheco River, approximately 5 miles upstream from the dredging area. The main stem of the Piscataqua River is entirely tidal.

The Piscataqua River, along with the deep-water Portsmouth Harbor, are an important source of economic activity in the region, carrying shipments that include oil, gas, coal, chemicals, minerals, rubber and plastics, and fish products. There are several marine terminals along the Piscataqua River, all located on the New Hampshire side of the river. The Maine side of the Piscataqua River does not have any major commercial/industrial facilities and consists primarily of residential land use.

The closest terminals are Sprague Energy River Road (directly across from the dredging area) and the Sprague Energy Avery Lane (approximately 0.5 mile downstream of the dredging area) (Figure 29). Cargo handled by the River Road terminal consists of kerosene, road salt, cement, fly ash, and gypsum (Magnusson et al., 2012). Cargo handled by the Avery Lane terminal consists of liquid asphalt, oil, and propane.

Other terminals that handle petroleum products are located downriver (Public Service of New Hampshire; National Gypsum/Irving Oil). The Portsmouth Harbor is also used by a large lobster fishing fleet, charter fishing vessels, commercial fishermen, and excursion boats, as well as submarines from the Portsmouth Naval Shipyard on Seavey Island in Kittery. Small-scale, light manufacturing is practiced in Portsmouth along the Piscataqua River and in many of the municipalities bordering the Great Bay estuary (Jones, 2000). Finally, the Piscataqua River receives treated wastewater discharges from treatment plants in Portsmouth, Kittery, and Newington (Seacoast, 2017).

Businesses along the Piscataqua River included Grimmel Industries, which operated a scrap-metal business on the state-owned port facility for 14 years. The business was closed by the U.S. Environmental Protection Agency (USEPA) in 2015 because of discharges of wastewater containing aluminum, copper, iron, lead, mercury, zinc, PCBs, and total suspended solids to the river (Seacoast, 2015). The facility was located approximately 3 nautical miles (nm) downstream of the dredging area.

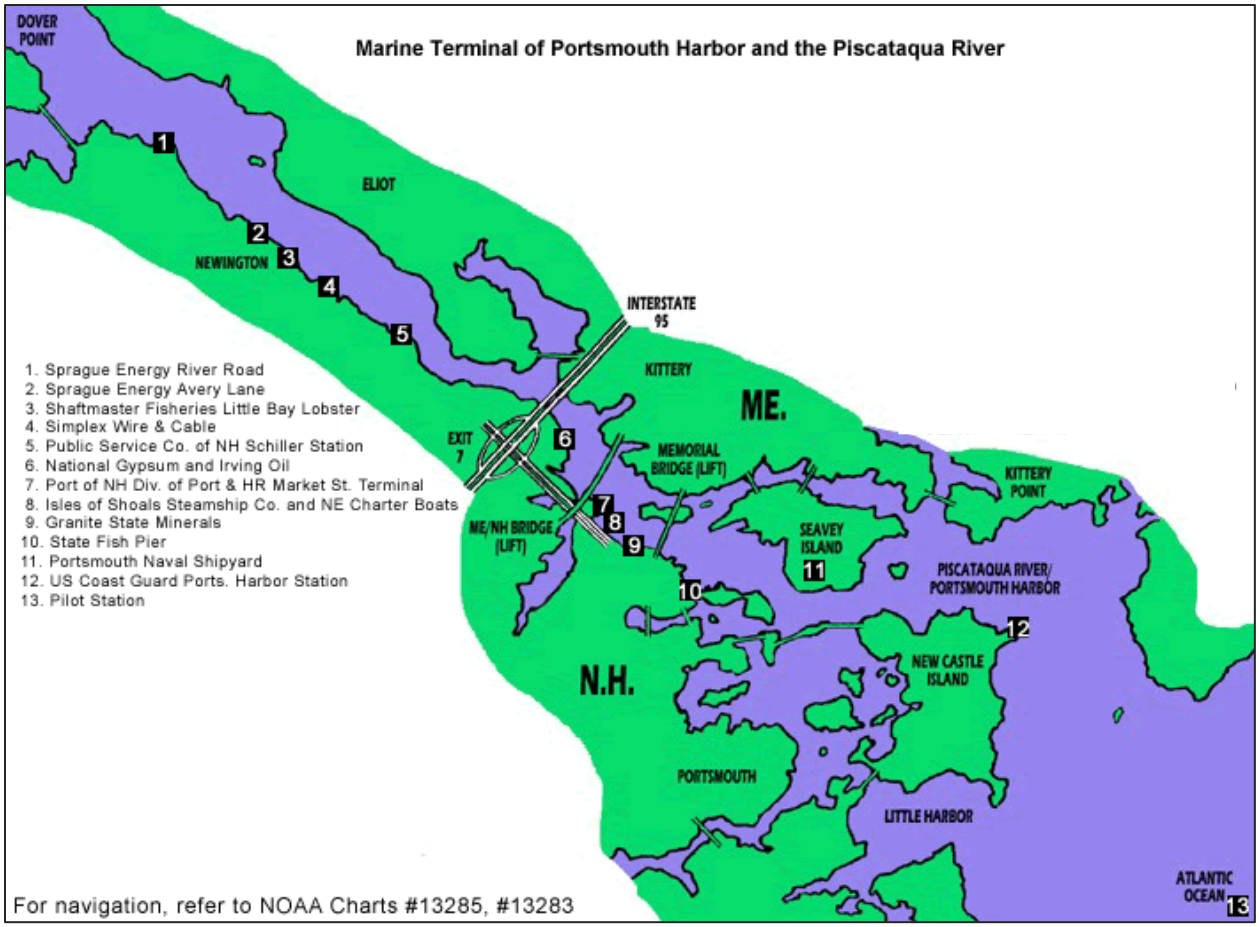

Figure 29. Marine terminals of Portsmouth Harbor and the Piscataqua River

5.2 Section 303(d) List – Water Quality

The Piscataqua River is listed on the 2016 Section 303(d) list of the Clean Water Act. Waterbodies on the 303(d) list only include waters that are impaired or threatened by contaminants and require the development of a comprehensive water quality study (*i.e.*, referred to as a Total Maximum Daily Load [TMDL] study) that is designed to meet water quality standards (NHDES, 2018). The Piscataqua River is listed as impaired for fish consumption (because of PCBs) and for shellfishing (because of PCBs and dioxin [including 2,3,7,8-TCDD]) (NHDES, 2017).

5.3 Chemical Characteristics of Sediments and Ecological Risk (2017 Borings)

Laboratory reports from the 2017 borings at the Piscataqua River site are provided in Appendices 5 to 7 of Attachment H. Chemical analytical data are summarized in Tables 15 to 19 and discussed below.

The sediment data were compared to sediment screening levels protective of ecological receptors in marine and estuarine environments developed by Long and Morgan (1991) and Long et al.

(1995), and discussed in MacDonald et al. (1996). Two guideline values, an effects range-low (ERL) and an effects range-median (ERM), were developed by compiling matching biological and chemical data from numerous modeling, laboratory, and field studies and determining the lower 10th percentile (ERL) and median or 50th percentile (ERM) of the distribution of the effects data. Long et al. (1995) noted that chemical concentrations below the ERL value represent a minimal-effects range, a range intended to estimate conditions in which effects would be rarely observed. Chemical concentrations equal to or above the ERL value, but below the ERM value, represent a possible-effects range within which effects would occasionally occur. Chemical concentrations equal to and above the ERM value represent a probable-effects range within which effects would frequently occur. For this evaluation, the detected concentrations of the breakdown products of the insecticide Dichlorodiphenyltrichoroethane (DDT), consisting of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT concentrations, were summed and also evaluated as Total DDx. ERL and ERM values were not developed for dioxins/furans. Therefore, an interim sediment quality guideline (ISQG) and a probable effects level (PEL) developed by the Canadian Council of Ministers of the Environment (CCME) for their Canadian Sediment Quality Guidelines for the Protection of Aquatic Life were used to compare the detected Total 2,3,7,8-Tetrachlorodibenzodioxin (2,3,7,8-TCDD) toxic equivalence (TEQ) concentrations (CCME, 2018). The ISQG is a value derived from a data set that met a lesser requirement than that of a full guideline and the PEL is the concentration above which adverse biological effects are expected to occur frequently.

5.3.1 Metals

Metals in sediments can occur naturally at low concentrations or may be detected at elevated concentrations because of anthropogenic sources. None of the metal concentrations at any of the 2017 boring stations exceeded the ERM values (Table 15). Most of the detected results also did not exceed the ERL values for metals. The exceptions were arsenic and mercury. Twelve out of 19 samples contained detected arsenic concentrations that exceeded the ERL value. In addition, one sample (S-02, 0-5ft) contained 0.26 mg/kg of mercury, exceeding the ERL value for mercury (0.15 mg/kg). Three other samples had low detections of mercury, well below the ERL value; mercury was not detected in the remaining 15 samples. The detected mercury concentrations were all below the background concentration in natural, undisturbed soils listed by MassDEP (2002) as 0.3 mg/kg.

Arsenic occurs naturally at elevated concentrations in New England sediments, often correlated with elevated arsenic concentrations in groundwater (*e.g.*, Robinson and Ayotte, 2007; Colman, 2011; Brown and Thomas, 2014). In a study of fill and native glacial sediments in central Massachusetts, Nelson et al. (2010) measured natural arsenic concentrations with means of 10 to 29 mg/kg in four borings to depths of 22 to 63 ft.

Anthropogenic sources of arsenic include mining, agricultural, and industrial sources. According to MassDEP (2018), there was commercial arsenic mining in New Hampshire during the 1800s, but arsenic used in the United States has been imported since 1985. Activities that could result in arsenic residuals in sediments include apple orchard spraying, coal ash disposal, and use of some pressure treated wood in construction.

Arsenic concentrations in the 19 analyzed samples of the 2017 borings ranged from 2.8 to 18 mg/kg, with a mean of 9.6 mg/kg. The ERL value is 8.2 mg/kg. At Station S-12, which included samples from four segments to a boring depth of 20 ft, the highest concentration was measured in the deepest sample (15-20 ft); the lowest arsenic concentration was measured in the surface core segment (0-5 ft). Arsenic concentrations in the deeper core segment 5-10 ft at Stations S-01, S-02, and S-14 were similar to arsenic concentrations in the surface core segment (0-5 ft) at these stations. There was no discernable spatial pattern of arsenic concentrations in the dredging area. This pattern suggests natural conditions, since arsenic from anthropogenic sources would be expected to higher in the shallower samples.

The measured arsenic concentrations in the dredging area were consistent with concentrations measured by Normandeau (2016) in the Little Bay estuary, 4.5 nm upstream from the Piscataqua River site. The Normandeau study tested surface sediments (mostly in 4-ft long cores) for a cable crossing. Arsenic concentration in the Little Bay estuary ranged from 6.1 to 12 mg/kg with a mean concentration of 8.4 mg/kg. The Little Bay sediments consisted predominantly of silt/clay as compared to predominantly sand at the Piscataqua River dredging area. Specifically, the Little Bay sediments consisted on average of 62% silt/clay, 37% sand, and less than 1% gravel. Fine-grained sediments are typically associated with higher levels of contaminants than coarse-grained sediment, because of the chemical binding characteristics of particulates in fine-grained sediments.

Measured concentrations of all 19 samples were lower than the background concentration of arsenic in undisturbed, natural soils listed by MassDEP (2002) as 20 mg/kg. Cumulatively, the observations described above indicate that the arsenic concentrations in the sediment body to be dredged reflect natural conditions rather than anthropogenic sources.

5.3.2 Massachusetts Extractable Petroleum Hydrocarbon (MAEPH)

The MAEPH, developed by MassDEP, is a risk-based method focused on quantifying individual fractions of extractable aliphatic and aromatic hydrocarbons, based on the number of carbon atoms included in the constituent compounds. Specifically, the method quantifies extractable aliphatic hydrocarbons within two specific ranges: C_9 through C_{18}, and C_{19} through C_{36}. Additionally, extractable aromatic hydrocarbons are quantified within the C_{11} through C_{22} range.

Most of the 19 analyzed samples had no detection of any of the hydrocarbons (Table 15). The exception was Sample S-02, 0-5 ft, where aromatics and aliphatics were detected at concentrations slightly above the RL of the laboratory, but below the RL of 25 mg/kg required by MassDEP (2014a). In addition, the most toxic constituents in petroleum hydrocarbon mixtures were either not detected (*e.g.*, benzene, toluene, ethylbenzene, xylenes were not detected) or detected infrequently at low concentrations (*e.g.*, individual or total PAHs).

5.3.3 Volatile Organic Compounds (VOCs)

VOCs were not detected in any of the 18 analyzed samples.

5.3.4 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs occur naturally in fossil fuels such as coal and oil. There are a multitude of human activities (*i.e.*, anthropogenic sources) that create PAHs in excess of concentrations occurring naturally in the environment. These anthropogenic sources include petroleum spills and burning of coal, wood, or oil. PAHs are grouped by their molecular weight. Low molecular weight (LMW) PAHs are generally associated with petroleum; high molecular weight (HMW) PAHs are generally associated with combustion products (NOAA, 1991).

PAHs were detected in four out of the 19 analyzed samples (Table 16). These four samples were from the upper core segment (0-5 ft), which implies that they may have been contributed by anthropogenic sources. PAHs were not detected in any deeper core segments (*i.e.*, below a boring depth of 5 ft). The Regional Implementation Manual (RIM) protocol specifies that PAHs are to be summed using half of the laboratory method detection limit (MDL) for compounds whose values were below the MDL (non-detects). Using this approach, the highest total PAH concentration of any sample was estimated to be 1,123 ug/kg (Sample S-02, 0-5 ft); the ERL value for total PAHs is 4,022 ug/kg. None of the measured concentrations in the four samples with PAH detections exceeded any ERL or ERM values, both for individual PAH compounds and for the sums of LMW PAHs, HMW PAHs, and total PAHs. Using the RIM approach with half the detection limit for non-detect samples, the mean total PAH concentration in the 19 analyzed samples was 87 ug/kg.

5.3.5 Pesticides

Pesticides were detected in four out of 19 analyzed samples (Table 17). Three of the four samples were from the upper segment (0-5 ft) of three stations; one sample with trace concentrations of hexachlorobenzene was from the 15-20 ft core segment of Station S-12. None of the measured concentrations exceeded any ERL or ERM values, with one exception. The detected 4,4'-DDE concentration in Sample S-02, 0-5 ft, was 3.1 ug/kg, exceeding the ERL of 2.2 ug/kg; however, the measured concentration was well below the ERM of 27 ug/kg. The Total DDx concentration in this sample (3.9 ug/kg) also exceeded the ERL value (but was well below the ERM value); the predominant component was 4,4'-DDE. DDE is one of the more common breakdown products of the pesticide DDT. The use of DDT was banned in the United States in 1970.

5.3.6 Polychlorinated Biphenyls (PCBs)

PCBs are a mixture of compounds based on the biphenyl molecule, chlorinated to various extents. PCBs were used for a number of industrial purposes, but have been phased out in the United States since the late 1970s.

PCBs were detected in two out of 19 analyzed samples (Table 18). The sum of the 26 analyzed PCB congeners in the first sample (S-02, 0-5 ft) was 24.3 ug/kg, slightly exceeding the ERL value of 22.7 ug/kg, but well below the ERM value of 180 ug/kg. The RIM protocol specifies that PCBs are to be estimated by doubling the sum of 18 PCBs used in the NOAA National Status and Trends Program (NOAA, 1991), and using half of the MDL for non-detect congeners (below the MDL). Using this approach, the total PCB concentration of Sample S-02 (0-5 ft) was estimated to be 43

ug/kg, also exceeding the ERL value. PCBs were not detected in the deeper core segment (5-10 ft) at Station S-02. The second sample with PCB detection (S-12, 5-10 ft) contained trace amounts of one PCB congener; the total PCB concentration in this sample was well below the ERL value. PCBs were not detected in the upper core segment (0-5 ft) at Station S-12. Using the RIM approach with half the detection limit for non-detect samples, the mean total PCB concentration in the 19 analyzed samples was estimated to be 4.3 ug/kg.

Certain PCB congeners exhibit dioxin-like toxicity and are additionally evaluated below with the dioxins/furans.

5.3.7 Dioxins/Furans

Dioxins and furans are not synthesized for any specific purpose. They are contaminants formed in the production of some chlorinated organic compounds, including a few herbicides. They are also created in the pulp and paper industry from a process that bleaches the wood pulp. In addition, they can be produced during combustion.

Eight or more dioxin/furan congeners were detected in the five analyzed samples (Table 19). The USEPA (2010; 2013) recommends that mixtures of PCB and dioxin/furan congeners that exhibit dioxin-like toxicity be assessed on the basis of their predicted toxicities relative to the toxicity of 2,3,7,8-TCDD. Twelve PCB congeners and seventeen dioxin/furan congeners have been assigned 2,3,7,8-TCDD toxic-equivalence factors (TEFs) according to the 2005 World Health Organization toxic equivalence (TEQ) weighting scheme (Van den Berg et al., 2006). Within a sediment sample, detected concentrations of these congeners were multiplied by the congener-specific TEF; the adjusted concentrations were summed as Total TEQ (PCB congeners), Total TEQ (dioxin/furan congeners), and Total 2,3,7,8-TCDD TEQ for the sum of all of them. The Total 2,3,7,8-TCDD TEQ concentration was almost entirely contributed by the Total TEQ (dioxin/furan congeners).

The highest detected Total 2,3,7,8-TCDD concentration, 10.9 pg/g in Sample S-02, 0-5 ft, was higher than the ISQG (0.85 pg/g) but lower than the PEL (21.5 pg/g) used by the CCME to evaluate sediment quality. The Total 2,3,7,8-TCDD concentrations in the other four samples ranged from 0.03 to 0.51 pg/g, lower than the ISQG used by the CCME. Normandeau (2016) also detected dioxins/furans at low concentrations in many samples at the Little Bay site; concentrations were all below the CCME's ISQG guideline values for Total 2,3,7,8-TCDD.

5.3.8 Perfluoro Compounds (PFCs)

The two PFCs that have been produced in the largest amounts within the United States are perfluorooctanoic acid (PFOA) and perfluorooctane sulfanate (PFOS). These two PFCs have been reported in the groundwater at the nearby Pease Air Force Base. PFOA and PFOS were analyzed in this study to evaluate potential accumulation in porewaters of the sediment body to be dredged.

PFOA and PFOS were not detected in any of the five analyzed samples (Table 15). The MDL for the two compounds ranged from 0.10 to 0.25 ug/kg. Testing of surface sediments by Normandeau (2016) in Little Bay also did not detect these two compounds; the detection limit of that study ranged from 1.83 to 2.00 ug/kg. There are no screening criteria for PFOA and PFOA in the United

States. As part of the Little Bay study, GEI (Appendix A2 in Normandeau, 2016) evaluated existing data and aqueous criteria for these two PFCs and concluded that the European proposed Probable No Effect Concentration (PNEC) of 6.7 ug/kg in marine sediment is very protective of marine organisms.

5.3.9 Ecological Risk

Ecological receptors include marine life that inhabit or use nearshore waters and the beach. As shown in Tables 15 to 19, concentrations of arsenic (in 12 samples), as well as concentrations of mercury, 4,4'-DDE and Total DDx, Total PCBs, and Total 2,3,7,8-TCDD TEQ (in 1 sample), were greater than the corresponding ERL or ISQG values but lower than the ERM or PEL values for ecological receptors. While a strict interpretation of this finding indicates that adverse health effects in ecological receptors could occur occasionally, the following should also be considered:

- The elevated mercury, DDE and Total DDx, and Total 2,3,7,8-TCDD concentrations were detected in only one sample (Sample S-02, 0-5) suggesting that these concentrations are not widespread in the proposed dredging area.
- The elevated arsenic concentrations, which range from 8.4 to 18 mg/kg, are comparable to background concentrations in soil, and the mean arsenic concentration for the 19 samples (9.6 mg/kg) is lower than the ERM. The background concentration of arsenic in undisturbed, natural soils was listed by MassDEP (2002) as 20 mg/kg.
- Chemical sample analyses were mostly from the upper segment (0-5 ft) of the sediment body to be dredged. This zone typically reflects 'worst-case condition' effects from potential anthropogenic contaminant sources. This pattern was also observed at the Piscataqua River site, where detected concentrations were found mostly in the upper core segment. For example, the exceedences of mercury, 4,4'-DDE, Total PCBs, and Total DDx, and Total 2,3,7,8-TCDD TEQ were from Sample S-02 (0-5 ft). Except for a trace concentration of DDD, these compounds were not detected in the deeper core sample (5-10 ft) at Station S-02. Similar observations were made at Station S-12; the 0-5 ft core segment contained traces of PAHs, while the three deeper 5-ft core segments (*i.e.*, depth range 5 to 20 ft) had no detections.
- Sediments would become mixed during the process of dredging at the Piscataqua River site and during placement at Nantasket Beach. Placement would consist of first pumping the sediment from the transport scow onto the beach and then spreading the sediment by bulldozer on the beach.

In summary, the risk screening evaluation, as conducted, indicates that Piscataqua River sediment used for beach nourishment would not affect the health of biota that contact them.

5.4 Screening-Level Human Health Risk Evaluation

This section evaluates the quality of the dredged sediment in the context of the potential for adverse health effects in human receptors that may contact the sediment, once placed on Nantasket Beach. Human receptors consist of people recreating on the beach, including young children, youths, and adults. A screening-level evaluation is made by comparing detected chemical concentrations in

sediment to criteria protective of these receptors, where available. Because neither the MassDEP nor the USEPA have derived sediment screening levels protective of people recreating on a beach, health risk-based screening levels were derived for the project that are protective of this type of recreational activity.

5.4.1 Approach

The USEPA's online Regional Screening Levels (RSLs) Calculator (USEPA, 2018) has the capability to derive screening levels protective of recreational exposure to chemicals in sediment. This RSL calculator was used to derive screening levels for this project. Exposures via inadvertent ingestion of and dermal contact with sediment while recreating on a beach for 4 hours/day, 15 days/year, for durations of 6 to 26 years appropriate for the different age groups, were evaluated. The exposure frequency (*i.e.*, 15 days/year) considers recreating at the beach once a week from Memorial Day through Labor Day or any other recreational scenarios equating to 15 days/year. Depending on the age group, the evaluation considered the inadvertent ingestion (*e.g.*, from hand-to-mouth contact) of up to 200 mg of sediment per day and exposure from sediment contacting the head, hands, forearms, lower legs, and feet throughout the day. The extent that the sediment adheres to the skin and the receptors' body weight was also considered. Receptor-specific exposure parameter values used to derive the screening levels are presented in Table 20. The screening levels were derived based on a 10^{-6} target cancer risk and a hazard index of 1 as per USEPA risk assessment guidance, and the lower of the two was used for screening, as presented in Table 21. The lowest of the derived screening levels for the different age groups were compared to the sediment data.

For lead, there are no toxicity values for deriving screening levels using the USEPA's online RSL calculator. However, the lead data from the Piscataqua River were conservatively compared to the USEPA screening level protective of exposure to lead in soil in a residential setting.

For PCBs, the screening level was derived based on the toxicity values for the PCB mixture Aroclor 1254 and compared to total PCB concentration (*i.e.*, the sum of the detected congeners) in each sample. The PCB congener data were also evaluated in terms of the potential for certain PCB congeners to exhibit dioxin-like toxicity, along with the dioxins/furans data, as described in Section 5.3.7.

For total petroleum hydrocarbons (TPH), screening levels were derived for three TPH fractions available in the USEPA online RSL calculator, aliphatic high (C_{19}-C_{32}), aromatic medium (C_9-C_{16}), and aromatic high (C_{17}-C_{32}), and compared to detected concentrations of the corresponding MAEPH fractions.

Screening levels could not be derived for three detected PAHs [acenaphthylene, phenanthrene, and benzo(g,h,i)perylene] and two detected pesticides (beta-Endosulfan and cis-nonachlor).

For information purposes, the sediment data were also compared to soil guidance values developed by the MassDEP that are intended to ensure that soil being excavated and relocated from a disposal site is not "contaminated soil" (MassDEP, 2014b). The guidance values are reportable concentrations, developed for two categories: Category RCS-1 which applies to locations with the highest potential for exposure, and are defined as "at or within 500 ft of a residential dwelling, a

residentially-zoned property, school, playground, recreational area or park"; RCS-1 also applies to locations within the boundaries of a groundwater resource area. Category RCS-2 applies to all other locations.

5.4.2 Risk Characterization

All detected chemical concentrations in Piscataqua River dredged sediment samples were lower than health risk-based screening levels protective of individuals that contact the sediment while recreating at a beach (Tables 15 to 19; Table 21). Also, all detected chemical concentrations in the sediment samples were lower than MassDEP reportable concentrations (referred to as Category RCS-1 and RCS-2) for soil. The more stringent Category RCS-1 values apply to locations with the highest potential for exposure, and are defined as "at or within 500 ft of a residential dwelling, a residentially-zoned property, school, playground, recreational area or park." In summary, the risk screening evaluation, as conducted, indicates that dredged sediments used for nourishment of Nantasket Beach would not affect the health of recreationists that contact them.

5.5 Chemical Characteristics - Summary

The risk screening evaluations, as conducted, indicate that Piscataqua River sediment used for beach nourishment at Nantasket Beach would not affect the health of biota or recreationists that contact them.

Table 15. Concentrations of solids, metals, MAEPH, and PFCs in sediments of the Piscataqua dredging area

Station	Sample No.	Lab Report Package	Total Solids (%)	Metals (mg/kg/ dry weight)									MA Extractable Petroleum Hydrocarbons (mg/kg)				PFCs (ug/kg)	
				Arsenic, Total	Cadmium, Total	Chromium, Total	Copper, Total	Lead, Total	Nickel, Total	Zinc, Total	Mercury, Total	Hexavalent Chromium	C11-C22 Aromatics (unadjusted)	C19-C36 Aliphatics	C9-C18 Aliphatics	2-Methyl naphthalene	Perfluoro-octanoic acid (PFOA)	Perfluorooctane Sulfonate (PFOS)
S- 01	0-5 ft	1	82.2	7.5	--	6.1	3.2	2.9	5.7	9.2	--		--	--	--	--		
	5-10 ft		78.2	4.9	0.007	6.9	3.3	3.0	5.0	8.4	0.0051		--	--	--	--		
S- 02	0-5 ft	3	69.1	8.4	0.23	48	9.5	22	8.2	29	0.26	--	11	7.3	--	--	--	--
	5-10 ft		82.5	6.4	0.010	3.7	3.6	2.1	5.6	8.4	--		--	--	--	--		
S- 03	0-5 ft	1	77.3	6.8	0.020	5.8	4.9	2.4	8.2	11.0	--		--	--	--	--		
S- 05	0-5 ft	3	86.3	15	0.024	8.4	8.2	8.8	14	15	--		--	--	--	--		
S- 06	0-5 ft	2	79.7	16	0.019	11	9.4	4.4	13	26	--	--	--	--	--	--	--	--
	5-10 ft		78.9	14	0.019	6.7	7.8	3.9	14	16	--		--	--	--	--		
S- 07	0-5 ft	1	81.2	9.0	0.008	5.4	4.8	2.9	6.8	9.3	--		--	--	--	--		
S- 08	0-5 ft	1	80.2	8.8	0.008	5.4	5.9	2.4	6.2	8.7	--	--	--	--	--	--	--	--
S- 09	0-5 ft	2	80.5	11	0.010	8.3	7.6	3.5	13	14	--		--	--	--	--		
S- 10	0-5 ft	1	81.9	9.3	0.010	11	6.4	3.9	10	16	--		--	--	--	--		
S- 12	0-5 ft	2	79.9	2.8	0.046	15	3.2	6.0	6.7	18	0.0190	--	--	--	--	--	--	--
	5-10 ft		79.9	4.8	--	4.0	3.3	1.7	4.5	7.1	--		--	--	--	--		
	10-15 ft		80.8	9.1	--	4.0	4.1	1.8	5.7	8.0	0.0097		--	--	--	--		
	15-20 ft		84.1	12	0.011	6.1	6.5	2.8	10	12	--		--	--	--	--		
S- 14	0-5 ft	2	79.9	18	0.018	22	18	6.5	25	37	--		--	--	--	--		
	5-10 ft		83.9	12	0.010	8.8	7.0	4.0	11	14	--		--	--	--	--		
S- 16	0-5 ft	3	81.2	6.9	0.007	6.0	6.0	3.0	8.7	11.0	--	--	--	--	--	--	--	--
Mean			**80.4**	**9.6**	**0.029**	**10.1**	**6.5**	**4.6**	**9.5**	**14.6**							--	--
ERL				8.2	1.2	81	37	46.7	20.9	150	0.15	--	--	--	--	--	--	--
ERM				70	9.6	370	270	218	51.6	410	0.71	--	--	--	--	--	--	--
Human Health SL				21	1,670	2,740,000	73,000	400	548	36,500	548,000	--	7,300	5,480,000	--	--	--	--
MA, RCS-1				20	70	100	1,000	200	600	1,000	20	100	--				--	
MA, RCS-2				20	100	200	10,000	600	1,000	3,000	30	200	--				--	

--	Not detected (for samples concentrations). Not available (for screening levels or guideline values)
0.013	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
2.6	Concentration that exceeds the respective ERL.

Table 16. Concentrations of PAHs in sediments of the Piscataqua dredging area

Station	Sample No.	PAHs (ug/kg dry weight)																		
		Low molecular weight (LMW)						High molecular weight (HMW)												
		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a)pyrene	Indeno(1,2,3-cd) pyrene	Dibenz(a,h) anthracene	Benzo(ghi) perylene	Total LMW PAHs(1)	Total HMW PAHs(1)	Total PAHs (1)
S- 01	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4*	*8*	*13*
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*9*	*13*
S- 02	0-5 ft	6.8	25	5.3	14	130	54	170	160	84	77	120	40	85	63	18	71	235	888	1,123
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4*	*8*	*13*
S- 03	0-5 ft	--	--	--	--	8.8	5.7	24	16	9.8	9.6	9.7	4.5	9.6	5.7	--	7.1	17	97	114
S- 05	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4*	*8*	*12*
S- 06	0-5 ft	--	2.2	--	--	--	--	2.1	2.2	5.9	6.1	6.6	2.9	7.5	4.3	--	6.4	6	45	51
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
S- 07	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
S- 08	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
S- 09	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
S- 10	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4*	*8*	*13*
S- 12	0-5 ft	--	3.1	--	1.5	12	7.2	29	19	16	16	16	7.3	16	8.6	2.4	9.8	25	140	165
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
	10-15 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
	15-20 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4*	*8*	*12*
S- 14	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*5*	*8*	*13*
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1*	*0*	*1*
S- 16	0-5 ft	--	--	--	--	5.1	1.8	6.8	5.5	3.5	3.2	2.6	1.7	2.4	3.2	--	--	10	31	40
Mean																		**19**	**69**	**87**
ERL		160	44	16	19	240	85.3	600	665	261	384			430		63.4		552	1,700	4,022
ERM		2,100	640	500	540	1,500	1,100	5,100	2,600	1,600	2,800			1,600		260		3,160	9,600	44,792
Human Health SL		27,900,000	--	83,700,000	55,800,000	--	418,000,000	55,800,000	41,800,000	30,500	3,050,000	30,500	305,000	3,050	30,500	3,050	--	--	--	--
MA, RCS-1		4,000	1,000	4,000	1,000,000	10,000	1,000,000	1,000,000	1,000,000	7,000	70,000	7,000	70,000	2,000	7,000	700	1,000,000	--	--	--
MA, RCS-2		20,000	10,000	3,000,000	3,000,000	1,000,000	3,000,000	3,000,000	3,000,000	40,000	400,000	40,000	400,000	7,000	40,000	4,000	3,000,000	--	--	--

--	Not detected (for samples concentrations). Not available (for screening levels or guideline values)
0.013	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
(1)	Total PAHs were calculated using half of the minimum detection limit (MDL) for non-detected compounds (per RIM [USEPA and USACE, 2004]).
13.2	Summary concentrations for PAHs and PCBs based solely on half of MDLs.

Table 17. Concentrations of pesticides in sediments of the Piscataqua dredging area

Station	Sample No.	Pesticides (ug/kg dry weight)																		
		Hexachloro-benzene	Lindane	Heptachlor	Aldrin	oxy-chlordane	Heptachlor epoxide	trans-Chlordane	cis-Chlordane	Endosulfan, alpha	trans-Nonachlor	4,4-DDE	Endrin	Endosulfan, beta	cis-Nonachlor	4,4-DDD	4,4-DDT	Methoxy-chlor	Toxaphene	Total DDx
S- 01	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 02	0-5 ft	--	--	--	--	--	--	--	--	--	--	3.1	--	0.068	--	0.81	--	--	--	3.91
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.02	--	--	--	0.02
S- 03	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 05	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 06	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 07	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 08	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 09	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 10	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 12	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	0.69	--	0.75	--	--	0.75
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	10-15 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15-20 ft	0.013	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S- 14	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.036	--	--	--
S- 16	0-5 ft	0.068	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ERL		--	--	--	--	--	--	--	--	--	--	2.2	--	--	--	2	1	--	--	1.58
ERM		--	--	--	--	--	--	--	--	--	--	27	--	--	--	20	7	--	--	46.1
Human Health SL		13,300	--	--	--	--	--	--	--	--	--	62,600	--	--	--	44,200	58,500	--	--	--
MA, RCS-1		700	3	300	80	--	100	--	--	500	--	6,000	10,000	500	--	8,000	6,000	200,000	10,000	--
MA, RCS-2		800	500	2,000	500	--	900	--	--	1,000	--	30,000	20,000	1,000	--	40,000	30,000	400,000	100,000	--

--	Not detected (for samples concentrations). Not available (for screening levels or guideline values)
0.013	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
2.6	Concentration that exceeds the respective ERL.

Table 18. Concentrations of PCBs in sediments of the Piscataqua dredging area

Station	Sample No.	PCBs (ug/kg dry weight)																											
		CI2-BZ#8 *	CI3-BZ#18 *	CI3-BZ#28 *	CI4-BZ#44 *	CI4-BZ#49	CI4-BZ#52 *	CI4-BZ#66 *	CI4-BZ#77	CI5-BZ#87	CI5-BZ#101 *	CI5-BZ#105 *	CI5-BZ#118 *	CI6-BZ#126	CI6-BZ#128 *	CI6-BZ#138 *	CI6-BZ#153 *	CI6-BZ#156	CI6-BZ#169	CI7-BZ#170 *	CI7-BZ#180 *	CI7-BZ#183	CI7-BZ#184	CI7-BZ#187 *	CI8-BZ#195 *	CI9-BZ#206 *	CI10-BZ#209 *	Total PCBs (Sum of 26 analyzed congeners)	Total PCBs (per RIM, USEPA and USACE, 2004)
S- 01	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
S- 02	0-5 ft	2.5	--	0.5	0.6	0.5	1	--	--	1.4	2.8	1.1	1.6	--	1.0	3.6	3.0	0.46	--	0.92	1.2	--	--	0.98	--	0.70	0.56	**24.3**	**43.0**
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 03	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
S- 05	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.6*
S- 06	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
S- 07	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 08	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 09	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 10	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 12	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
	5-10 ft	1.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.5
	10-15 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*2.0*
	15-20 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 14	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
	5-10 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
S- 16	0-5 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*1.9*
Mean																													**4.3**
ERL		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	22.7	
ERM		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	180	
Human Health SL		--																										7,990	
MA, RCS-1		--																										1,000	
MA, RCS-2		--																										4,000	

--	Not detected (for samples concentrations). Not available (for screening levels or guideline values)
0.013	Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.
13.2	Summary concentrations for PAHs and PCBs based solely on half of MDLs.
2.6	Concentration that exceeds the respective ERL.

Table 19. Concentrations of dioxins/furans in sediments of the Piscataqua dredging area

Station	Sample No.	Dioxin / Furan (pg/g)																								
		2,3,7,8-TCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDD	OCDF	Total TCDD	Total TCDF	Total PeCDD	Total PeCDF	Total HxCDD	Total HxCDF	Total HpCDD	Total HpCDF	Total 2,3,7,8-TCDD TEQ
S- 01	0-5 ft																									
	5-10 ft																									
S- 02	0-5 ft	--	--	1.2	--	--	1.9	12	5.7	3.4	5.6	--	--	490	92	3.4	2700	180	2.3	--	7.1	16	280	69	2600	250	10.9
	5-10 ft																									
S- 03	0-5 ft																									
S- 05	0-5 ft																									
S- 06	0-5 ft	--	--	--	--	--	0.2	--	--	--	--	--	--	0.4	0.2	--	7.1	0.4	--	0.2	0.2	0.093	0.5	--	1.2	0.2	0.03
	5-10 ft																									
S- 07	0-5 ft																									
S- 08	0-5 ft	--	--	--	--	--	0.38	--	--	--	--	--	--	0.3	0.1	--	2.6	--	--	--	--	--	0.4	--	0.56	0.1	0.04
S- 09	0-5 ft																									
S- 10	0-5 ft																									
S- 12	0-5 ft	--	--	0.1	--	--	0.29	0.6	0.4	0.2	0.2	--	0.1	12	2.7	--	140	4.4	--	--	1.1	0.5	12	1.6	34	5.9	0.51
	5-10 ft																									
	10-15 ft																									
	15-20 ft																									
S- 14	0-5 ft																									
	5-10 ft																									
S- 16	0-5 ft	--	--	--	--	--	0.24	--	--	--	--	--	--	0.39	0.25	--	5.90	0.75	--	--	--	--	0.24	--	1.40	0.25	0.03
Mean																											
ISQG		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.85
PEL		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	21.5
Human Health SL		--																									153
MA, RCS-1		--																									20
MA, RCS-2		--																									50

Table 20. Exposure parameter values for risk-based screening levels

Exposure Parameter *(1)*	**Units**	**Beach Recreators**					
		Child		**Youth** *(2)*		**Adult**	
Exposure duration (ED)	yr	6		10		26	*(3, 4)*
Exposure frequency (EF)	day/yr	15	*(3, 5)*	15	(3, 5)	15	*(3, 5)*
Exposure time (ET)	hr/day	4	*(3)*	4	(3)	4	*(3)*
Ingestion rate, sediment (IR)	mg/day	200		100		100	
Surface area (SA)	cm^2/day	2,373	*(6)*	6,032	(6)	6,032	*(6)*
Adherence factor (AF)	mg/cm^2	0.2		0.07		0.07	
Body weight (BW)	kg	15		80		80	

Notes:

(1) USEPA RSL Online Calculator recreator default exposure parameter values were used except as noted

(2) Youth assumed to be 6-16 years old consistent with USEPA RSL Online Calculator

(3) Professional judgment

(4) Exposure duration assumed to be entirely as an adult

(5) Exposure frequency assumes once per week from Memorial Day through Labor Day

(6) For child, weighted average of mean values for the head, hands, forearms, lower legs, and feet (male and female, birth to <6 years). For youth and adult, weighted average of mean values for head, hands, forearms, lower legs, and feet (male and female, 21+ years).

Table 21. Derived human health screening levels

Detected Chemical	CAS Number	Human Health Screening Levels						Screening Level for Comparison	
		Child	*basis*	Youth	*basis*	Adult	*basis*		*basis*
Metals (mg/kg)									
Arsenic, Inorganic	7440-38-2	21	*ca*	125	*ca*	48	*ca*	21	*ca*
Cadmium (Diet)	7440-43-9	1,670	*nc*	16,700	*nc*	16,700	*nc*	1,670	*nc*
Chromium(III), Insoluble Salts	16065-83-1	2,740,000	*nc*	29,200,000	*nc*	29,200,000	*nc*	2,740,000	*nc*
Copper	7440-50-8	73,000	*nc*	779,000	*nc*	779,000	*nc*	73,000	*nc*
Lead and Compounds	7439-92-1	--	--	--	--	--	--	400 *(1)*	*nc*
Mercuric Chloride	7487-94-7	548	*nc*	5,840	*nc*	5,840	*nc*	548	*nc*
Nickel Soluble Salts	7440-02-0	36,500	*nc*	389,000	*nc*	389,000	*nc*	36,500	*nc*
Zinc and Compounds	7440-66-6	548,000	*nc*	5,840,000	nc	5,840,000	*nc*	548,000	*nc*
Low Molecular Weight PAHs (ug/kg)									
Acenaphthene	83-32-9	83,700,000	*nc*	754,000,000	*nc*	754,000,000	*nc*	83,700,000	*nc*
Acenaphthylene	208-96-8	--	--	--	--	--	--	--	--
Anthracene	120-12-7	418,000,000	*nc*	3,770,000,000	*nc*	3,770,000,000	*nc*	418,000,000	*nc*
Fluorene	86-73-7	55,800,000	*nc*	503,000,000	*nc*	503,000,000	*nc*	55,800,000	*nc*
Naphthalene	91-20-3	27,900,000	*nc*	251,000,000	*nc*	251,000,000	*nc*	27,900,000	*nc*
Phenanthrene	85-01-8	--	--	--	--	--	--	--	
High Molecular Weight PAHs (ug/kg)									
Benzo(a)anthracene	56-55-3	30,500	*ca*	293,000	*ca*	338,000	*ca*	30,500	*ca*
Benzo(a)pyrene	50-32-8	3,050	*ca*	29,300	*ca*	33,800	*ca*	3,050	*ca*
Benzo(b)fluoranthene	205-99-2	30,500	*ca*	293,000	*ca*	338,000	*ca*	30,500	*ca*
Benzo(g,h,i)perylene	191-24-2	--	--	--	--	--	--	--	--
Benzo(k)fluoranthene	207-08-9	305,000	*ca*	2,930,000	*ca*	3,380,000	*ca*	305,000	*ca*
Chrysene	218-01-9	3,050,000	*ca*	29,300,000	*ca*	33,800,000	*ca*	3,050,000	*ca*
Dibenz(a,h)anthracene	53-70-3	3,050	*ca*	29,300	*ca*	33,800	*ca*	3,050	*ca*
Fluoranthene	206-44-0	55,800,000	*nc*	503,000,000	*nc*	503,000,000	*nc*	55,800,000	*nc*
Indeno(1,2,3-cd)pyrene	193-39-5	30,500	*ca*	293,000	*ca*	338,000	*ca*	30,500	*ca*
Pyrene	129-00-0	41,800,000	*nc*	377,000,000	*nc*	377,000,000	*nc*	41,800,000	*nc*
Pesticides (ug/kg)									
4,4'DDD	72-54-8	44,200	*nc*	399,000	*ca*	154,000	*ca*	44,200	*nc*
4,4'-DDE	72-55-9	62,600	*ca*	401,000	*ca*	154,000	*ca*	62,600	*ca*
4,4'DDT	50-29-3	58,500	*ca*	356,000	*ca*	137,000	*ca*	58,500	*ca*
Endosulfan, beta	33213-65-9	--	--	--	--	--	--	--	--
Hexachlorobenzene	118-74-1	13,300	*ca*	85,200	*ca*	32,800	*ca*	13,300	*ca*
Nonachlor, cis	5103-73-1	--	--	--	--	--	--	--	--
Polychlorinated Biphenyls (ug/kg)									
PCBs (as Aroclor 1254)	11097-69-1	7,990	*ca*	42,800	*ca*	16,500	*ca*	7,990	*ca*
Dioxins/Furans (pg/g)									
2,3,7,8-Tetrachlorodibenzo(p)dioxin	1746-01-6	153	*ca*	930	*ca*	358	*ca*	ca	*ca*
Total Petroleum Hydrocarbons (TPH) (mg/kg) *(2)*									
TPH Aliphatic High (C19-C23)	--	5,480,000	*nc*	58,400,000	*nc*	58,400,000	*nc*	5,480,000	--
TPH Aromatic Medium (C9-C16)	--	7,300	*nc*	77,900	*nc*	77,900	*nc*	7,300	--
TPH Aromatic High (C17-C32)	--	59,000	*nc*	547,000	*nc*	547,000	*nc*	59,000	--

(1) USEPA regional screening level for residential soil as sediment screening level cannot be calculated in the USEPA online RSL Calculator

(2) TPH fractions available in the USEPA online RSL Calculator and used as surrogates for detected MassDEP Extractable Petroleum Hydrocarbons (C19-C36 Aliphatics and C11-C22 Aromatics). The oral reference doses (RfDs) used in the USEPA online RSL Calculator are somewhat different than the oral RfDs recommended by the MaDEP (2003), as follows:

- USEPA online RSL Calculator: RfD for TPH Aliphatic High (C19-C23) = 3 mg/kg-day; RfD for TPH Aromatic Medium (C9-C16) = 0.004 mg/kg-day; RfD for TPH Aromatic High (C17-C32) = 0.04 mg/kg-day
- MassDEP: RfD for C19-C32 Aliphatics = 2 mg/kg-day; RfD for C9-C32 Aromatics = 0.03 mg/kg-day

Basis: *ca* = based on a 10^{-6} target cancer risk; *nc* = based on a noncancer hazard index of 1
CAS = Chemical Abstract Service

6. Implementation of Nourishment at Nantasket Beach

This section provides a brief overview of practical issues associated with the dredging, transportation, and placement, as relevant for understanding the suitability of the material for nourishing Nantasket Beach.

6.1 Dredging at the Piscataqua River

Dredging of the sediment in the Piscataqua River would be performed by a marine construction firm contracted by the USACE. The nature of the deposit in the Piscataqua River dictates its removal process. The sediment body to be removed was long considered bedrock and so for many decades was left out of harbor improvement plans. Dredging would occur during specific environmental windows. The most critical window is dictated by two species of sturgeon.

Dredging is permitted to occur between mid-October and mid-April (a window of six months). The USACE expects it will spend four months removing the till and other unconsolidated materials, one month for drilling and blasting of rock, and the final month for removal of the blasted rock.

The USACE expects that the dredging contractor would likely use a mid-range (16 to 21 cy), heavy gage, heavy-toothed bucket. A very large excavator is also a possible equipment choice. The sediment is expected to be placed into scows with a capacity of 3,500 to 5,000 cy. Once filled to capacity, the loaded scow barges would be towed to Nantasket Beach for offloading. If there are scow loads that, in the opinion of the construction inspectors, appear to have too great a silt/clay percentage to place on the beaches or nearshore sites, then those scows would be directed to the selected ocean disposal site for disposal.

6.2 Transportation

The Federal base plan is for disposal at an ocean site about 11 nm offshore of the harbor mouth, halfway between the Isles of Shoals and Boon Island in about 300 ft of water. The distance from the Piscataqua River dredging area to the disposal site is approximately 17 nm. The distance from the dredging location to Nantasket Beach is approximately 59 nm. For transportation to Nantasket Beach, more scow/tug pairs would need to be added to the project equipment schedule to assure that dredging at the Piscataqua River site could proceed without interruptions.

6.3 Placement at Nantasket Beach

Direct beach placement of Piscataqua sediments at Nantasket Beach would require a barge-mounted pump system. The system would create a slurry of water and sediment to facilitate hydraulic transportation of the sediment to the beach. A floating pipeline would be used to direct the material from the pump to the targeted nourishment location on the beach. The length of this pipeline is anticipated to be approximately 2,600 ft long. The mooring location for the barge-mounted pump would be generally seaward of the 24 ft MLLW contour. The specific location would be determined after further review of bathymetric information and after coordination with the marine contractor. If the pipe is longer, a booster pump may be required. It may be prudent

to equip the pump with a grizzly set-up to exclude cobbles from the slurry, which would avoid clogging of the pipeline. The Piscataqua River surveys indicate that the cobble content is small to minimal; however, the amount of cobble in the dredged material would not be fully known until the Piscataqua River site is dredged.

Once discharged onto the beach, the sediment would naturally dewater and settle. It is likely that there would be several dewatering sites along the length of the beach. The dewatering process would create a plume of suspended fine-grained sediment in the littoral zone of the beach. The sediment in the plume would naturally dissipate and settle offshore in less energetic environments. Natural coastal processes (waves, tides) along the beach would continually rework the material and sort the grain sizes, leaving the coarser (*e.g.*, sandy) material in place. The finest sediment fractions (silt/clay) in the nourishment material would be winnowed for a period of time and transported off the beach. This sorting process of different grain sizes would reestablish the zonation of sediment textures that presently characterize the beach.

Following dewatering, the sediment can be moved on the beach using heavy construction equipment. Equipment would likely include bulldozers, excavators, front-end loaders, and dump trucks. Material would be moved into the shape dictated by the nourishment design. The topography of the beach would be surveyed during construction to ensure the beach is built to the correct elevations and slopes.

A specific construction management plan would be developed in coordination with the dredge contractor prior to the project. It is anticipated that this project would require standard marine construction equipment and practices to transport and handle the suitable beach nourishment sediment.

6.4 Implementation – Summary

Implementation of the nourishment project is feasible. There are no impediments that would limit dredging, transportation, and placement of the dredged material.

7. Permitting Requirements

This section summarizes permitting requirements for the nourishment project at Nantasket Beach.

7.1 Regulatory Compliance

The anticipated permit and other compliance documents for beach nourishment are as follows:

- **MEPA:** Expanded Environmental Notification Form (EENF), and request for a Waiver from preparation for Environmental Impact Report (EIR). The EENF would describe the project and its alternatives, and assess potential environmental impacts and mitigation measures. An alternative process could consist of submitting a basic Environmental Notification Form (ENF) followed by a two-step EIR (Draft and Final). The most appropriate approach is to be discussed with MEPA. The Secretary of Energy and Environmental Affairs would issue a Certificate determining that the EENF or EIR is adequate, and allowing the project to proceed to permitting.

- **Hull Conservation Commission:** Notice of Intent (NOI) review under the Massachusetts Wetlands Protection Act (WPA). The NOI is also submitted to MassDEP. The Conservation Commission would issue an Order of Conditions (and Certificate of Compliance upon project completion).

- **MassDEP:** Chapter 91 Waterways License. An individual 401 Water Quality Certification (WQC) application would not be required. A Final Order of Conditions issued pursuant to the wetlands regulations at 301 CMR 10.00 would suffice as the WQC. Beach nourishment is one of the activities listed in 314 CMR 9.03(2) for which the Order of Conditions may serve as the WQC.

- **MA Office of Coastal Zone Management (CZM):** Federal CZM consistency review and certification.

- **USACE:** If the nourishment project is funded by the State of Massachusetts (without federal funding), the project would either require a General or Individual Permit to address Section 10 and Section 404 permit requirements. In case of federal funding for the project, these requirements would be addressed by the USACE as part of their requirements under the National Environmental Policy Act (NEPA).

Critical will be the anticipated schedule for dredging of the Piscataqua River area by the USACE. A start of dredging in mid-October 2018 would require an accelerated approach to obtain the needed permits.

7.2 Pre-filing Consultations with MEPA and Participating Agencies

Completion of the permitting process requires early coordination and pre-filing consultations with permitting agencies and other participating agencies, including: MEPA, MassDEP, CZM, Massachusetts Division of Marine Fisheries (DMF), Massachusetts Natural Heritage and Endangered Species Program (NHESP), Massachusetts Historical Commission (MHC), the

Massachusetts Board of Underwater Archaeological Resources (BUAR), Hull Conservation Commission, and the USACE New England District. The goal for pre-filing consultations would be to achieve a common understanding of agency expectations and information needs to be addressed in the MEPA documents and permit applications when filed, thereby avoiding any gaps or deficiencies that might delay project permitting and implementation. Pre-filing consultations also serve as an opportunity to achieve consensus on the optimum MEPA review process, give the agencies advance notice of the upcoming filings, and generally help to streamline review and decision-making. There should also be agreement on a timeline for site visits, public hearings, and responses to questions and comments. Frequent consultations with permitting agencies shall also occur during the permitting process.

Initial coordination with the DMF indicates that the dredging window at the Piscataqua River site (mid-October to mid-April) would be consistent with the placement window at Nantasket Beach. DMF's restrictions for shore zone fishes would apply for the period between May 1 and November 1, if the dredged sediments were placed into the subtidal zone at Nantasket Beach (Kate Frew, DMF, personal communication, February 9, 2018). Based on current plans, sediments would be placed into the intertidal zone at Nantasket Beach. In addition, considering mobilization needs for the dredging contractor at the Piscataqua River site, sediment would be expected to arrive at Nantasket Beach after November 1. Furthermore, DMF would consider a waiver to reduce the protective window by a couple of weeks, should some of the material be placed into the subtidal zone at Nantasket Beach before November.

7.3 Information and Analyses for Permitting

If the approach of an EENF is selected for MEPA, a draft Table of Contents (TOC) for the EENF would be prepared for the agency coordination meeting. A tentative draft for a MEPA document is provided in Attachment G. The TOC outlines the information and analyses that MEPA and permitting agencies would likely require. The EENF shall be a comprehensive document that includes the information needed by permitting agencies to make their decisions on the project. For accelerated permitting (dredging in October 2018) draft permit applications would be included in the EENF filing to allow for early review and feedback from agencies.

For the Nantasket Beach nourishment project, using Piscataqua River dredged material as a source, the agencies would be primarily concerned with the following issues:

- Sediment characteristics, existing and proposed conditions
- Sediment transport, existing coastal processes and changes expected post-nourishment
- Short-term and long-term effects of nourishment in terms of resiliency and mitigation of flood impacts
- Short-term and long-term enhancement of coastal beach as a natural resource and for its recreational value
- Analysis of alternatives and rationale for selection of preferred design

- Demonstration of no adverse impacts on coastal and aquatic resources (including water quality, fish and shellfish, birds, and aquatic vegetation)
- Public access to the waterfront
- Long-term monitoring, adaptive management, and future nourishment options.

These issues were considered in the TOC for the MEPA document (EENF or EIR) (Appendix G).

7.4 Post-construction Monitoring

Post-placement monitoring would likely require beach profile surveys and evaluation of survey data to determine nourishment stability (seasonally for first year, annually thereafter, and after storm events). The monitoring plan would need to provide sufficient data to assess shoreline changes and shifting of beach fill, evaluate whether the project is performing as designed, evaluate impacts, and identify maintenance and re-nourishment requirements.

7.5 Permitting – Summary

It is expected that permits would be received considering the interest by stakeholders in this nourishment project. However, if dredging by the USACE was to occur in the fall of 2018, a well-coordinated, streamlined approach between all agencies and organizations would be required to complete the permitting for the project in time.

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Appendix E

Benthic Invertebrates from the Nantasket Beach Fill Project

(Pratt, 1996; Attachment A in USACE, 2002)

Benthic invertebrates from the Nantasket Beach fill project.

Sheldon D. Pratt
13 Sherman Court
Wakefield, R.I. 02879

June 16, 1996

Background

The New England Division, US Corps. of Engineers obtained 15 core samples from the southern part of Nantucket Beach, Massachusetts . Five samples were taken from each of three tidal elevation levels . The samples were sieved to 0.5 mm, preserved, and transported to the University of Rhode Island where invertebrates were removed from sediments, identified, and counted.

Methods

It was possible to separate most of organisms from sample sand and gravel by repeated suspension and decantation from a tall pitcher. The remaining sediments were sieved on 2.0 mm and 0.5mm screens. The material retained on the 2 mm. screen was sorted without magnification from glass trays. Organisms removed by suspension, and sediment passing through the coarse sieve were examined under low-power dissecting microscopes.

Organisms were identified to species in most cases. Counts of organisms and the volume of sample residue were entered on a computer spread sheet (MS Excel). Identified organisms were preserved in 70% alcohol and archived at the University of Rhode Island Graduate School of Oceanography.

Results and discussion

Counts of benthic fauna are provided in Table 1. This table lists all species found in NED,COE samples taken at North Nantasket in 8/3/95 even if they were not present in the 1996 study. Total individuals and species and the volume and constituents of sieve residue found in each sample are listed at the end of the table.

The number of individuals per sample varied from 1 to 9. Nine living taxa were found in the whole collection. Most samples had only 1 to 3 species, Four species were abundant enough to be able to recognize patterns of distribution. A polychaete, *Paraonis fulgens* was present in "mid' and "low" samples. Each of three species of haustorid amphipods had a different distribution pattern: *Amphiporeia virginiana* was found at all levels, *Haustorius canadensis* was found in two "high" samples, and *Parahaustorius longimerus* was found in "mid" and "low" samples.

The density and distribution of *P. fulgens* in this collection was similar to that found in samples taken from North Nantasket Beach in August, 1995. Two species which are usually found subtidaly (*Nephys picta and Spiophanes bombyx*) were associated with *P. fulgens* in North Nantasket but absent in this collection.

The occurrence of *A. virginiana* in low numbers at all elevations (1 to 5) contrasts with the August 1995 finding of high densities (24 to 458) at low elevations. In this study the *A. virginiana* identified were females brooding young and juveniles. It is possible that the difference in density of *A. virginiana* in the two studies is due to seasonal rather than spatial differences. changes increases in density at lower elevations during the summer in a pattern similar to that found for dominant species In a long term study of a New Hampshire beach, Jaramillo et al.(1987) found increasing densities of *A. virginiana* at low elevations over the summer

Croker (1970) describes *A. virginiana* as " not as restricted to infaunal living as other haustoriids (with) large numbers seen swimming in the surf and semi-liquid sand". This behavior suggests less sensitivity to sediment variables and more rapid recolonization of disturbed areas than for deeper burrowing haustoriids.

Bivalve mollusks were not important in these samples. Only a few *Mytilus edulis* (blue mussel) spat and recently dead *Spisula sollidisima* (surf clam) spat were found.

The supratidal area of beaches where macroalgae, eelgrass and marshgrass is deposited often supports a diverse assemblage of amphipods, isopods, insects and oligochaetes .No element of this assemblage was seen in samples from North Nantasket or from the present study area.

There are very few studies of New England beach fauna which can be used to interpret data from Nantasket and to predict effects of disturbance. The Jaramillo et al.(1987) study was made at a beach which rebuilt after a period of erosion. Recolonization by opportunistic and preexisting species of polychaetes took place within one or two years. Amphipod populations built more slowly and were largely recovered after four years.

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Acknowledgment Sample sorting was carried out by M.E Jackman.

Sheet1

Table 1. Benthic organisms recovered from samples collected at Nantasket MA, May 10,1969
(d.)=dead Order of importance of sieve residue constituent coded 1-3.

LEVEL	HIGH					MID					LOW				
SAMPLE	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
RHYNCHOECOELA sp.															1
POLYCHAETA															
Nephtys picta															
Paraonis fulgens							1	2		1	5		1		8
Scolelpsis squamata		1(lg)													
Spiophanes bombyx															
OLIGOCHAETA spp.	1									1					
MOLLUSCA															
Mytilus edulis spat		1			1				2	1					
Spisula sollidisima spat					(1 d.)				(1 d.)						
CRUSTACEA															
ISOPODA															
Chiridotea tuftsi															
AMPHIPODA															
Acanthohaustrius millsi															
Amphiporeia virginiana	1		1	2	1	1	5	3		1	1	1	4	1	
Amphiporeia sp.															
Gammarus duebeni	1														
Haustorius canadensis		1	3												
Parahaustorius longimerus									7	1			1		
Number of individuals	3	3	4	2	2	1	6	5	9	5	6	1	6	1	9
Number of species	3	3	2	1	2	1	2	2	2	5	2	1	3	1	2
Sieve residue volume (cm)	50	80	10	600	50	35	125	30	180	50	50	115	75	75	65
sand	2			2		1	1	1	1	1	1	1	1	1	1
pebbles	1	1	1	1	1		2								
shell			2		2		3	2	2		2		2	2	2
					Myt										

Appendix F

Surf Clam Survey (2007)

Battelle, 2007

(*) Main report. The complete report with the field data sheet attachment is included on the CD as a separate file

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US ARMY CORPS OF ENGINEERS
New England District

Contract No. DACW33-03-D-0004
Delivery Order No. 25

January 12, 2007

Final Report

SURF CLAM SURVEY IN SUPPORT OF FEASIBILITY STUDY:

Hydraulic Clam Dredging
Nantasket Beach
Hull, MA

FINAL REPORT

for

Hydraulic Clam Dredging—Nantasket Beach,
Hull, MA

Submitted to

Department of the Army
U.S. Army Corps of Engineers
North Atlantic Division
New England District

Contract No. DACW33-03-D-0004
Delivery Order No. 25

January 12, 2007

Prepared by

Battelle
397 Washington Street
Duxbury, MA 02332
(781) 934-0571

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APPENDICES

Appendix A: Field Sampling Log Forms

1.0 INTRODUCTION

1.1 Project Description

Nantasket Beach is located in the city of Hull, Massachusetts, which is located approximately 25 miles southeast of Boston, Massachusetts. The US Army Corps of Engineers New England District (NAE) and the Massachusetts Department of Conservation and Recreation (DCR) have been partnered in a Section 103 Storm Damage Reduction Study for the area behind Nantasket Beach and the DCR Seawall since the 1990's. Numerous alternatives have been investigated during the extended study period for the Nantasket Beach Feasibility Study. A leading candidate has been the construction of a beach fill project in front of the 5,500 foot seawall. This alternative involves placing sandy material along Nantasket Beach. To evaluate the potential impacts of this alternative to surf clam (*Spisula solidissima*) populations in the project area, an abundance survey of surf clams is necessary.

1.2 Scope of Work

The project scope of work consisted of hydraulic clam dredging along six transect lines (approximately 2,072 meters (6,800 feet) long) parallel to Nantasket Beach. The six transect lines were located at 6-foot depth intervals (mean lower low water (MLLW)). The transects followed the 1, 7, 13, 19, 25, and 31 feet MLLW depth intervals. Commercial grade hydraulic clam dredge equipment was used to survey the transects for surf clam resources. Dredge tows were accomplished at alternate 100-meter (328 feet) increments along the length of each transect. Tows were completed along each transect with an overall project total of 53 tows at the intervals specified in the Statement of Work (SOW). Andy Lynn Boats performed the hydraulic clam dredging activities under the supervision of a Battelle Chief Scientist.

1.3 Organization of this Report

This report was prepared in accordance with the requirements outlined in the NAE SOW for Nantasket Beach, Hull, MA. This report is organized in four sections. Section 1.0 is an introduction and describes the project and scope of work. A summary of the materials and methods used in support of this project is presented in Section 2.0. Results of sampling effort are discussed in Section 3.0. References are provided in Section 4.0. Appendix A contains the Field Sampling Logs (Tow Log Form and Shellfish Measurement Data Form).

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2.0 MATERIALS AND METHODS

2.1 Sample Collection/Processing

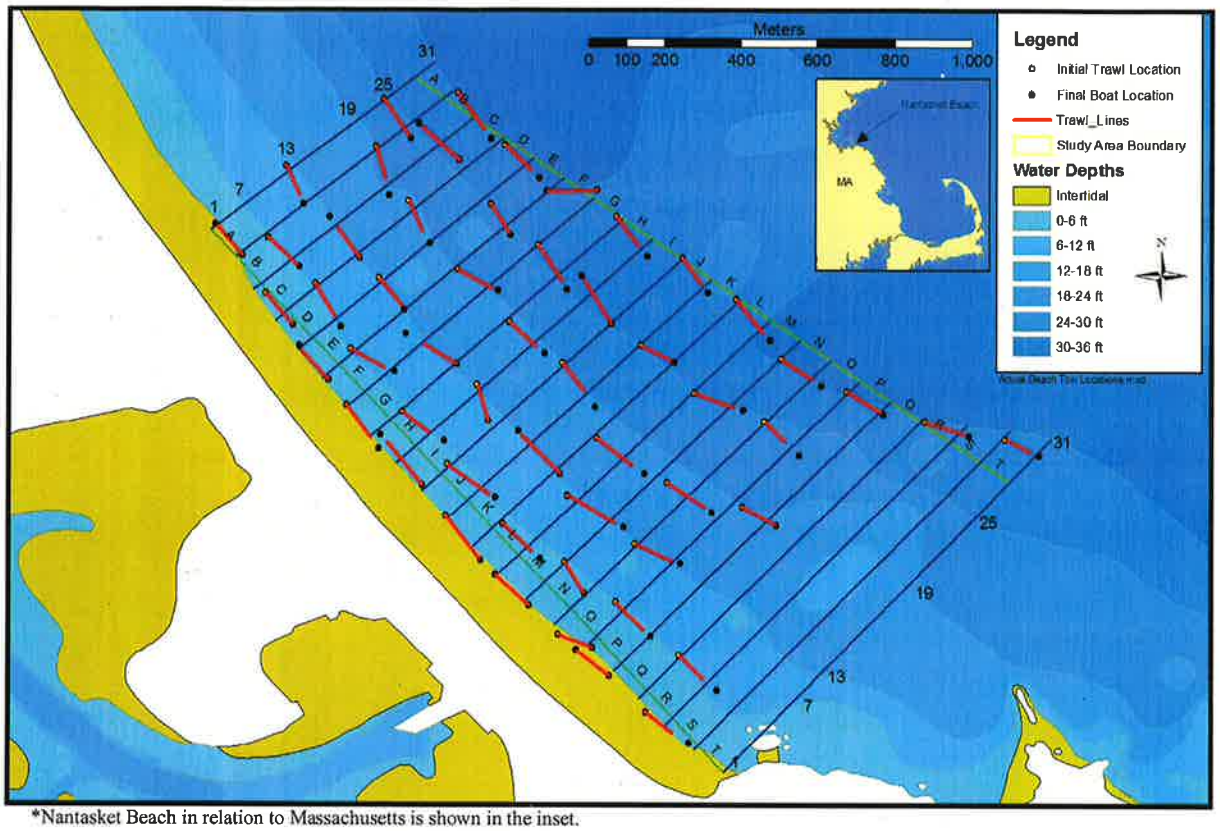
On December 11, 12, 14, 15, and 16, 2006, hydraulic tows were conducted at each of the 6 transects located in Nantasket Beach. A total of 53 tows for a distance of approximately 100 meters each were conducted along the 6 transects. On December 16, 2006; a representative from NAE (Todd Randall) observed the dredging operations and provided guidance regarding conducting tows in a rocky portion of the sampling area. The transects were located at 6-foot depth intervals (mean lower low water (MLLW)) and followed the 1, 7, 13, 19, 25, and 31 feet MLLW depth intervals (Figure 2-1). Table 2-1 provides the coordinates of each tow.

Hydraulic dredging methods are summarized below. Complete details on the survey/sampling methods can be found in the Nantasket Beach Sampling and Analysis Plan (SAP) (Battelle 2006).

Table 2-1. Actual Tow Locations and Coordinates.

Tow ID	End Tow Time	Begin Longitude	Begin Latitude	End Longitude	End Latitude
1-A	12/11/06 15:11	-70.864265	42.280701	-70.865097	42.281399
1-C	12/15/06 10:12	-70.863503	42.279751	-70.862633	42.279018
1-E	12/11/06 14:58	-70.861504	42.277817	-70.862450	42.278515
1-G	12/15/06 9:20	-70.860718	42.276966	-70.859947	42.276100
1-I	12/11/06 14:46	-70.858780	42.275368	-70.859901	42.276417
1-K	12/15/06 9:32	-70.857880	42.274448	-70.856750	42.273449
1-M	12/11/06 14:34	-70.855270	42.272400	-70.856300	42.273117
1-O	12/15/06 9:45	-70.854332	42.271702	-70.853264	42.271385
1-Q	12/11/06 14:17	-70.852783	42.270718	-70.853798	42.271332
1-S	12/16/06 8:35	-70.851181	42.269585	-70.850197	42.269115
7-B	12/15/06 10:29	-70.863365	42.281017	-70.862419	42.280384
7-D	12/16/06 9:01	-70.861885	42.279701	-70.861130	42.278965
7-F	12/15/06 10:57	-70.860580	42.278316	-70.859451	42.277916
7-H	12/16/06 9:13	-70.858833	42.276833	-70.857880	42.276268
7-J	12/16/06 10:24	-70.857765	42.275551	-70.856285	42.274933
7-L	12/16/06 9:27	-70.855835	42.274166	-70.854897	42.273483
7-N	12/11/06 14:01	-70.854134	42.273384	-70.853516	42.272652
7-P	12/16/06 9:43	-70.852348	42.272266	-70.851402	42.271633
7-R	12/16/06 9:59	-70.850151	42.270950	-70.849297	42.270351
13-A	12/11/06 12:02	-70.862632	42.282665	-70.862281	42.281867
13-C	12/12/06 14:08	-70.860664	42.280849	-70.861450	42.281551
13-E	12/11/06 12:19	-70.859886	42.279999	-70.859116	42.279366
13-G	12/12/06 13:50	-70.858147	42.278252	-70.859070	42.278782
13-I	12/11/06 13:42	-70.856834	42.277584	-70.856499	42.276733
13-K	12/12/06 13:29	-70.854187	42.275551	-70.855553	42.276482
13-M	12/15/06 14:17	-70.853981	42.274750	-70.852249	42.274216
13-O	12/15/06 14:34	-70.851799	42.273602	-70.850433	42.273335
19-B	12/12/06 14:34	-70.860085	42.282818	-70.859581	42.282051

Tow ID	End Tow Time	Begin Longitude	Begin Latitude	End Longitude	End Latitude
19-D	12/12/06 14:58	-70.858734	42.281666	-70.858299	42.280918
19-F	12/12/06 15:27	-70.857536	42.280182	-70.856148	42.279800
19-H	12/16/06 10:44	-70.855553	42.278915	-70.854713	42.278301
19-J	12/16/06 11:07	-70.853882	42.277733	-70.853134	42.277050
19-L	12/15/06 13:20	-70.852783	42.276115	-70.851570	42.275467
19-N	12/15/06 13:39	-70.850647	42.275166	-70.849419	42.274532
19-P	12/14/06 14:55	-70.848434	42.274651	-70.847382	42.274216
25-A	12/14/06 12:47	-70.859718	42.284233	-70.858887	42.283401
25-C	12/15/06 15:00	-70.857452	42.282951	-70.858635	42.283768
25-E	12/14/06 13:03	-70.856300	42.281799	-70.855766	42.281101
25-G	12/14/06 13:15	-70.854668	42.280750	-70.853996	42.279800
25-I	12/15/06 14:49	-70.852585	42.279133	-70.853554	42.280132
25-K	12/14/06 13:29	-70.851570	42.278435	-70.850586	42.278084
25-M	12/14/06 13:50	-70.849800	42.277134	-70.848396	42.276951
25-O	12/16/06 11:32	-70.847267	42.276566	-70.846664	42.275867
31-B	12/14/06 9:30	-70.857117	42.284382	-70.856354	42.283382
31-D	12/14/06 11:38	-70.855652	42.283100	-70.854851	42.282452
31-F	12/12/06 12:24	-70.853050	42.282150	-70.854614	42.282135
31-H	12/14/06 9:48	-70.852753	42.281399	-70.851448	42.280567
31-J	12/14/06 11:51	-70.850136	42.280315	-70.849503	42.279701
31-L	12/14/06 10:05	-70.848701	42.279301	-70.847534	42.278568
31-N	12/14/06 12:03	-70.847237	42.277882	-70.845947	42.277500
31-P	12/14/06 10:28	-70.845100	42.277302	-70.844017	42.276817
31-R	12/14/06 12:12	-70.842651	42.276501	-70.841316	42.276299
31-T	12/14/06 10:48	-70.839935	42.276134	-70.839081	42.275818



*Nantasket Beach in relation to Massachusetts is shown in the inset.

Figure 2-1. Actual Tow Locations Conducted at Nantasket Beach, Hull, MA.

2.1.1 Surf Clam Collections

Hydraulic dredge tows were conducted to the depth intervals specified in the SOW and summarized in the Nantasket Beach SAP (Battelle 2006). Battelle's subcontractor, Andy Lynn Boats, was responsible for conducting the hydraulic tows.

A commercial hydraulic dredge, which measured 30" W X 15"H, was used to collect surf clams. The dredge was equipped with 4" steel rings and a 2-¾"mesh catch net. Due to the size of the catch net, clams less than 3 inches in size could have been potentially lost during the retrieval of the dredge. The dredge sampled about 4 feet below the sediment. The catch bag size was estimated to hold 12 bushels of clams. However, it should be noted that the catch bag was not retrieved full for any of the tows. To verify the actual distance of the tow, 4 events were marked in the NavSam© system. The 4 events that were marked in the NavSam© system were 1) when the dredge was on the bottom, 2) when the pump for the tow began, 3) when the pump was stopped, and 4) when the dredge was off the bottom. In most cases, the tows were conducted longer than 100 meters to ensure that the distance of 100 meters was achieved. The vessel was positioned to follow the 6-foot depth intervals by subtracting the tidal height from the measured water depth. The tidal heights were determined from an incremental tide chart. The water depth was measured from reading the echo sounder.

Commercial shellfish species retained in the dredge of each tow were identified and divided into separate bushel baskets by species. If the catch for a species was less that one bushel basket for a tow, the entire

catch was counted. If the entire catch for a species for a single tow was more than one bushel basket, the total number of baskets for that tow was recorded and one bushel basket was counted. In cases where partial bushels were collected, the amount of organisms in the bushel were visually estimated. Custody forms were not applicable. For surf clams, the individuals counted were also measured. Surf clams measured were sorted into three size classes (less than 3 inches in length, 3 to 5 inches in length, and greater than 5 inches in length), enumerated, and recorded. Surf clam length was measured at the longest dimension of the surf clam shell. Other commercial shellfish species collected were not measured. Once the clams were enumerated and measured (surf clams only), the entire catch were discarded overboard where tows were not being conducted to ensure that the discarded species were not captured in another tow.

2.2 Quality Assurance/Quality Control Procedures

Field activities used in the collection of surf clams followed approved SOPs or the SAP (Battelle 2006).

2.2.1 Chain of Custody

Surf Clams and all other organisms were collected for measurements and counts only and returned to collection locations.

2.2.2 Data Audits/QA Review

All collection data from the field received internal verification and validation.

2.2.3 Protocol Deviations

A total of seven (7-T, 13-Q, 13-S, 19-R, 19-T, 25-Q, and 25-S) tows were not conducted in the southern area of Nantasket Beach due to the area being rocky (Figure 2-1). During the survey, several attempts were made to conduct tows in the rocky area, however, the dredge became lodged in the rocks on each attempt. On the last day of the survey, the NAE Project Manager, Todd Randall was aboard the vessel and made the decision not conduct the last seven tows, which were identified as rocky areas through use of the vessel's echo sounder, so as to not damage the dredge.

3.0 RESULTS

This section summarizes results obtained from Surf Clam Abundance survey at Nantasket Beach, Hull, MA. During the five days of sampling, a total of 53 tows out of 60 tows were conducted along 6 transects parallel to the shore. Seven tows (7-T, 13-Q, 13-S, 19-R, 19-T, 25-Q, and 25-S) were not conducted in the southern end of the sampling area due rocky conditions per discussions with the NAE Project Manager Todd Randall (see Figure 2-1).

3.1.1 Tow Data

Table 3-1 provides details on the tow lengths, the target water depths, and the start and end water depths for each tow. The average tow length for all tows was 110.82 meters. The shortest tow length of 78.71 meters was conducted at tow location 31-T, which was due to rocks breaking the dredge knife. The longest tow length of 154.54 meters was conducted at tow location 13-M.

There were four tows (13-A, 25-I, 31-H, and 31-J) where the measured water depth was 2 feet greater than the target water depth at some point during the tow. The +2 foot difference in water depth for three of the tows (13-A, 25-I, 31-H) occurred at the end of the tow. However, tow 31-J was conducted with a +2 foot difference for both the start and end water depths of the tow. However, all four tows were within 4 feet of the target water depths. It should be noted that both tows 31-H and 31-J did not follow the target contour depth because for portions of transect 31, that depth contour curved further east outside of the sampling area (see Figure 2-1). The NAE Project Manager, Todd Randall, instructed the crew to stay within the sampling area rather than follow the contours of transect 31 in this area.

Table 3-1. Tow Data, including Length of Tow and Water Depths.

Tow ID	Length of tow (m)	Target Water Depth[1] (FT)	Start Water Depth (FT)	End Water Depth (FT)	Target Water Depth Minus Start Water Depth (FT)	Target Water Depth Minus End Water Depth (FT)
1-A	103.59	7.2	8	8	-0.82	-0.82
1-C	108.53	4.5	5	5.5	-0.51	-1.01
1-E	110.05	7.0	8	8	-0.96	-0.96
1-G	115.41	5.7	5	5.5	0.69	0.19
1-I	148.90	6.9	8	8.5	-1.13	-1.63
1-K	145.01	5.5	6	6	-0.53	-0.53
1-M	116.50	6.5	7	7	-0.53	-0.53
1-O	94.78	5.0	5.5	6	-0.5	-1
1-Q	107.98	6.2	7	7	-0.76	-0.76
1-S	96.44	7.3	9	9	-1.67	-1.67
7-B	105.07	11.0	11	10	-0.04	0.96
7-D	102.89	13.9	14	13	-0.07	0.93
7-F	103.14	10.1	9	11	1.13	-0.87
7-H	100.60	13.9	13	14	0.93	-0.07
7-J	139.98	12.2	12	13	0.2	-0.8
7-L	108.41	13.6	12	12	1.6	1.6
7-N	96.12	12.7	13	13	-0.27	-0.27
7-P	105.08	13.4	14	14	-0.6	-0.6

Tow ID	Length of tow (m)	Target Water Depth[1] (FT)	Start Water Depth (FT)	End Water Depth (FT)	Target Water Depth Minus Start Water Depth (FT)	Target Water Depth Minus End Water Depth (FT)
7-R	96.95	12.7	14	14	-1.3	-1.3
13-A	93.34	15.3	13.5	12	1.82	3.32
13-C	101.46	17.3	17	17	0.3	0.3
13-E	94.85	16.0	15	16.5	1.02	-0.48
13-G	96.26	16.7	17	16	-0.3	0.7
13-I	98.65	18.2	18	17	0.19	1.19
13-K	152.93	16.2	17	17	-0.8	-0.8
13-M	154.54	13.7	13	14	0.66	-0.34
13-O	116.35	13.9	14	14	-0.1	-0.1
19-B	94.90	23.8	25	23	-1.22	0.78
19-D	90.61	24.6	25	25	-0.43	-0.43
19-F	121.99	25.3	25	26	0.25	-0.75
19-H	97.22	23.7	24	24	-0.3	-0.3
19-J	97.83	23.2	23	22	0.16	1.16
19-L	123.27	19.4	18	18	1.41	1.41
19-N	123.31	19.4	18	18	1.4	1.4
19-P	99.32	21.4	21	21	0.38	0.38
25-A	115.15	25.7	25	25	0.65	0.65
25-C	133.20	26.3	28	28	-1.66	-1.66
25-E	89.30	25.8	27	27	-1.24	-1.24
25-G	119.32	25.8	27	26	-1.16	-0.16
25-I	136.92	26.0	27	28.5	-0.97	-2.47
25-K	89.99	25.9	26	26	-0.06	-0.06
25-M	117.41	26.2	25	27	1.18	-0.82
25-O	92.21	28.6	29	29	-0.42	-0.42
31-B	127.77	35.2	36	35	-0.79	0.21
31-D	97.80	32.1	33	34	-0.91	-1.91
31-F	128.82	33.0	33	33	-0.03	-0.03
31-H	141.83	34.7	33	32	1.69	2.69
31-J	85.99	31.8	28	28	3.83	3.83
31-L	126.06	34.2	33	36	1.17	-1.83
31-N	114.37	31.7	32	33	-0.26	-1.26
31-P	104.26	33.6	35	35	-1.36	-1.36
31-R	112.25	31.7	32	32	-0.32	-0.32
31-T	78.71	33.1	33	32	0.13	1.13

[1] Target Depth is Mean Lower Low Water (MLLW) plus tidal height.

The photos below provide a photo sequence of the dredging process. The first photo is of the dredge, catch bag, and water pump hose attached to the dredge. The second photo shows the dredge being deployed into the water with the water pump activated. In the third photo, the crew is hauling back the dredge containing catch from a tow. Lastly, the fourth photo shows a small surf clam catch in a bushel basket.

Photo 1

Photo 2

Photo 3

Photo 4

3.1.2 Abundance Data

This section provides detail on the abundance of surf clams as well as other species collected in the dredge. Table 3-2 presents detailed information on the numbers and sizes of surf clams caught in each tow. The tows with the largest number of bushels of surf clams were 1-G and 1-I, each with five bushels, and 1-C retained almost six bushels of surf clams. In contrast, there were 11 tows where no surf clams were retained. Of these 11 tows, nine of the tows were from transect 31. The other two tows were from locations on transects 19 and 25.

Table 3-2 also provides the abundance of clams per square meter (clams/m^2). There were two calculations used to calculate clams/m^2 based on the number of bushels per catch. In the calculation, the width of the dredge is 0.762 meters.

1) If the number of bushels is greater than one:

   (number of clams in one bushel * number of bushels)/(length of tow(m) * width of dredge (m))

2) If the number of bushels is less than one:

   (number of clams)/(length of tow * width of dredge (m))

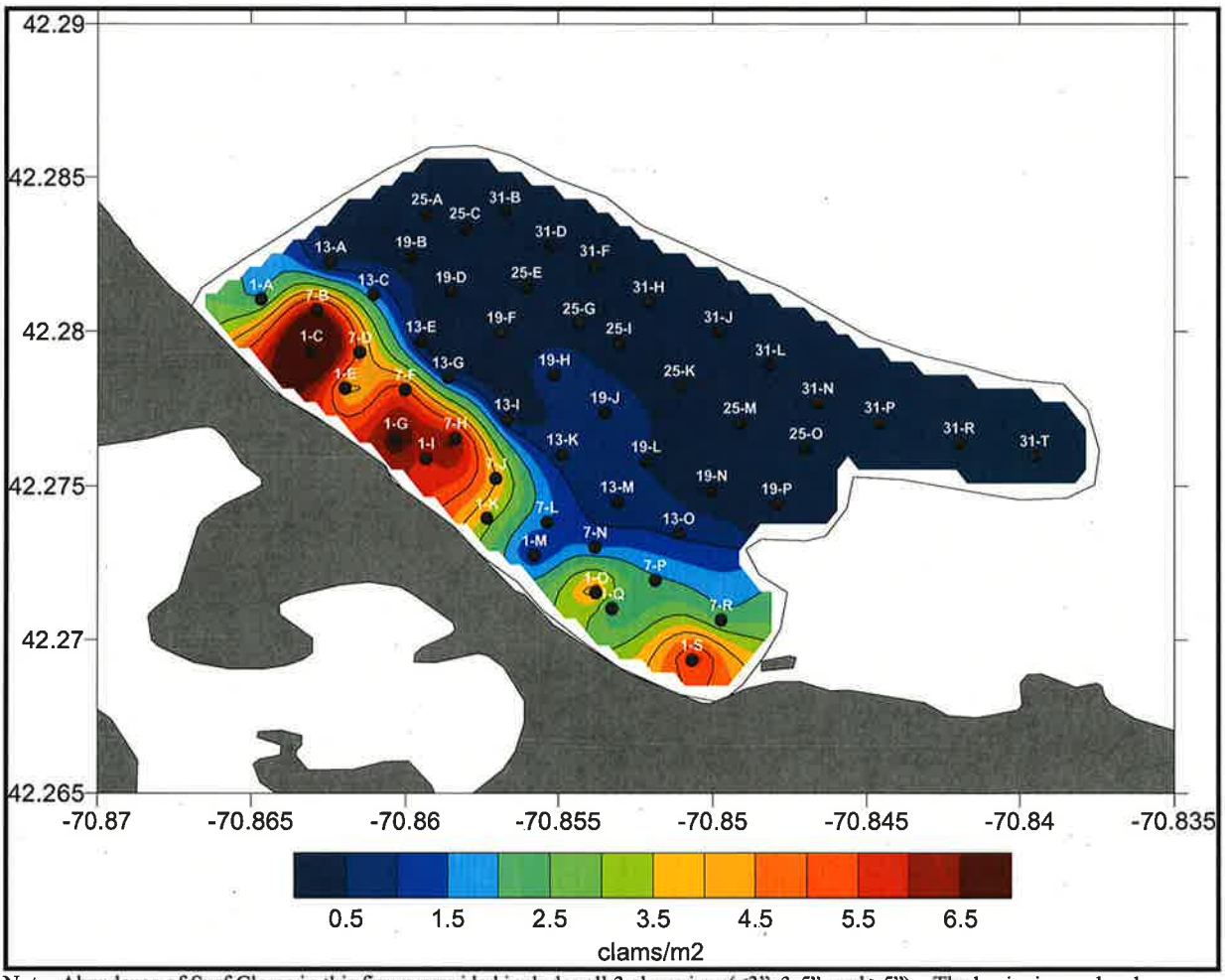
Table 3-2. Surf Clam Abundance Data per Trawl for the Three Class Sizes.

Tow ID	# of Bushels	# of < 3" Clams/ Bushel	# of 3-5" Clams/ Bushel	# of >5" Clams/ Bushel	Surf Clams Not Measured[1]	Total # of Surf Clams/ Bushel	# of Clams/ m^2	# of <3" Clams/ m^2	# of 3-5" Clams/ m^2	# of >5" Clams/ m^2
1-A	1.10	2	115	15	1	133	1.85	0.03	1.60	0.21
1-C	5.75	3	112	13	0	128	8.90	0.21	7.79	0.90
1-E	2.67	5	92	20	3	120	3.82	0.16	2.93	0.64
1-G	5.00	4	100	17	0	121	6.88	0.23	5.69	0.97
1-I	5.00	7	114	13	0	134	5.91	0.31	5.02	0.57
1-K	2.75	5	104	15	0	124	3.09	0.12	2.59	0.37
1-M	0.75	1	63	11	8	83	0.94	0.01	0.71	0.12
1-O	2.50	4	88	31	2	125	4.33	0.14	3.05	1.07
1-Q	1.75	0	61	41	4	106	2.25	0.00	1.30	0.87
1-S	3.75	1	86	26	1	114	5.82	0.05	4.39	1.33
7-B	4.33	6	78	31	1	116	6.27	0.32	4.22	1.68
7-D	3.00	13	84	28	0	125	4.78	0.50	3.21	1.07
7-F	3.75	4	77	26	3	110	5.25	0.19	3.67	1.24
7-H	4.75	2	68	34	2	106	6.57	0.12	4.21	2.11
7-J	3.33	0	96	25	2	123	3.84	0.00	3.00	0.78
7-L	1.00	6	88	39	0	133	1.61	0.07	1.07	0.47
7-N	1.00	4	74	39	1	118	1.61	0.05	1.01	0.53
7-P	2.00	0	23	61	0	84	2.10	0.00	0.57	1.52
7-R	2.00	1	28	54	2	85	2.30	0.03	0.76	1.46
13-A	0.75	0	22	18	3	43	0.60	0.00	0.31	0.25
13-C	1.50	0	21	63	1	85	1.65	0.00	0.41	1.22

Tow ID	# of Bushels	# of < 3" Clams/ Bushel	# of 3-5" Clams/ Bushel	# of >5" Clams/ Bushel	Surf Clams Not Measured[1]	Total # of Surf Clams/ Bushel	# of Clams/ m^2	# of <3" Clams/ m^2	# of 3-5" Clams/ m^2	# of >5" Clams/ m^2
13-E	0.25	0	4	17	5	26	0.36	0.00	0.06	0.24
13-G	1.00	0	3	57	1	61	0.83	0.00	0.04	0.78
13-I	0.25	1	7	11	1	20	0.27	0.01	0.09	0.15
13-K	1.00	0	16	63	4	83	0.71	0.00	0.14	0.54
13-M	1.00	0	17	61	0	78	0.66	0.00	0.14	0.52
13-O	1.00	3	16	67	1	87	0.98	0.03	0.18	0.76
19-B	0.25	0	5	12	3	20	0.28	0.00	0.07	0.17
19-D	0.25	0	5	15	1	21	0.30	0.00	0.07	0.22
19-F	0.13	0	0	10	0	10	0.11	0.00	0.00	0.11
19-H	1.00	0	10	60	3	73	0.99	0.00	0.13	0.81
19-J	1.00	1	16	52	4	73	0.98	0.01	0.21	0.70
19-L	0.75	0	14	35	1	50	0.53	0.00	0.15	0.37
19-N	0.25	0	5	20	1	26	0.28	0.00	0.05	0.21
19-P	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
25-A	0.13	0	0	8	0	8	0.09	0.00	0.00	0.09
25-C	0.06	0	2	3	1	6	0.06	0.00	0.02	0.03
25-E	0.13	0	2	8	0	10	0.15	0.00	0.03	0.12
25-G	0.06	0	0	1	0	1	0.01	0.00	0.00	0.01
25-I	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
25-K	0.06	0	1	1	0	2	0.03	0.00	0.01	0.01
25-M	0.06	0	1	0	1	2	0.02	0.00	0.01	0.00
25-O	0.06	0	1	3	1	5	0.07	0.00	0.01	0.04
31-B	0.06	0	1	1	0	2	0.02	0.00	0.01	0.01
31-D	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-F	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-H	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-J	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-L	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-N	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-P	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-R	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00
31-T	0.00	0	0	0	0	0	0.00	0.00	0.00	0.00

[1] Surf Clams were either not measured because they were broken or were observed falling out of the dredge while the dredge was being retrieved.

Figure 3-1 shows the total abundance of surf clams over the sampling area. For illustration of abundance on this and the following abundance maps, the tow start and stop coordinates were averaged to obtain one point in the center of the tow. The highest total abundance of surf clams collected per square meter was concentrated along transects 1 and 7 in the northern end of the sampling area. It should be noted that only one tow along transect 31 collected any surf clams (Table 3-2). The scale used on Figure 3-1 is from 0.5 to 6.5 clams/m^2.



Note: Abundance of Surf Clams in this figure provided includes all 3 class sizes (<3", 3-5", and >5"). The beginning and end coordinates were averaged to obtain one point in the center of the tow for the abundance map.

Figure 3-1. Total Abundance of Surf Clams Collected Per Square Meter

Figure 3-2 presents the distribution of the total abundance and three size classes (<3", 3-5", and >5") of surf clams along each transect. The greatest number of surf clams collected at any transect was the 3-5 inch size class. The smallest number of clams found overall was the < 3 inch size class and these were only found in the two innermost transects (< 7 feet MLLW). However, the number of <3 inch size clams collected could be biased low as discussed in Section 2.1.1. The larger surf clams were found further off shore, however, abundance decreased rapidly at water depths greater than 7 feet MLLW. Beyond the 13 foot MLLW depth, the abundance of the largest surf clams (> 5 inches) appeared to increase compared to the 3-5 inch surf clams. In addition, the smaller surf clams appeared to be concentrated in the northernmost section of the shallower water (Figure 3-3) while the larger surf clams were more evenly distributed along the sampling transects, with greater numbers found in the northernmost sections (Figures 3-4 and 3-5).

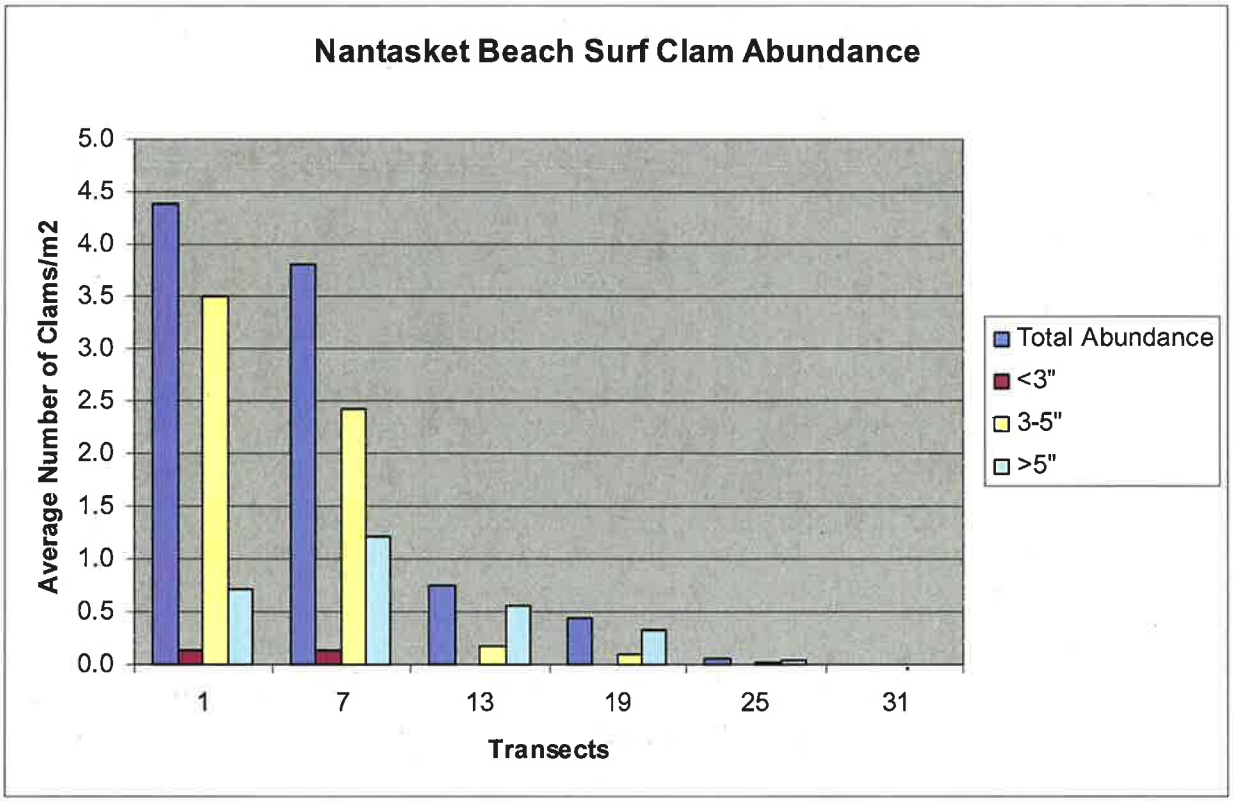
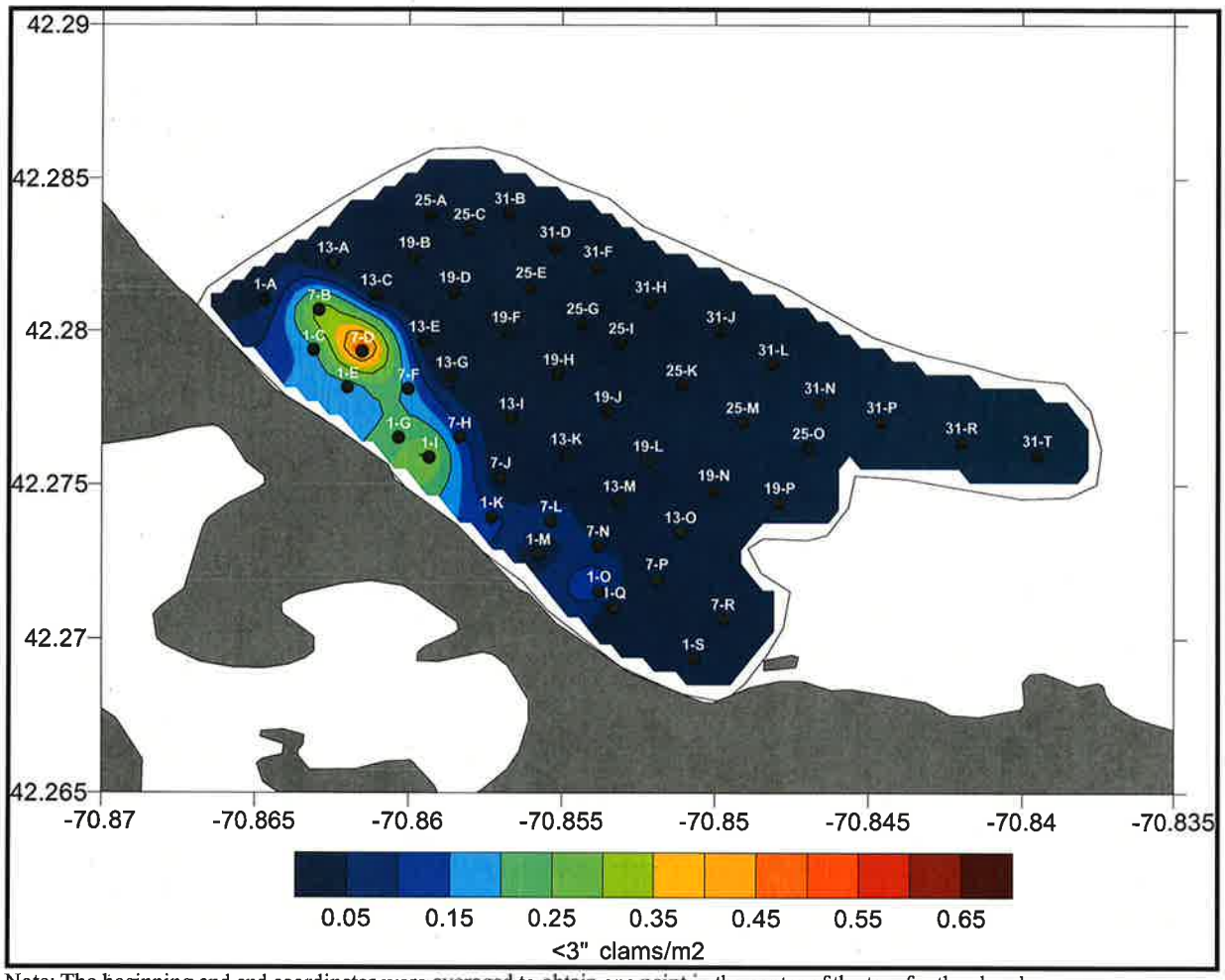


Figure 3-2. Distribution of Surf Clams and Size Classes for Each Transect

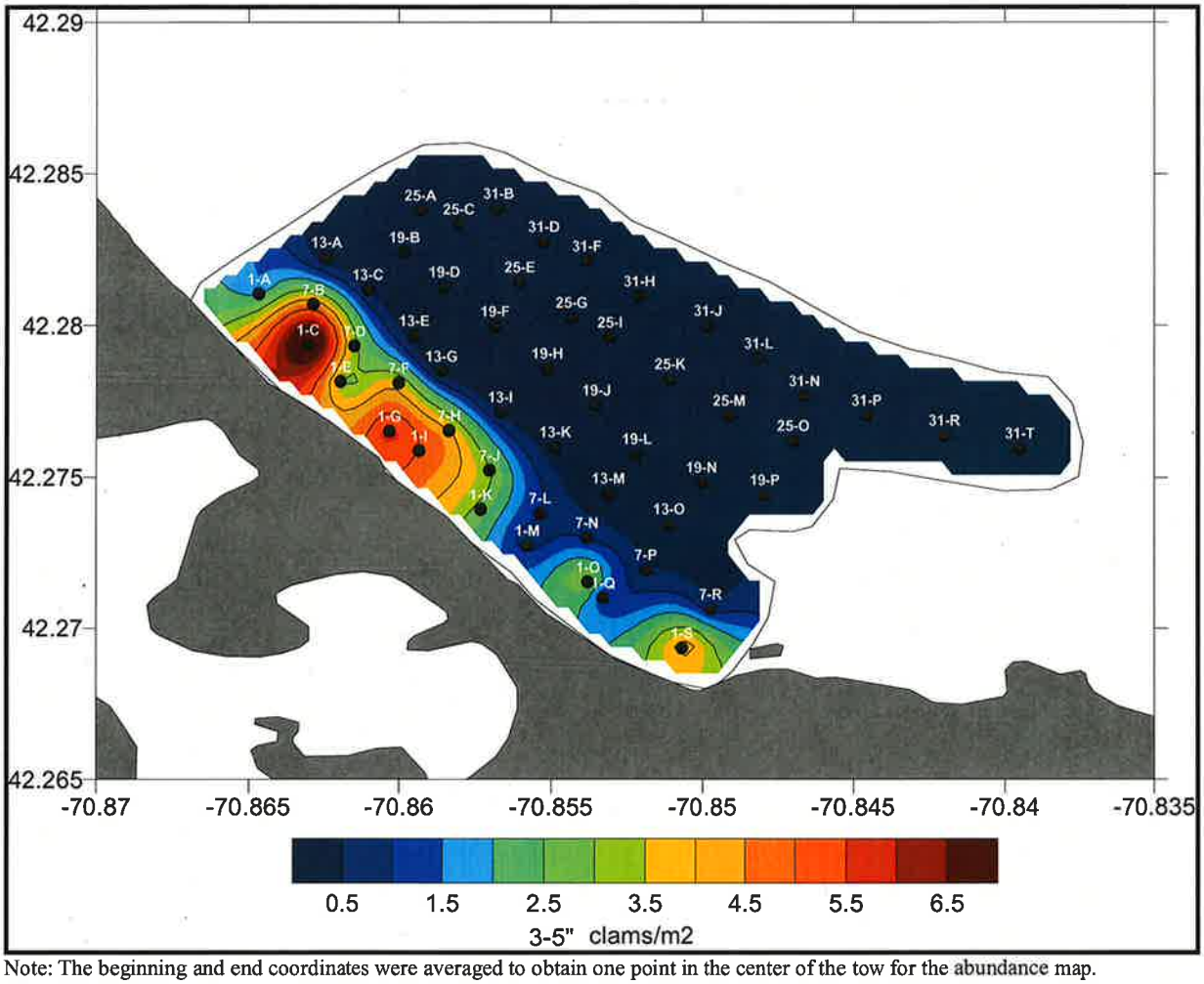
The smaller surf clams, those that were less than 3 inches in size, were concentrated in the northern end of transects 1 and 7 (Figure 3-3). The highest concentration of less than 3 inch surf clams was found in the area of tow 7-D. The scale used on Figure 3-2 is from 0.05 to 0.65 clams/m^2.



Note: The beginning and end coordinates were averaged to obtain one point in the center of the tow for the abundance map.

Figure 3-3. Abundance of <3" Surf Clams Collected Per Square Meter

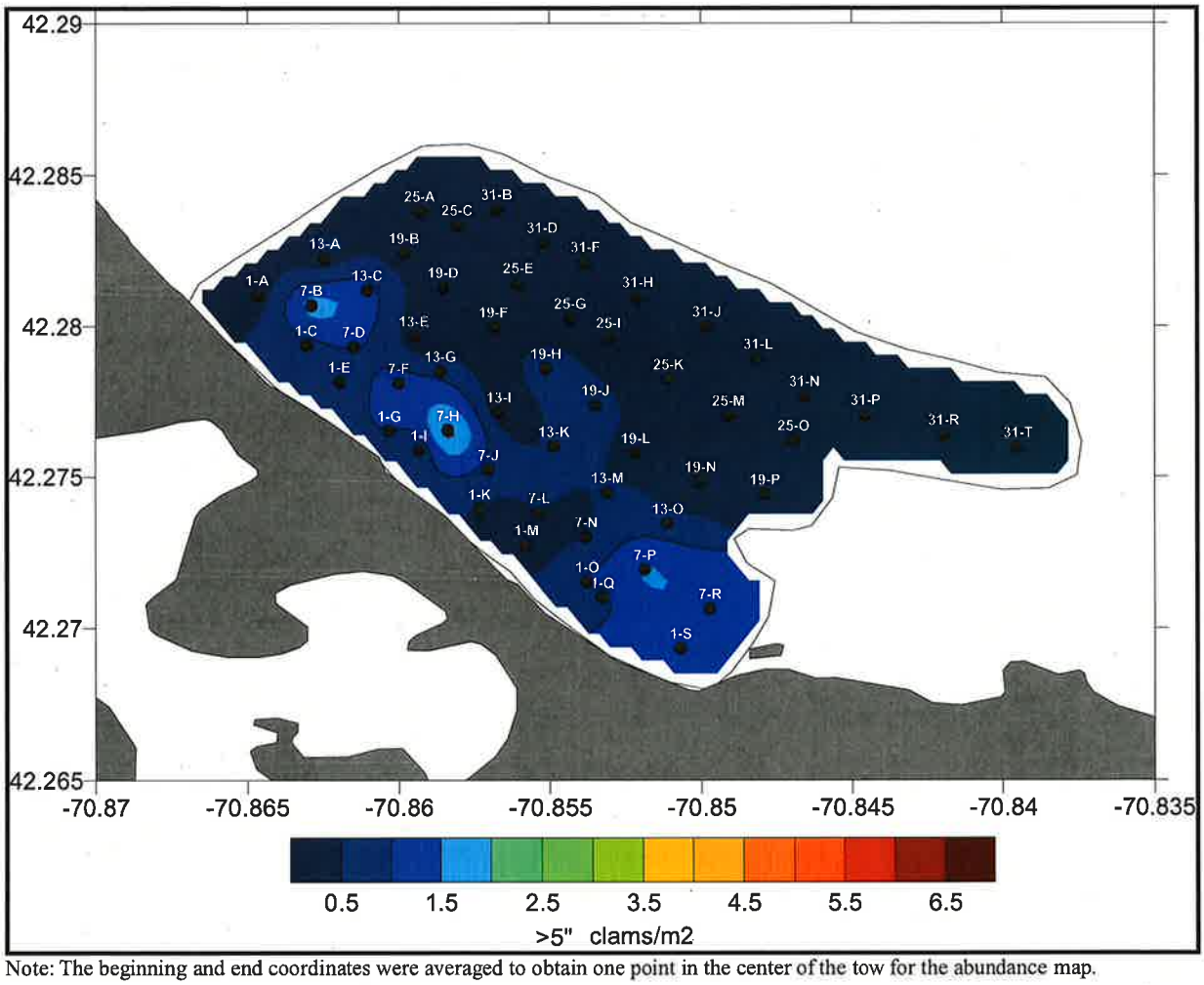
Surf clams that were 3-5 inches in size were also concentrated in the northern end of the sampling area (Figure 3-4). Higher concentrations of the 3-5 inch size class of surf clams were observed on transect 1. The highest concentration of the 3-5 inch surf clams was found in the area of tow 1-C. The scale used on Figure 3-3 is from 0.5 to 6.5 clams/m^2.



Note: The beginning and end coordinates were averaged to obtain one point in the center of the tow for the abundance map.

Figure 3-4. Abundance of 3-5" Surf Clams Collected Per Square Meter

Figure 3-5 provides the abundance of surf clams that were greater than 5 inches. The largest size class of surf clams collected was concentrated along transects 1 and 7 with most instances occurring on transect 7. The highest concentration of the greater than 5 inch surf clams was found in several areas; 7-B, 7-H, and 7-P. The scale used on Figure 3-4 is from 0.5 to 6.5 clams/m^2.



Note: The beginning and end coordinates were averaged to obtain one point in the center of the tow for the abundance map.

Figure 3-5. Abundance of >5" Surf Clams Collected Per Square Meter

During the survey, species other than surf clams were also collected in the tows. Table 3-3 provides data for these species including the tow ID and count per tow for each species. As with the surf clams, the other species collected were returned to the sampling area once counted. There were seven different types of species collected besides surf clams. However, none of the species were collected in significant numbers. There were two other species of shellfish collected, razor clams and blue mussels. In addition, two different species of crabs were collected, sand crabs and lady crabs. Furthermore, window pane flounder, black-back flounder, moon snails, and worms were also collected in some of the tows.

Table 3-3. Data for Other Species Collected During the Survey.

Tow ID	Species	Count per tow
1-C	sand crab (*Cancer irroratus*)	3
	worms	numerous
1-G	sand crab (*Cancer irroratus*)	1
1-I	moon snail (*Polinices duplicatus*)	1
	razor clam (*Ensis directus*)	1
1-K	window pane flounder (*Scophthalmus aquosus*)	1
1-M	window pane flounder (*Scophthalmus aquosus*)	1
	sand crab (*Cancer irroratus*)	1
	razor clam (*Ensis directus*)	1
1-O	window pane flounder (*Scophthalmus aquosus*)	1
	sand crab (*Cancer irroratus*)	1
1-S	lady crab (*Ovalipes ocellatus*)	1
	moon snail (*Polinices duplicatus*)	1
	razor clam (*Ensis directus*)	2
7-B	lady crab (*Ovalipes ocellatus*)	6
	razor clam (*Ensis directus*)	4
	sand crab (*Cancer irroratus*)	1
7-D	razor clam (*Ensis directus*)	1
	sand crab (*Cancer irroratus*)	3
	moon snail (*Polinices duplicatus*)	1
7-F	worms	numerous
7-H	lady crab (*Ovalipes ocellatus*)	2
	sand crab (*Cancer irroratus*)	1
	razor clam (*Ensis directus*)	2
7-J	sand crab (*Cancer irroratus*)	4
	razor clam (*Ensis directus*)	1
7-L	sand crab (*Cancer irroratus*)	1
13-C	window pane flounder (*Scophthalmus aquosus*)	2
13-M	moon snail (*Polinices duplicatus*)	1
	razor clam (*Ensis directus*)	1
13-0	razor clam (*Ensis directus*)	8
	window pane flounder (*Scophthalmus aquosus*)	1
	worms	numerous
19-H	moon snail (*Polinices duplicatus*)	2
	razor clam (*Ensis directus*)	9

Tow ID	Species	Count per tow
19-J	razor clam (*Ensis directus*)	4
19-L	moon snail (*Polinices duplicatus*)	1
	sand crab (*Cancer irroratus*)	3
	razor clam (*Ensis directus*)	1
	worms	numerous
19-N	black-back flounder *(Pseudopleuronectes americanus)*	1
25-E	razor clam (*Ensis directus*)	1
	worms	numerous
25-K	blue mussel (*Mytilus edulis*)	1
	worms	numerous
	razor clam (*Ensis directus*)	14
25-O	razor clam (*Ensis directus*)	1
	sand crab (*Cancer irroratus*)	1
31-D	blue mussel (*Mytilus edulis*)	1
	moon snail (*Polinices duplicatus*)	1
31-H	sand crab (*Cancer irroratus*)	1
31-J	blue mussel (Mytilus edulis)	2
	sand crab (*Cancer irroratus*)	1
31-L	blue mussel (*Mytilus edulis*)	2
31-N	blue mussel (*Mytilus edulis*)	1

4.0 REFERENCES

Battelle. 2006. Final Sampling and Analysis Plan, Surf Clam Survey In Support Of Feasibility Study: Hydraulic Clam Dredging, Nantasket Beach, Hull MA. Prepared under Contract No. DACW33-03-D-0004, Delivery Order No. 25. December 1, 2006. 20 pp + Appendices.

Appendix G

Nantasket Beach, Hull, MA 2017 Beach Nesting Bird Summary Report

Audubon, 2017

(provided by Conservation Commission, Town of Hull)

Nantasket Beach, Hull, MA
2017 Beach Nesting Bird Summary Report

Prepared by Gabrielle Gareau and Autumn Jorgensen
Mass Audubon Coastal Waterbird Program

Mass Audubon
Protecting the Nature of Massachusetts

For further information, please contact:

Katherine Parsons, Director
Coastal Waterbird Program
PO Box 275
Cummaquid, MA 02637
(503) 362-7475 x9351
kparsons@massausubon.org

Sue MacCallum, Director
South Shore Sanctuaries
2000 Main Street
Marshfield, MA 02050
(781) 837-9400
smaccallum@massaudubon.org

Abstract

Monitoring of the beach at Nantasket for nesting Piping Plover began on March 21 and continued through August 17, 2017. Four pairs of Piping Plover nested at the site, with a total of seven nest attempts. There were also two pairs and a lone male present on the beach and exhibiting territorial and breeding behaviors but none of these nested. Four nests hatched 16 chicks total and 8 chicks survived to 25 days old, which is the age the state considers chicks to be fledged, giving an overall productivity of 2.0. However, one chick is presumed to have died before it could actually fly, as it disappeared despite the rest of the brood still being present. Known causes of nest loss were storm overwash and abandonment. Piping Plover chick losses were primarily of young chicks and were likely due to exposure during cool, wet weather. Human use of the site causes disturbance to nesting plovers and chicks but the presence of off-leash dogs remains the largest threat to the nesting birds.

Site Characteristics

Nantasket Beach is approximately 4.3 miles in length and borders the eastern side of the town of Hull, Massachusetts. It is sandy cobbled beach consisting of a public section in the southern end and a private, residential beach section at the northern end. While the beach at high tide can be quite narrow, there is a wide expanse of tidal flats that emerge at low tide. This tidal flat is of critical importance to nesting Piping Plover (*Charadrius melodus*) as it provides the best foraging for both the adults and chicks.

Potential nesting habitat for Piping Plovers is primarily located between Malta Street and D Street. This stretch of beach provides a good substrate mix of sand and cobble with scattered vegetation cover that is ideal for nesting. Additionally, this area has a slightly wider open beach between the dune and the high tide line which is the preferred nesting location for plovers.

Most of the beach is backed by a simple dune system that is 5-20 meters wide and can be two meters or more in height. This dune system is primarily bordered by a road to the west that prevents it from migrating inland. There are a few areas, notably north of Coburn Street, where there is no dune development and paved parking areas have been placed where the dune would otherwise grow.

The public section of the beach is managed by the Department of Conservation and Recreation (DCR). The remainder of the beach is maintained by the Town of Hull with trash pickup by hand after Memorial Day with trucks used before Memorial Day for large debris and beach raking taking place only in the case of extreme seaweed deposits.

Monitoring Activity

Monitoring for nesting Piping Plovers by the Coastal Waterbird Program (CWP) Biologist began on March 21 and ended on August 17. Visits to the site covered the nesting habitat which is mostly concentrated between Malta Street and D Street. Regular checks were also conducted of the rest of the site from the public Department of Conservation and Recreation beach north to roughly G Street where the beach narrows. Monitoring tasks included counting adult plovers, searching for nests, and checking on active nests and pairs. Additionally, CWP biologists regularly interacted with beach goers, informing them about monitoring activities and educating them about the nesting birds. The symbolic fencing was inspected on every visit and moved or repaired as needed throughout the season. On average, the site was visited three times a week in April and early May and four to five times a week from mid-May until mid-August when the last chicks had fledged.

In addition to monitoring activities, CWP staff attended meetings and made presentations regarding Piping Plovers. An early season meeting in April with town officials takes place every year and is important for introducing all stakeholders and informing each other about the latest management activities. Staff also attended other planning meetings throughout the season, particularly in preparation for the Fourth of July weekend. In May, CWP biologists presented a natural history of Piping Plovers for members of the public interested in acting as Beach Ambassadors and communicated regularly with the ambassadors throughout the season. In July, CWP staff gave presentations about Piping Plovers and monitoring efforts at a public meeting of the Hull Beach Management Committee and at a meeting for town officials relating to the Nantasket Beach Management Plan. Town of Hull officials are actively supportive and interested in the protection efforts as demonstrated by the two-way communication, on-site police support, commitment of time and staff on holiday weekends, and the pre-season meeting involvement.

Piping Plovers

Piping Plover adults were first observed at Nantasket on April 3, when there were 7 seen foraging on the tidal flats. Based on behavior, these were apparently 3 pairs and a lone male. This early arrival of pairs that seem already established suggests that they may be returning pairs that had nested at the site the prior year. The lone male was seen with a mate on April 11, making a total of four breeding pairs for the 2017 season.

The first nests were found on April 25. The four pairs had a combined total of 7 nest attempts. Each nest attempt is given a unique alpha-numeric identifier with the number indicating which pair the nest belonged to and the letter representing which attempt the nest is – A for a first nest, B for the second and so on. The locations of these nests are shown on the maps appended at the end of this report. Pair 4 had a single nest attempt and the other three pairs had two nests each. Each pair had one nest that hatched, and there were

three nests that failed. The causes of nest loss this season are varied. One nest was lost to overwash during a storm on May 25-26 that coincided with exceptionally high monthly tides. One nest was abandoned by the adults when it was 3-4 days away from its expected hatch date. There was no evidence of significant human disturbance in the area and the reason for the abandonment is unknown. The cause of the last nest loss is unknown, although the sand in the area was heavily disturbed suggesting that a dog had been running and/or digging near the nest, possibly burying, crushing or eating the eggs in the process. It remains possible that a predator had taken the eggs and the dog activity happened afterward, so ultimately, the cause cannot be known.

The first nest to hatch belonged to Pair 2. All 4 chicks hatched between May 24 and 26, and the second nest also hatched 4 chicks a few days later on May 31-June 1. Five of these eight young chicks were lost between June 2 and June 6. The causes of chick losses are typically difficult to determine, but young chicks are especially vulnerable to predation and thermal stress. A huge storm with cold temperatures, heavy rains, strong winds, and high surf moved through the area June 4-6. Since chicks from two broods disappeared at this time, it is likely that they were lost to exposure due to the cold, wet weather.

The remaining three chicks from these two broods survived past 25 days old, which is the benchmark age for Piping Plover chicks being considered fledged set by the state for reporting purposes. At 25 days of age, none of these chicks were yet able to fly. When it was 26 days old, one of the chicks was noted to have a leg injury that was affecting its ability to run and keep up with its parents and sibling. This chick was last seen on July 2 when it was 31 days old and is presumed to have died from causes related to its injury. The chicks were not yet able to fly and the other chick from this brood and both parents were still present at the site for another 10 days. For the census reporting, the injured chick is counted as a fledgling, although in reality it did not survive to adulthood.

Just as the earlier chicks were beginning to fledge, two more nests hatched four chicks each over the busy Fourth of July weekend, on July 1 and July 4. On July 3, the older brood was being stalked by an immature Ring-billed Gull. Despite constant efforts of the parents to chase the gull off and even after the CWP biologist had scared the gull away multiple times, one of the chicks disappeared later that day, likely taken by the gull. Two more chicks disappeared for unknown reasons between July 12 and 17. The remaining five chicks from these broods also fledged, for a total of 8 fledglings produced over the course of the season (although again, one of these did not actually survive to adulthood). Overall productivity for the 2017 season, defined as the number of chicks fledged per pair that attempted nesting, is 2.0.

In an unusual occurrence, Pair 2, which had the oldest brood on the beach, decided to re-nest once their first chick was close to fledging age. This double-brooding is not common among Piping Plovers given the long periods of time needed for incubation and chick rearing, although it has been reported several times over the years given the close monitoring the species receives. The pair still tended their older chick while incubating the

new nest. This second nest was not successful and was the one lost to unknown causes outlined above.

The adult Piping Plovers left the site as their chicks fledged. By late July, even the females from the remaining broods began departing, leaving the chicks in the care of the males. This is common for late season broods. The females expend an enormous amount of energy to lay their relatively large eggs and need to focus on foraging to build up enough fat reserves to successfully make it to their wintering grounds. The last observation of Piping Plover on Nantasket was on August 17 when just two fledglings were seen.

Non-Breeding Piping Plovers

This season there were additional plovers that spent significant time on Nantasket, even defending territories, but ultimately did not nest. If a pair is present on the site for more than two weeks and has exhibited breeding behaviors, they are included in the total count of pairs for state census reporting. There were two pairs and a lone male that had territories but did not nest on Nantasket in 2017.

A pair was seen between A and E Streets beginning on April 20, when the male was seen scraping and the female was foraging nearby. This pair was almost always seen together, and was seen at least once a week until May 17. They never had a well-defined area of scraping but had a few scrapes between A and C Streets throughout their time at the site.

Throughout May, there were two lone males near Adams Street. On May 17 they were each seen courting two females (one female was banded and one was not). The male south of Adams Street was seen consistently with a female from June 2 through June 15 and a second Piping Plover that may have been the same female (we can't be sure as no courtship was observed during this period) was seen near him until July 2. The pair was seen courting all through the census period in early June, but no nest attempt was ever found. The male continued to have scrapes as long as he was on site, until July 20.

The second lone male never did find a mate. He had a small territory north of Adams Street and was frequently seen scraping on the intertidal slope of the beach, although he also had scrapes higher near the dune. He wasn't always near his territory so it was hard to keep track of him but he was present from at least May 9 to June 2, and may have been seen as late as June 7.

There were also a number of post-breeding migrant Piping Plovers that stopped over at Nantasket between July 10 and July 22. On nearly every site visit during this period, there were between 5 and 10 extra adult plovers and 1-3 extra fledglings foraging on the flats at low tide or resting on the upper beach at high tide. On two occasions, two of these migrant adults were banded, one of which was the female that had been courted by the lone males earlier in the season. Nantasket is a prime stopover site for migrating plovers with its wide sandy flats that provide good foraging habitat.

Beach Management

Symbolic Fencing

Symbolic fencing was erected on April 13, 2017 by the Mass Audubon South Shore Sanctuaries CWP Biologist. The substrate underlying the surface sand on the open beach is made up predominantly of cobble, making installation of wooden fence posts particularly difficult so fiberglass poles are used for fencing.

Initially, four areas of fencing were established around actively territorial pairs in areas where they had been scraping and showing other signs of breeding. Areas fenced were south and north of Kenberma Street and south and north of Coburn Street. Paths through the dune close to areas of plover activity were initially left open, even if it meant putting up fencing on both sides of the path. Paths were closed and fenced areas on either side merged as nests were found close enough to the paths that pedestrians would disturb the incubating bird off the nest.

Throughout the season fencing was extended and adjusted according to nesting activities. The fence was extended when nests were located near the fence line to give the birds a larger buffer to potential disturbance. On April 29, the fenced area south of Kenberma was moved about 80m south once the pair decided to nest outside their initial area of activity, and it was moved north again on June 7 when the pair re-nested back in their original territory.

Two fenced areas were added on May 17 for two scraping males near Adams Street; one south of Rhoda's Beach Path and one in front of the house at 165 Beach Avenue. Both of these areas were vandalized between June 15 and 17, with posts removed and all twine and signs placed on the ground. Despite searching at the time, the posts were not found. The Rhoda's Path fence was replaced and the #165 fence was completely taken down since that male was no longer on site. The missing posts were discovered on June 20, after they had been returned to the beach in a bundle and left by one of the access paths regularly used by CWP staff.

Once chicks were on the beach, special “Families Ahead” signs were placed at the paths near the broods to make beach goers aware of the possibility of encountering defensive adults with their chicks. All fencing was removed on August 15 after all chicks had fledged.

Typically, fencing is erected prior to the arrival of Piping Plovers at known nesting sites; however, since plovers have only been nesting on Nantasket for a few years, it has become standard practice to wait and see where the pairs establish territories before fencing. In future years, this should change and fencing should go up proactively, particularly now that several years of nest location data indicate that the pairs are generally selecting the same sites year after year.

Since one brood had just hatched at the beginning of the Fourth of July weekend, perpendicular fence lines were temporarily set up from their existing fence down into the intertidal. This is called accordion fence and is only extended when a CWP staff member is present on the beach, so that they can move it back before the tide rises into it. This accordion fence provides a safe refuge for young chicks to access the cool, wet sand of the intertidal area and allows them to forage in this are with less disturbance. Pedestrians can still walk past since the tide is far out, and the fence is pulled back as the tide rises so that there is never a time when pedestrians are blocked from walking past. Accordion fencing was only used this year over the Fourth of July weekend when the chicks were very young and the beach was exceedingly busy.

Predators

No predator control or removal methods were used at Nantasket. Crow, cat, dog, racoon, fisher, and coyote tracks were seen at times throughout the season. Crows were recorded being on site almost every visit, as were Herring, Ring-billed and Great Black-backed gulls. Cat tracks were frequently seen near Coburn Street and north, and cats were seen several times in this area. On at least two occasions, an off-leash cat was being walked on the beach near A Street by a woman who was also walking a dog on leash.

No nests were known to be lost to predators this year although nest 2B may have been. An immature Ring-billed Gull was seen trying to get close to the chicks in brood 1B on July 3 and one of these chicks disappeared later that day. On July 5 a Ring-billed Gull, possibly same individual, was also trying to approach brood 3B. A chick was lost from this brood between July 12 and 17, but it is unknown if the Ring-billed Gull was responsible for the loss as it was only observed around the brood once.

Dogs on the beach and off leash are frequently not in immediate control by the owners were a problem throughout the season. On several occasions, off-leash dogs were witnessed chasing Piping Plovers or other shorebirds. No dogs are allowed on the beach after June 1, however, many people still regularly walked their dogs, even when they knew the rule.

Beach Cleaning

On May 31 a front end loader was used for removal of large wooden debris from 7:30 a.m. to 11:00 a.m. A Mass Audubon CWP staff member escorted the vehicle around active Piping Plover chicks as it moved from A Street to the DCR beach.

For garbage removal over the extended Fourth of July weekend, the Department of Public Works planned to do most trash removal by hand for pickup along the road but had a front end loader ready if needed. At a Fourth of July strategic planning meeting, DPW staff and the CWP biologist arranged a communication plan so that there could be an escort for the

vehicle if it were to be used as there were still unfledged chicks on the beach. Ultimately, no machinery was needed on the beach for trash removal but having a plan in place ensured that a qualified monitor was available if necessary.

Incidents and Violations

Fence Vandalism

There were only a few instances of fence vandalism this season. On April 24, someone pulled a sign off one of the fence posts and due to the nature of its attachment, the sign lifted the line of twine off the post as well. This left the entire fence line along the north and west sides of the fenced area open and without barrier. The sign was thrown across the fenced area, landing near the opposite end of the enclosure. The pair in this fenced area had luckily not yet nested at the time and was not adversely impacted. None of the fence materials were damaged and the fence was repaired immediately once noticed.

On June 17, the fiberglass poles from one entire area of symbolic fencing north of Adams Street were removed. The poles were taken and the signs and twine were left in rough position on the ground. The other fencing in the area, south of Adams Street, had the oceanward posts removed although the posts in the rear near the dune remained in position. This southern area was re-fenced using metal poles. Fencing was not restored to the northern area as the male that had been using the territory was no longer at the site. Despite searching the area, no sign of the missing posts was found during site visits on either June 17 or 19. On June 20, the missing poles were found in a bundle placed in a clearly visible position beside one of the access paths regularly used by CWP staff.

Dog Bylaw Violations

Dogs were regularly seen off leash on nearly all visits prior to June 1. Often, the dogs were out of the control of their owners. Beginning June 1, regulations state that no dogs are allowed on the beach at all, even on leash. Many dog owners still continued to walk their dogs after June 1. Most complied with removing dog from beach when informed of the no dog rule, but others did not, and some with off-leash dogs simply leashed the dog instead of removing it. Many dog walkers quickly hurried from the beach when they noticed CWP staff heading their way before being intercepted.

Dogs were also seen on multiple occasions chasing adult Piping Plovers. These dogs were always off leash. When CWP biologists witnessed this behavior, they spoke to the dog owners about leashing the dogs and informing them about the protected nature of the birds under the Endangered Species Act.

Some local residents that own dogs have vocalized their opposition to the June 1 dog ban as they like to walk their dogs on the beach in the early morning before the beach gets crowded. These dog owners do have a genuine concern since the Town of Hull does not have any dog parks and has limited off-road areas for dog walkers. The dog owners that come to public meetings to discuss this issue tend to be responsible owners that keep their dogs on leash and pick up pet waste. Of course, many owners are not so responsible and the law is in place to protect public health. There is a need in Hull for open areas in which dog walking is permitted in the summer.

Parking Lot Issues

The homes from 133-145 Beach Avenue have a parking lot area built in the dune that accrues a lot of sand over the winter. The Conservation Commission would not permit machinery to remove this sand during the nesting season because Pair 1 had two nest attempts within 6 feet of the parking lot retaining wall. Once the nest had hatched, sand removal could occur with a CWP staff member on site to monitor for disturbance to chicks. Both the Conservation Agent and a maintenance worker who was contracted to do this work had been informed by the CWP biologist that a monitor was required while work proceeded. On August 2, CWP staff noticed that sand had been removed but Mass Audubon had not been notified that removal would occur. It is not clear if machinery was used for the removal. One of the chicks from the brood in this area had not yet fledged when the removal happened.

Communicating with the homeowners along the parking lot should occur each spring. They should be informed that any work needing machinery should be completed before April 1, and that any work being done after that date will need a trained CWP monitor to be present to ensure no disruption to nesting birds. The CWP staff is accommodating to requests for this type of monitoring given advance notice.

Public Outreach

No specific public education or outreach programs were undertaken this year. Mass Audubon has begun developing educational materials and programs for heavily used urban beaches in the Boston area and Nantasket would be a great beach to expand these educational efforts. Most people were indifferent to the birds and the fencing but many were curious and wanted more information. A small proportion of beach goers were more antagonistic, mostly because they lacked knowledge about why the fences were there and they were upset that any area was closed. Education programs on the beach during the nesting season would give the public a basic understanding of Piping Plover biology and the reasons for the management actions being undertaken.

Officials in the Town of Hull are very supportive of the protection efforts and work cooperatively with Mass Audubon. Police and Conservation departments especially are involved in preseason planning, reaching out to beachfront homeowners, discussions about management decisions, and enforcement issues.

Overall the relationship with beach visitors was positive. Visitors and Hull residents were interested and entertained with the chicks nesting on the beach. The few negative interactions mostly occurred when asking people to leash their dogs.

Beach Ambassadors

Mass Audubon CWP Staff conducted a training session for volunteers to act as Piping Plover Ambassadors on May 10. This training included a presentation of Piping Plover life history and the roles of an ambassador. Regular communication with volunteer ambassadors happened through posting to a private website. Ambassadors were not as active posting on the site this year as in previous years although many were still out watching the birds and speaking to the public.

Management Recommendation Summary

1. Maintain open and consistent communication between the CWP biologists and Conservation Agent. This relationship is crucial as it is the main connection through which information about the nesting season is shared between the Town of Hull and Mass Audubon.

2. Symbolic fencing should be erected around potential nesting areas as early as possible in the season after territories can be identified. Close monitoring by CWP staff in the early season is necessary to identify the areas of Piping Plover territories that are likely to be used for nesting. Consultation with homeowners prior to fencing is important to maintain good relations with the community. The Town's Conservation Agent has been responsible for this communication, which works well.

3. Consider developing specific signage to place at the entrance paths to the beach, to be seen as people step onto the beach. Several members of the public complained that the fencing was not visible enough and they or their dogs bumped into it, despite it having signs on each corner. Although "Families Ahead" signs warning pedestrians that there were chicks on the beach were placed at paths beginning in June, it may be beneficial to have informational signs reminding people that there are nesting birds present earlier in the season.

4. A meeting should be held in late March or early April with the Hull Town Manager, Conservation Agent, Police Chief, Department of Public Works and Mass Audubon

staff to discuss plans for the season. Subsequent meetings during the season, such as for Fourth of July preparations or Beach Management Plan discussions should continue to include Mass Audubon staff to ensure that species protection laws are being considered in combination with other management actions.

5. Maintain communication between CWP staff and the Department of Public Works regarding any beach clean-up efforts. Areas to be symbolically fenced should have debris removed as early as feasible and DPW staff or beach clean-up volunteers should not enter fenced areas in order to remove debris. If machinery or vehicles of any sort are needed on the beach once chicks are present, a CWP staff member should be present to accompany the vehicle in order to avoid disturbing chicks.

6. When vehicles are used on the beach for beach management after the April 1 start of the nesting season (e.g. beach raking, debris removal), the area should be monitored by CWP staff according to state and federal guidelines to determine the presence of birds before any work begins and a CWP staff member should be present during the entire time vehicles are on the beach to prevent birds or nests from being disturbed.

7. Increased enforcement of leash law by the police department and animal control prior to June 1st is critical early in the season to prevent dogs from chasing Piping Plover adults, or entering symbolically fenced areas where they may accidentally step on or deliberately eat eggs. Off-leash dogs disturb incubating Piping Plovers off their nests early in the season, leaving eggs vulnerable to the elements and potentially delaying egg hatching. There are also nests that hatch prior to June 1st and the young chicks are extremely vulnerable to off-leash dogs.

8. Starting June 1st, no dogs are allowed on the beach. This is should continue to be enforced daily as residents continue to walk dogs on the beach throughout the season. Many local residents are understandably upset that they are prevented from using one of their favorite walking sites in the summer as they feel they are responsible dog owners. The town should consider creating an area for residents to walk their dog in the summer, such as opening an area of bayside beach that does not have high numbers of beach goers.

9. The Piping Plover Volunteer Ambassador program should be continued and enhanced in future years. Having dedicated time slots or specific tasks to assign to Ambassadors might help to formalize the program and keep volunteers active with sharing observations.

10. Consider developing an education program for beach goers. Mass Audubon is developing education materials for urban beaches and could consider expanding these education efforts to Nantasket Beach in future seasons.

Nantasket Beach, Hull, MA Map 1 of 3: Overview

Coastal Waterbird Program South Shore 2017

Mass Audubon
Protecting the Nature of Massachusetts

Observer names:
Gabrielle Gareau
Autumn Jorgensen
Hannah Masood

PIPL Census: 6/2/2017

Symbolic Fence
PIPL A Nest
PIPL B Nest

Coastal Waterbird Program
PO Box 275, Cummaquid, MA
02637

Nantasket Beach, Hull, MA Map 2 of 3: Kenberma

Coastal Waterbird Program South Shore 2017

Mass Audubon
Protecting the Nature of Massachusetts

Observer names:
Gabrielle Gareau
Autumn Jorgensen
Hannah Masood

PIPL Census: 6/2/2017

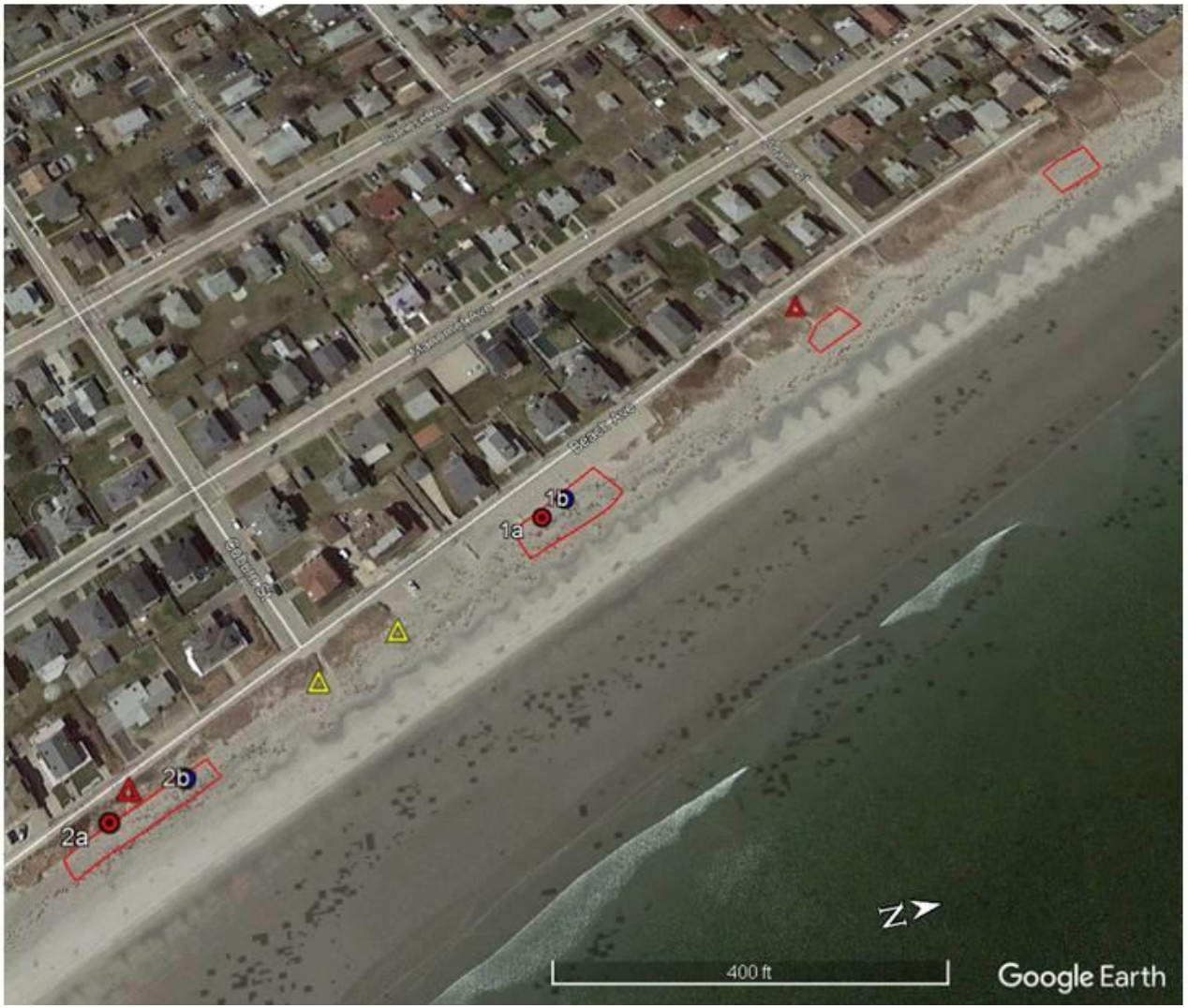
- Symbolic Fence
- PIPL A Nest
- PIPL B Nest
- Families Ahead Sign

Coastal Waterbird Program
PO Box 275, Cummaquid, MA
02637

Nantasket Beach, Hull, MA Map 3 of 3: Coburn

Coastal Waterbird Program South Shore 2017

Mass Audubon
Protecting the Nature of Massachusetts



Observer names:
Gabrielle Gareau
Autumn Jorgensen
Hannah Masood

PIPL Census: 6/2/2017

- Symbolic Fence
- PIPL A Nest
- PIPL B Nest
- Families Ahead Sign
- Area Closed Sign

Coastal Waterbird Program
PO Box 275, Cummaquid, MA
02637

Appendix H

Nantasket Beach Reservation Master Plan, Hull, MA

Source: DCR, 2016

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Nantasket Beach Reservation Master Plan

Hull, MA

June 2016

dcr MASSACHUSETTS DEPARTMENT OF CONSERVATION AND RECREATION

dcr
Massachusetts

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Department of Conservation and Recreation

Leo P. Roy, Commissioner

Matthew Sisk, Deputy Commissioner

Norman J. Orrall, P.E., Chief, Division of Planning & Engineering

Patrice Kish, Acting Chief, Bureau of Planning, Design & Resource Protection

Joe Orfant, Chief, Bureau of Planning & Resource Protection (Retired)

Robert Lowell, Acting Chief Engineer

Mike Misslin, Acting Chief Engineer (Retired)

Priscilla Geigis, Director of State Parks

Samantha Overton, Deputy Director of State Parks

Mike Galvin, Project Manager

Rick Corsi, Senior Planner

Karl Pastore, South Region Director

Susan Kane, Islands District Manager

Matt Tobin, Islands District Field Operations Team Leader

Kevin Conway, Nantasket Beach Reservation Park Supervisor

Paul DiPietro, Water Resources and Flood Control Engineering Section Head (Retired)

The Consultant Team

Crosby Schlessinger Smallridge, LLC: Landscape Architecture, Urban Planning & Urban Design

Louis Berger: Civil & Transportation Engineering

Special Thank You to the Citizens Advisory Committee

Phil Bellone

Richard Billings, Chief of Police

Dennis Blackall

Stephen Blum (representing Rep. Garret Bradley)

R. Marc Fournier, Director of Public Works

Justin Gould

Greg Hargadon

(Former) Senator Robert Hedlund

Robert Hollingshead (Fire Chief)

Rhoda Kanet

Nancy Kramer

Jim Lampke

Rick Lawrence

Phil Lemnios (Town Manager)

Frank Lyons, Fire Chief

Estelle MacDonald

Joan Meschino

Christopher J. Oliveri

David Twombly

Judith Van Hamm

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- Summary of Comments
- *Nantasket Beach Reservation Traffic Analysis Report*, Louis Berger, 2014 (under separate cover)
- *Nantasket Beach Reservation Facilities Utilization Report*, Louis Berger, 2014 (under separate cover)
- *Nantasket Beach Reservation Parking Demand and Capacity Study*, Louis Berger, 2015 (under separate cover)

EXECUTIVE SUMMARY

Illustrative plan of the Master Plan recommendations.

In 2005, in conjunction with a project for seawall and beach accessway repairs at Nantasket Beach, the Massachusetts Department of Conservation and Recreation (DCR) initiated this *Nantasket Beach Reservation Master Plan* for the landside facilities of the Reservation.

The overarching goal for the *Nantasket Beach Reservation Master Plan* is to provide an enhanced natural and recreational experience at Nantasket Beach, with:

- Attractive amenities to support a wide range of activities,
- Safe and convenient access for pedestrians, cyclists, transit and ferry passengers and automobile users,
- Connections to adjacent bicycle paths and parking areas, as well as commercial and entertainment opportunities, and
- Increased amenities for high-tide and shoulder-season visitors.

The plan is designed to provide visitors with a "great day" at the Reservation from arrival to departure, while aiding the DCR in operating and maintaining the Reservation. The recommendations described throughout this master plan were developed to achieve that vision, and to respond to DCR's needs and concerns, as well as the concerns that were expressed by the community and the Citizens Advisory Committee throughout the master plan process.

The Plan recommendations are divided into the following categories:

- The Promenade/Boardwalk
- Open Space and Recreational Amenities
- Landscaping and Green Space
- Operations and Maintenance Area
- Vehicle and Pedestrian Access and Circulation
- Year Round Operations
- Interpretive Opportunities
- Wayfinding and Signage
- Phasing

Key recommendations include:

- Create Nantasket Green - a major new park at the foot of Wharf Avenue, providing a welcoming entrance to visitors and an important gathering spot.
- Provide a continuous boardwalk with shade shelters and artist spaces, extending the length of the Reservation.
- Create a bicycle lane (adjacent to the boardwalk in most locations) extending the length of the Reservation and connecting to existing and proposed (by the Town of Hull) bicycle routes; along with new bicycle racks and opportunities for bicycle rental.
- Relocate both the David A. Cook and Tivoli Bath Houses to more protected locations.
- Expand playgrounds at both the David A. Cook and Mary Jeanette Murray Bath Houses.
- Improve plazas adjacent to the Bernie King Pavilion and Tivoli Bath House.
- Plant new landscaping throughout the Reservation.
- Reconfigure Nantasket Avenue/Hull Shore Drive intersection to improve traffic flow and allow for a more efficient and reorganized DCR operations and maintenance facility.
- Repair existing buildings.
- Recommend potential options for the Dormitory Building, Clocktower Building and Police Station to improve utilization and provide additional funding for building maintenance.
- Improve parking operations and continue monitoring of parking demand and capacity.

Implementation of the Master Plan will result in:

- New open space: 2.38 acres including 1.02 acre Nantasket Green + potential for additional 5.88 acres (from potential future conversion of parking lots to parkland)
- Continuous boardwalk with shade shelters and artist spaces: 2.68 acre boardwalk
- Continuous bike path: 1.3 miles
- More protected locations for Cook Comfort Station and Tivoli Bath House
- Expanded playgrounds
- Improved plazas
- New landscaping: 1.76 acres
- Enhanced vehicular/pedestrian access and circulation and parking
- New interpretive opportunities
- Introduction of wayfinding and signage program
- Improved operations and maintenance area
- Improved parking signage and real-time availability information
- Ongoing monitoring of parking demand.

1. INTRODUCTION

Aerial view of Nantasket Beach Reservation looking north.

In 2005, in conjunction with a project for seawall and beach accessway repairs at Nantasket Beach, the Massachusetts Department of Conservation and Recreation (DCR) initiated this Nantasket Beach Reservation Master Plan process for the Reservation's landside facilities.

Nantasket Beach has been a popular summer destination for city dwellers since the middle of the 19th century. The beach itself, an incredible natural resource, is one of the busiest beaches near Boston. The water is consistently clean and the Reservation is within a one hour drive of much of the Boston Metropolitan Area.

The Reservation includes a number of attractive historic structures, three bath houses, a comfort station and convenient parking, yet the overall Reservation has few additional amenities. Much of the land is taken up with surface parking lots. Existing seating and shade areas - as well as parking lots - are barren, with large expanses of concrete and minimal plantings to soften the environment.

The scope of this master plan included coordinating Reservation needs and community planning efforts to develop recommendations for:

- Visitor amenities such as open space, bath houses and recreation areas
- Parking, traffic and pedestrian access
- Accessibility
- Maintenance facilities
- The overall appearance of the Reservation.

Visitors enjoying a beautiful day at Nantasket Beach.

Public Process

This master plan was guided by a public process that included both a series of eight Citizens Advisory Committee (CAC) and public meetings. The CAC provided significant input into the development of the Plan, reviewing and commenting on analysis and recommendations at eight meetings over the course of the project. Several of these meetings were open to the public to elicit feedback on the master plan as it was developed. Meetings also were held with the Hull Board of Selectmen and the Town of Hull.

The Nantasket Beach Reservation, located on the Atlantic Ocean on the northern shore of southeastern Hull, MA, is owned and operated by the DCR. The 26-acre Reservation encompasses approximately 1.3 miles of beachfront (6,800 linear feet), and includes the beach and adjacent visitor amenities, associated parking areas, and an operations and maintenance facility. It is bounded approximately by:

- Phipps Street to the north
- Hull Shore Drive and Nantasket Avenue (Route 228) to the west
- The driveway from Nantasket Avenue to the southern end of the DCR parking lot to the south
- The Atlantic Ocean to the east.

When the master plan was initiated, the Town of Hull had recently prepared the *2004 Nantasket Focused Area Study*, and the Hull Redevelopment Authority (HRA) was moving forward with a plan for residential development on their parcels across Hull Shore Drive from the northern end of the Reservation. More recently, the Town has constructed streetscape improvements along Nantasket Avenue, between Water Street and Bay Street, and prepared a new plan for the HRA property and the adjacent commercial area.

The Beach & Promenade

The beach runs along a beautiful long and narrow strip of land (only 450 – 500 feet wide in some locations) that separates the Weir River and the Atlantic Ocean. At low tide the beach is a wide, expansive area that accommodates hundreds of beachgoers. At high tide much of the beach is under water.

A beachfront promenade, located adjacent to the seawall (or revetment), runs along the entire length of the Reservation and provides visitors physical and visual access to the beach, as well as passive and active recreation opportunities. The seawall serves as seating along the promenade.

The beach is accessible from the promenade via concrete stairs and ramps built into the seawall. New entry stairs, accessible ramps and railings were constructed to improve access as part of the 2007 seawall improvements.

At right, from top: A busy beach at high tide; the beach at low tide; new ramps have improved beach accessibility.

Beachfront Buildings & Adjacent Amenities

Below are descriptions of buildings and adjacent amenities found within the Nantasket Beach Reservation. Recommendations for maintenance activities on individual buildings are included in the *Nantasket Beach Reservation Facilities Utilization Report*, prepared in 2014 by Louis Berger as part of this master plan project, and available under separate cover.

The buildings, which are open to the public, include three bath houses, one comfort station and an open-air pavilion. All three bath houses underwent renovation during spring and summer 2007.

Mary Jeanette Murray Bath House

The Mary Jeanette Murray Bath House (MJM) is the centerpiece of the Reservation. Built in the Art Deco style, the MJM is one of the more architecturally significant buildings within the Reservation. The building has an area of approximately 3,640 square feet and currently is used as a bath house and community venue. It is in good condition overall, and was recently renovated.

The MJM Bath House is currently underutilized by the public as the main doors are locked when there are no scheduled events. The wings of the building, which contain restrooms and changing rooms, are open to visitors regardless of event scheduling. Space within the bath house also is underutilized. In each of the two wings there is a large, empty open space reserved for gatherings and a utility room that is either largely empty or used for minimal storage. The manager's office on the beach side of the building is partially used for cleaning supplies and first aid supplies (including an automated external defibrillator [AED]).

Historic Relevance

The Massachusetts Historic Commission (MHC) has determined that the building appears to be eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District. The building was constructed in 1935 and reconstructed in the late 1990s.

Adjacent Amenities

Shade structures (pergolas) with benches are located on the north and south sides of the bath house. These are the primary shade structures for the Reservation and are heavily used by casual visitors and as gathering areas for large groups. A beach volleyball court is located directly north of the bath house and a small playground with a play structure is located directly to the south. The playground was expanded in 2008.

From top: View of Mary Jeanette Murray Bath House from Nantasket Avenue; pergolas adjacent to the MJM Bath House provide a popular semi-shaded gathering area; the playground to the south of the bath house.

Bernie King Pavilion

Also on the oceanfront, south of the MJM Bath House, is the renovated Bernie King Pavilion. Originally built in the late nineteenth century, this 10,800 square foot open air facility is primarily used for seasonal concerts and dance events, and contains a privately-operated concession stand. The Pavilion is a popular spot to picnic during summer months, as it provides concession, seating and shade areas, and allows views to the beach and ocean. On Sunday afternoons visitors come to dance to live music.

In 1999, elevated levels of lead were identified on the Pavilion's exterior and interior. The facility subsequently underwent a $940,000 reconstruction, which was completed in 2004.

Adjacent Amenities

An open waterside plaza adjacent to the Pavilion has picnic tables and benches, although the lack of shade structures and plantings make this a somewhat inhospitable picnic area.

At left, from top: View of the Bernie King Pavilion from Nantasket Avenue; Sunday afternoon dancing at the Pavilion.

Tivoli Bath House

The Tivoli Bath House, located near the southern end of the Reservation, is a single story concrete structure built in 1981; it has an area of approximately 1,500 square feet and contains restroom and shower facilities. The building suffers from repeated storm and wave damage due to its unprotected location so close to the ocean.

Adjacent Amenities

Just north of the Tivoli Bath House is a raised and widened portion of the promenade with a row of picnic tables and a row of benches with telescopes. The tables and benches are far apart and have no shade protection.

Comfort Station (205 Nantasket Avenue)

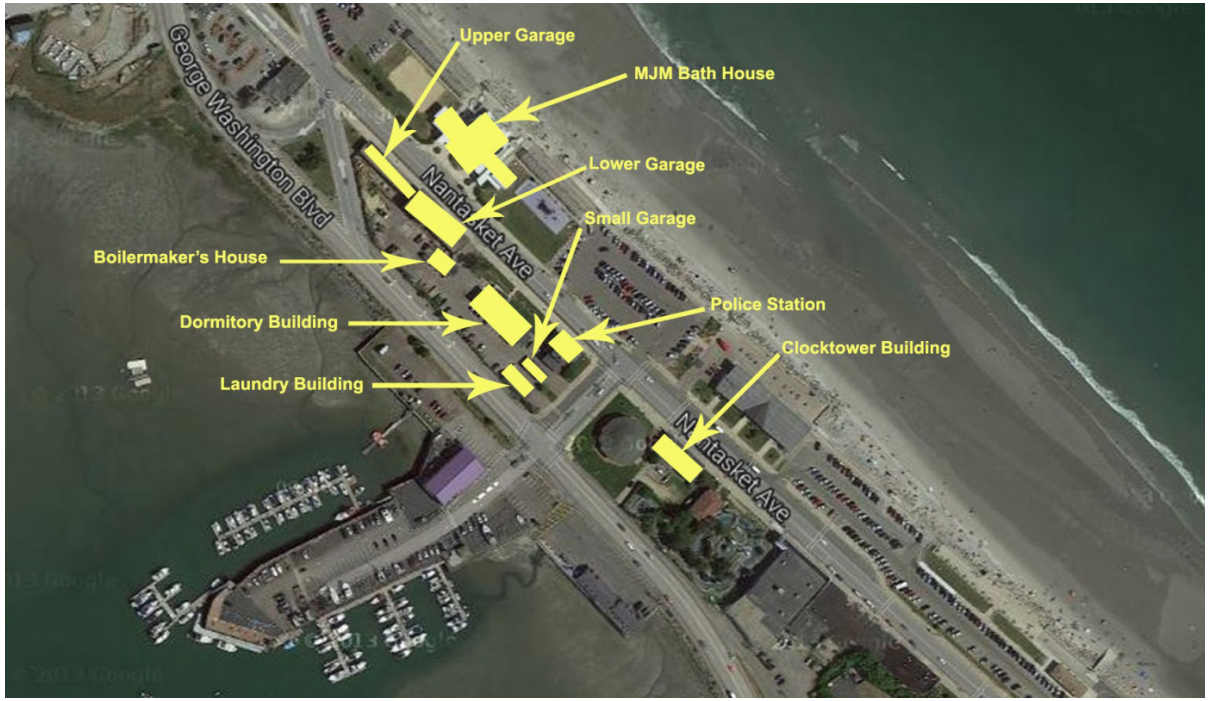
The Comfort Station, located on Nantasket Avenue adjacent to the Clocktower Building, is across Nantasket Avenue from the beach and the Bernie King Pavilion. The structure has an area of approximately 1,500 square feet and is used as a public restroom facility. It is in good condition.

From top: The beachfront plaza adjacent to the Bernie King Pavilion; view of the Tivoli Bath House from the south; view of the beachfront plaza north of the Tivoli Bath House.

From top: View of the Comfort Station from Nantasket Avenue; view of the David A. Cook Comfort Station from Hull Shore Drive.

David A. Cook Comfort Station

The David A. Cook Comfort Station is located at the northern end of the Reservation on Hull Shore Drive. The single-story red brick structure was built in 1953 and has an area of approximately 2,800 square feet. It contains public restroom and shower facilities and is in adequate condition. Additional space in the building is currently underutilized.



Location of the buildings within the Operations and Maintenance Facility, and the nearby Clocktower Building.

Landside Operations / Maintenance Buildings

Other DCR-owned buildings are found on the 3.5-acre block bounded by Wharf Avenue, Nantasket Avenue and George Washington Boulevard. The block is across Nantasket Avenue from the MJM Bath House. Some of these buildings date back to 1898. The buildings, described below, are used primarily by DCR operations and maintenance staff. The site also encompasses uncovered storage bins used for sand, salt and landscaping materials; two fuel pumps and a ramp used by trucks for unloading trash into an adjacent dumpster.

Dormitory Building

The two-story Dormitory Building has an area of approximately 9,000 square feet and is in overall poor condition. It was originally built in 1898 and used as a Metropolitan Police barracks. The main floor is currently used as the DCR's operations office building with some space available for dry and hazardous materials storage. The upper floor is largely vacant. During the summer, parking passes are sold from the building.

View of the Dormitory Building from Nantasket Avenue.

Historic Relevance

Although the MHC has not undertaken any formal survey or analysis of historical relevance for the Dormitory Building, it is likely that it would be considered eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District.

Police Station Building

The two-story former Police Station has an area of approximately 4,000 square feet and is in very poor condition. It was built in 1901 and used as a police station by the former Metropolitan District Commission (the predecessor agency to DCR). It is currently vacant and entry is prohibited due to high levels of asbestos. There is a crawl space, but no full basement, under the building.

Major rehabilitation work will be necessary for this building to be re-used.

Historic Relevance

The MHC has determined that the building appears to be eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District.

Small Garage (Fire Safety Building)

The small wooden garage building, also known as the Fire Safety Building, has an area of approximately 1,000 square feet and is in overall poor condition. It is currently used for cold storage of parking supplies such as signs and posts.

Historic Relevance

The MHC has not undertaken a formal survey or analysis of historical relevance for the Small Garage.

Laundry Building

The Laundry Building is a World War II-era, single-story structure of approximately 900 square feet. It is in overall adequate condition. It is currently used for dry storage of lumber and is sometimes referred to as the "wood storage room".

Historic Relevance

The MHC has not undertaken a formal survey or analysis of historical relevance for the Laundry Building. It was likely moved to the location and therefore would not be an original contributing element within a potential Nantasket Beach Reservation Historic District.

At right, from top: View of the Police Station Building from Nantasket Avenue; view of the Small Garage/Fire Safety Building from Wharf Avenue; view of the Laundry Building from Wharf Avenue.

Lower Garage

The Lower Garage (with attached carpenter shop), built in 1903, is a single-story red brick structure composed of two attached building segments (a garage and a carpenter shop) and is approximately 5,000 square feet. It is in overall good condition. Its major use is vehicle and maintenance storage but the facility also provides heated storage and houses the carpentry shop. The building is not prone to flooding, making it ideal for storage of sensitive goods such as toilet paper and waste oil. There are two bathroom facilities and a shower in the building.

All available floor space for vehicle and maintenance storage is used to its fullest extent. There is currently no pedestrian door to access the main part of the garage; only overhead garage doors. This decreases the energy efficiency of the building and causes unnecessary wear and tear to the motorized overhead door equipment.

Historic Relevance

The Lower Garage is included in the MHC Inventory of Historic and Archaeological Assets of the Commonwealth. MHC has determined that the building appears to be eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District.

At left, from top: View of the Lower Garage from Nantasket Avenue and from the maintenance yard; view of the Upper Garage from the maintenance yard.

Upper Garage

The Upper Garage is a single-story red brick structure built in 1900. It has an area of approximately 2,750 square feet and is in overall good condition. Its major use is vehicle and maintenance storage. Due to current space restrictions, the garage cannot accommodate a truck equipped with a plow and sander. The building is prone to flooding; during large storm events, up to 1.5 feet of water may be seen on the floor. This may be due to the overhead doors on the Nantasket Avenue side of the building that do not seal well with the concrete slab floor. There is no bathroom located in this building.

All available floor space for vehicle and maintenance storage is used to its fullest extent. The heated garage provides the best shelter for sensitive equipment. Desired improvements for this building include additional overhead doors on the George Washington Boulevard side of the building and expanded floor space.

Around 2007, the building's interior was temporarily divided to provide leased space, and the section of

the building fronting Nantasket Avenue was leased to an art studio ("Studio at the Beach"). DCR recently discontinued that lease and the entire building is once again used for vehicles and maintenance storage.

Historic Relevance

Although the MHC has not undertaken any formal survey or analysis of historical relevance for the Upper Garage Building, it is likely that it would be considered eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District.

Boilermaker's House

The Boilermaker's House has an area of approximately 780 square feet and is in overall poor condition. It is currently used as a break room for lifeguards and as office space for the lifeguard supervisor. There is a functioning bathroom in the building.

Historic Relevance

The MHC has not undertaken a formal survey or analysis of historical relevance for the Boilermaker's House. It was likely moved to the current location and would not be an original contributing element within a potential Nantasket Beach Reservation Historic District.

From top: View of Upper Garage from Nantasket Avenue, with art studios opened to the sidewalk; view of the Boilermaker's House.

From top: View of the Paragon Carousel and Clocktower Buildings; closeup of the Clocktower Building; fun on the carousel.

Other Reservation Structures

The Clocktower Building and Paragon Park Carousel are located within the Reservation on the south side of Wharf Avenue.

Paragon Carousel

Built in 1928, the Paragon Carousel was part of Paragon Park, an amusement park that opened in 1905. It is a local landmark and tourist attraction, moved to its current location following the 1985 closing of Paragon Park. The Carousel is privately owned by the non-profit Friends of the Paragon Carousel, although it is located on DCR land.

Clocktower Building

The Clocktower Building and the adjacent land for the Carousel have been leased to the "Friends of the Paragon Carousel". The long-term lease expired on June 30, 2016. The basement currently houses the mechanical equipment for the Carousel and a workshop where the Carousel horses are maintained. The first floor houses a museum focused on Paragon Park and an ice cream parlor. The upstairs is used for storage but has no electricity, heat or plumbing.

The expiration of the lease in 2016 provides an opportunity for DCR to find alternative and/or additional uses for the building. Regardless of the uses on the first and second floor, DCR would like to allow the mechanical equipment for the Carousel to remain in the basement and the Carousel itself to remain on the adjacent land. This building is currently an important part of the funding and operation of the Carousel. However, the Clocktower Building itself continues to fall into disrepair. It is important that the funds required for much needed maintenance improvements and ongoing maintenance and operations of the building be generated by revenues from the lease of this building, or that an additional source of funding be identified (i.e., a capital campaign by the "Friends of the Carousel" to raise funds to fully rehabilitate the building).

Historic Relevance

The building is included in the MHC's Inventory of Historic and Archaeological Assets of the Commonwealth. MHC has determined that the building appears to be eligible for listing as a contributing structure within a potential Nantasket Beach Reservation Historic District. It was constructed in 1903 as a restaurant and waiting area for the ferry and train to Boston.

Pedestrian & Vehicular Access

Contributing to the beach's appeal is its high level of pedestrian and vehicular accessibility from adjacent, largely residential areas, and its proximity to the Boston metropolitan area. Based on a 2006 Visitor Survey (see page 13), 91 percent of the visitors come by car. That number may have decreased to some extent since the introduction of the Greenbush Line Commuter Rail Service from Boston, but the reduction is likely small because of the lack of weekend service.

There are 26 crosswalks linking pedestrians to the Reservation beachfront (see page 19). The crosswalks are fairly evenly distributed at intersection and mid-block locations along Nantasket Avenue and Hull Shore Drive and connect to bath houses and other public facilities. Many of the crosswalks, however, are not at stop signs, limiting the degree to which pedestrians are protected.

Sidewalks along both sides of Nantasket Avenue in the Reservation are generally in good condition. Sidewalks on the western side of Hull Shore Drive (abutting vacant Hull Redevelopment Authority property) are deteriorating and in need of improvement. The sidewalk on the eastern side of Hull Shore Drive in this location was recently reconstructed.

Transit

Transit access to the Reservation is somewhat limited. Bus Route 714 runs from Pemberton Point to Hingham Center, with stops on Nantasket Avenue. It connects to the Greenbush Commuter Rail Line at Nantasket Junction; however, there is no commuter rail service on weekends, and bus and train schedules are not coordinated. The bus provides access to the ferry terminal at Pemberton Point, which has ferry service from Long Wharf in Boston.

The 220 bus route connects the Quincy Center Massachusetts Bay Transportation Authority (MBTA) station to Nantasket Junction. A passenger could take the MBTA Red Line or Old Colony Commuter Rail to Quincy Center, then take the 220 bus to Nantasket Junction and transfer to the 714 bus to Nantasket Beach, but this three-seat journey would be lengthy and difficult to coordinate.

Bicycles

Bicycle racks are located in several locations throughout the Reservation. The Town of Hull's Bicycle Plan was adopted in 2007 and proposes an extensive network of bike routes throughout the Town (see illustration on page 14); most of the plan has not been implemented to date. An existing bike path along the southwest side of George Washington Boulevard connects to Hingham. DCR also intends to stripe bike lanes on Wharf Avenue to connect cyclists from George Washington Avenue to the beach. At this time of this report, a MassDOT study of a more formalized bikepath on both sides of George Washington Boulevard from Hull to Hingham is underway.

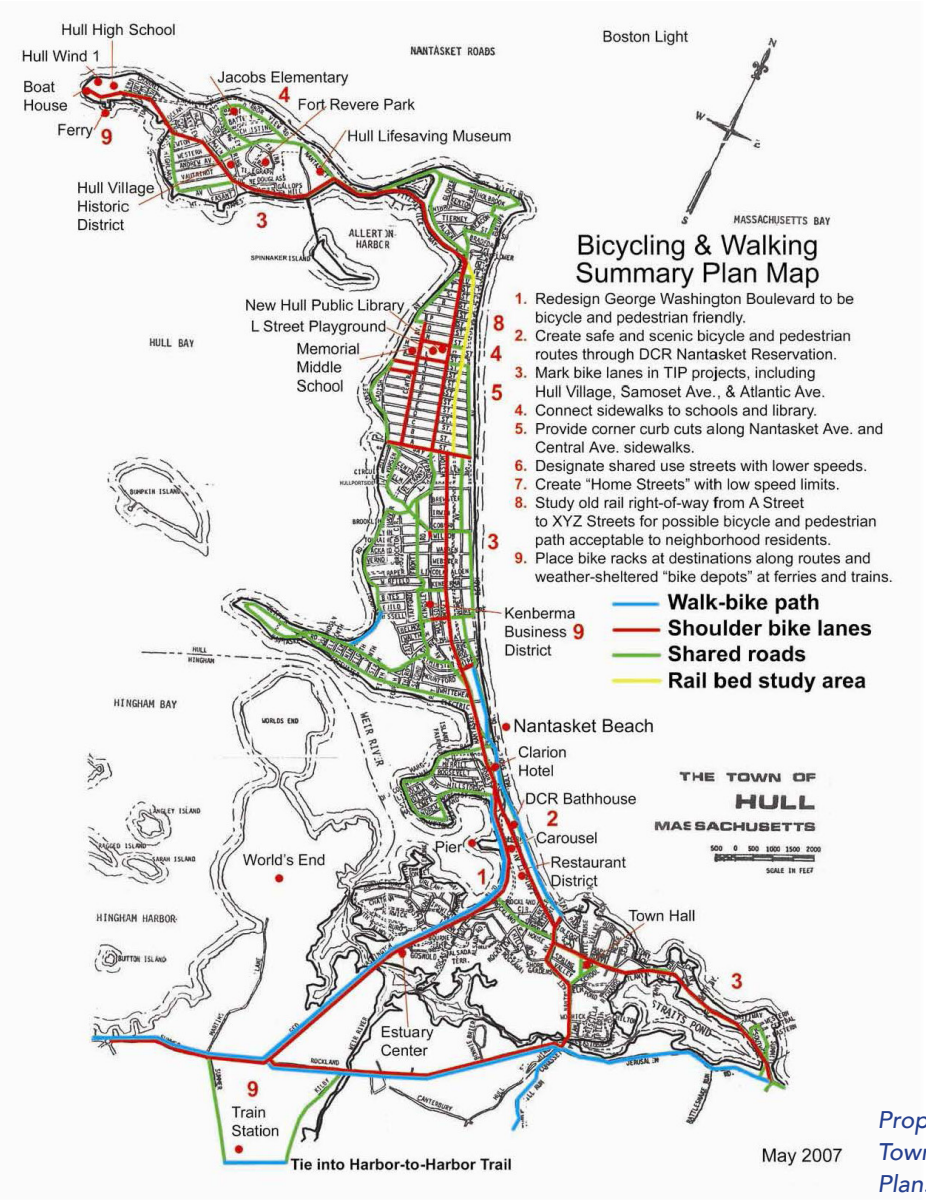
Parking

There are approximately 1,203 existing public parking spaces within the Reservation, including both on and off-street parking (see aerial photo on p. 3), plus an additional 900 spaces on vacant lots owned by the Hull Redevelopment Authority.

Most of the surface parking areas are adjacent to the beachfront, with the highest concentration of public parking found at the southern end of the Reservation. Two large overflow lots are located on George Washington Boulevard near the southern end of the Reservation.

These lots are separated from Nantasket Avenue by a large condominium development (Horizons Condominiums). Pursuant to a Massachusetts Public Waterfront Act Chapter 91 License, a path adjacent to the north edge of the Horizons Condominiums parking lot was constructed to provide a more direct link from

From top: Existing promenade and parking lots have minimal amenities; view of skating rink in the overflow lot on George Washington Boulevard.



Proposed route map from the Town of Hull's 2007 Bicycle Plan.

the DCR parking lots on George Washington Boulevard to Nantasket Avenue and the beach. However, this path remains fenced off from public use because a short section is on property owned by others and the public is prevented from using this path. This path will increase the attractiveness of these underutilized lots. The DCR continues to negotiate with the property owner regarding the lease or acquisition of the necessary right of way. These negotiations are at an impasse as of this printing.

Most of the parking lots are to the south of the MJM Bath House and most of the on-street parking spaces are to the north.

User Survey

An informal visitor survey was conducted to gain a better understanding of visitors' use and impressions of the Reservation. The responses provided valuable background information for development of the master plan.

Specifically, a total of 101 individual surveys were conducted on Monday, July 24; Sunday, July 30; and Wednesday, August 16, 2006. Although a few of the comments regarding facilities are now out of date, the majority of the responses are still relevant. The responses are summarized on the following pages.

Visitors

Almost 90 percent of the visitors surveyed were from outside of Hull. It is assumed that many Hull residents use the Town portion of the beach, rather than the DCR portion of the beach. Respondents came from areas west and south of Hull, from up to 40 miles away.

Ninety-one percent of respondents came to the beach by car. This is consistent with the finding that most of the people on the DCR beach are not from Hull (transit connections to the beach were very limited – the Greenbush Line did not reopen until October 2007). Seven percent of respondents walked (Hull residents) and two percent drove a motorcycle.

Young crowds (13-25 years of age) tended to congregate at the southern end of the beach near the Tivoli Bath House, whereas families (adults with children under 18 years of age) tended to congregate at the northern end of the beach near the Cook Comfort Station. Approximately twenty-five percent of the respondents came with children under 18 years old.

Beach Facilities, Maintenance & Security

Overall, beach users had relatively positive responses regarding DCR's operation of the beach and the conditions at the Reservation. Forty four percent of respondents gave "cleanliness of facilities" the highest two scores (scoring was on a scale of 1 to 5) and 40 percent gave cleanliness the lowest two scores.

Beach Experience

Seventy-two percent of the respondents reported swimming. Twenty-eight percent said they had not been in the water, but many of these respondents said they would be going in shortly.

Beach Access

Seventy-six percent of the respondents thought there were enough beach access points. Many commented that existing access through the seawall would be adequate if ramps and stairs were improved, repaired, and cleared of large revetment boulders. Subsequent to the survey, the ramps and stairs were improved, and new ramps were added, as part of the seawall improvements. The ramps now meet ADA accessibility standards.

Eighty percent of respondents thought there was an adequate number of crosswalks on Nantasket Avenue and Hull Shore Drive.

Parking

Parking was often described as being convenient. Sixty-six percent gave ease of parking either the highest or second highest rating. Respondents on the northern half of the beach reported more parking difficultly than those to the south. The most often cited problems with parking were "high prices" and lack of parking in lots near the Mary Jeanette Murray Bath House. Sixty-four percent of respondents said they would not consider using a remote parking lot with shuttle service, even if it meant more green space within the Reservation.

Attraction to Local Restaurants & Shops

Sixty-seven percent of the respondents said they had been, or planned to go, to a restaurant, shop, museum or other business in town while at the beach. A third of the respondents who suggested improvement ideas for the Reservation wanted more food related facilities (more beach vendors, more convenient food).

Beach Replenishment

Sixty six percent of the respondents said they would support beach replenishment with sand of another color. Seventy four percent of the respondents said they would like a wider beach at high tide.

Suggestions for Additional Amenities

Respondents identified the need for the following additional amenities:

- Bath houses
- Shower related facilities
- Water fountains
- Park areas/picnic areas with benches
- Umbrella/chair rentals
- Recreational facilities
- Convenient food related facilities
- Trash cans
- Shops.

The arcades across Nantasket Avenue from the Tivoli Bath House and Bernie King Pavilion.

3. GOALS

The overarching goal for the *Nantasket Beach Master Plan* is to provide an enhanced natural and recreational experience at Nantasket Beach, with:

- Attractive amenities to support a wide range of activities.
- Safe and convenient access for pedestrians, cyclists, transit and ferry passengers and automobile users.
- Connections to adjacent bicycle paths and parking areas, as well as commercial and entertainment opportunities.
- Increased amenities for high-tide and shoulder-season visitors.

In order to focus the master planning process, the following master plan goals, organized around five focus areas, were developed.

The Beach

- Provide and improve amenities on the beach (such as bath houses, shade structures, a widened promenade, space for vendors, bike paths, and other amenities as determined appropriate).
- Improve public access to beach for people of all ages, abilities, and backgrounds, including: bicycle access, accommodation of public transportation, and improved parking and roadway design.
- Create a gateway to Nantasket Beach for arriving visitors.
- Foster local commerce by improving connections between the beach and local businesses

and encouraging a variety of uses that benefit from the beach setting.

- Interpret the historical context and natural resource systems of the beach and the region.
- Preserve the essential character-defining features of the landscape while adapting the beach for contemporary uses.
- Develop year-round uses along the beach.
- Link Nantasket Pier to the Reservation.

Operations

- Establish an annual beach users meeting as a means of coordinating activities, sharing ideas and voicing concerns.
- Promote and accommodate regional events and programs on the beach.
- Ensure beach maintenance operations are adequately staffed and equipped.
- Maintain beach stability and sustainability.
- Ensure public safety by providing lifeguards and maintaining a clean beach.

Access & Circulation

- Provide safe and continuous bicycle, skating, and pedestrian access along the entire length of the beach promenade.
- Separate foot paths and bike paths in order to ensure safety and ease of movement for all users.
- Provide a comfortable, safe, and secure experience for visitors by reducing congestion and minimizing conflicts on the promenade, streets, and bike paths.
- Establish easier and safer pedestrian movement from the beach to local businesses and remote parking, promoting pedestrian friendliness.
- Improve traffic flow and access to parking, including use of signage to direct pedestrians and vehicles.
- Increase public transportation to Nantasket Beach and create connections to existing and planned transit (i.e., bicycle connections to the MBTA rail station and to potential future ferry operations).
- Increase the use of the rear lot along George Washington Boulevard and open the pedestrian right-of-way along the Horizons Condominiums.

The Built Environment

- Ensure that all building uses on DCR property are public in nature.
- Make efficient use of DCR's existing buildings and operations area.
- Rehabilitate buildings consistent with programming for Nantasket Beach and maintenance operations.
- Provide multi-use public facilities and spaces that are flexible, well-designed, and easily maintained.

The Natural Landscape

- Diversify plant communities in the Nantasket Beach area, to the degree that climate permits, for a healthier and more attractive landscape.
- Establish a sustainable and maintainable landscape.

4. RELATED STUDIES

Crosswalk locations (does not include crosswalks 22-26 to the north).

The results of two studies conducted simultaneously with the final phase of this Master Plan are summarized below and incorporated into this Master Plan. The final reports are available under separate cover:

- *Nantasket Beach Reservation Traffic Analysis Report*, Louis Berger, 2014.
- *Nantasket Beach Reservation Facilities Utilization Report*, Louis Berger, 2014.

The results of a third study, *Nantasket Beach Reservation Parking Demand and Capacity Study*, Louis Berger, 2015, are discussed in Chapter 5 and also available under separate cover.

From left: Roadway realignment alternatives A, B and C.

Traffic Analysis Report

This traffic study assessed traffic flow and pedestrian/bicycle interaction at and around the Nantasket Beach Reservation during the summer months and recommended modifications to improve circulation, as appropriate. Traffic, pedestrian, and bicycle flow were counted in 2006 and analyzed for year 2013 (existing conditions) and year 2033 (forecasted conditions).

Pedestrian Crossings

The pedestrian counts at crosswalks within the study area were high, with a total of 996 pedestrians using crosswalks during the 12 pm to 1 pm hour on a Saturday. The most heavily used crosswalk was number 17 with 151 pedestrians; the crosswalk is located on Hull Shore Drive near a number of restaurants (i.e., Hull's Kitchen, Dry Dock, Daddy's Dogs).

The report included the following recommendations:

- Crosswalk 4 was utilized by only 11 pedestrians during the Saturday peak hour. This crosswalk does not have a clear destination from the beach and could be removed to reduce the number of locations where vehicles yield to pedestrians.
- Crosswalks 8 and 9, which both lead to the arcade buildings, could be combined. A total of 175 pedestrians are expected to use this proposed crossing during the Saturday peak hour. A push-button activated flashing beacon and warning sign would be appropriate at this combined location.

- Crosswalks 17 and 18 may also be viable candidates for a pedestrian signal. These crosswalks service 151 and 118 pedestrians during the peak hour, respectively. Installing a push-button activated flashing beacon and warning sign at one or both of these locations would encourage safe crossing over the two-lane Hull Shore Drive and allow larger groups of people to gather and cross at the same time.
- All crosswalks at intersections should remain. Drivers generally proceed more cautiously at intersections, creating a safer environment for pedestrians when compared to mid-block crosswalks.

Traffic Alternatives for Improvements to the Maintenance Yard

Aside from the existing conditions, two alternatives were examined to re-configure traffic in the vicinity of the DCR operations and maintenance area and thereby make the yard space more compact and efficient for operations while reducing frontage on Nantasket Avenue. Specifically, the traffic alternatives being considered at the intersections of Hull Shore Drive, Nantasket Avenue and George Washington Boulevard are as follows:

- **Alternative A**: The existing condition remains. (Estimated construction cost: $0)
- **Alternative B**: Realignment of the cut-through portion of roadway from George Washington Boulevard westbound. (Estimated construction cost: $340,000 in 2016$)
- **Alternative C**: Relocation of the cut-through portion of roadway from George Washington Boulevard westbound to the current intersection of George Washington Boulevard and Nantasket Avenue. The southeastern terminus of Hull Shore Drive is also shifted to align with this proposed intersection. (Estimated construction cost: $1,060,000 in 2016$).

From a traffic capacity perspective all three of the intersection alternatives would operate at level of service (LOS) "B" during the current year and at LOS "C" in the year 2033. LOS "B" is classified as reasonably free flow. LOS "C" is classified as stable flow and also considered a passing level of service.

Alternative C would provide the largest amount of yard space for maintenance operations. The decision to move forward with any of the alternatives will need to consider factors such as property ownership, concerns of local residents, and long-term plans for the community.

In 2015, the Town of Hull (with support from DCR) studied changes to the existing roadway system, including making both Nantasket Avenue and Hull Shore Drive two-way, and increasing the number of through streets between them to improve connections and create smaller, more developable blocks on the Hull Redevelopment Authority owned parcels between Water and Phipps Streets. Alternative B would be most compatible with these changes and is therefore included in the master plan drawings. Alternative B would accommodate either the existing one-way street system or the two-way system proposed by the Town. DCR is amenable to a temporary trial of the two-way road system.

Other Findings

In addition to revising the roadway alignment, the report includes the following recommendations:

- The intersection of Nantasket Avenue, Phipps Street and Mountford Road is currently operating at a failing level of service during the Saturday peak hour. Recommended mitigation for this location is to improve the signing system for parking at DCR lots. In recent years DCR has utilized four variable message signs (VMS) at select parking lots to alert drivers when lots are full. Adding VMS boards at other parking

lot entrances and updating the signs regularly would allow drivers to be aware of full lots and empty spaces allowing them to spend less time circulating. All other stop-controlled locations are currently operating at LOS "B" or better.

- All signalized intersections analyzed are currently operating at LOS "C" or better during the Saturday peak hour. If signalized intersections are found to be a bottleneck in future years, updating the fixed signal timing may decrease delays. Actuated signal timing systems are another option if an acceptable LOS is not achieved in the field. Actuated signal timing allows sensors to notify the controller of waiting vehicles to decrease unnecessary stop delay.

Facilities Utilization Report

The *Nantasket Beach Reservation Facilities Utilization Report* assessed the maintenance operations and associated facilities at the Nantasket Beach Reservation. Several options were developed to improve operations on the site and at the same time allow for vacating some of the buildings for other potential uses. Options were developed jointly with DCR staff.

Maintenance Operations

Maintenance operations at the Reservation are ongoing year-round to keep the facility functioning as expected for public use. The busiest time of year is during the summer months from Memorial Day to Labor Day but the area is open year-round from dawn to dusk. During the winter months the staff is responsible for snow removal. Storm management is necessary year-round. The maintenance crews are currently using all garage and yard space available and are in need of additional covered/heated storage for critical equipment.

The Town of Hull has expressed an interest in relocating the operations and maintenance functions to a less central location to enable the Town to reuse the existing operations and maintenance site and buildings for other uses. Chapter 289, Acts of 2010, allows the Town to lease this area for a minimum of 99 years. However, leasing the land to the Town of Hull is contingent upon Sections 2 and 3 of Chapter 289, which state: "The lease authorized in Section 1 shall be granted only if the lessee agrees to assume the costs of any surveys and other expenses deemed necessary by the commissioner of capital asset management and maintenance for the lease." And "The town of Hull shall compensate the commonwealth for the property described in section 1 by providing necessary storage space for maintenance equipment of the department of conservation and recreation." To date, no development proposal for the existing maintenance operations site has been put forth and no relocation site or funding for the DCR maintenance operations has been designated. This master plan assumes DCR's continued presence on this site, although DCR looks forward to the opportunity to work with the Town and/or potential developer on the reuse of the site, should the conditions of Chapter 289 be met.

Buildings

There are a number of buildings on site that are not used to capacity. The Dormitory Building is currently utilized by DCR as office space. The Clocktower Building is leased out and the Police Station is closed due to asbestos and major water damage. Maintenance of the buildings on site is a major factor in any future planning. Many buildings are 100+ years old and need substantial repairs and upgrades as summarized by DCR maintenance staff and documented in the report (and summarized in Chapter 2 of this Master Plan).

Aside from long-term layout changes, several repairs and modifications to the facilities are needed, as summarized on the following pages:

1. Dormitory Building

- Inspection and possible repairs to the roof
- Assessment of structural integrity of the building
- Re-pointing of all brick work
- Inspection and repair of the brick foundation and support columns due to salt damage
- Extensive gutter and fascia replacement on both porches
- Relocation of the generator from the basement of the Dormitory Building to an area protected from flooding.

2. Laundry Building (if not planned to be demolished)

- Asbestos abatement (if not completed previously)
- Inspection and repair of rotten sills
- Replacement of windows.

3. Small Garage/Fire Safety Building (if not planned to be demolished)

- Inspection and repair of rotten sills
- Replacement of doors and windows.

4. Lower Garage

- Inspection and possible repairs to the roof
- Repair of overhanging eaves
- Re-pointing of all brick work
- Repair or replacement of all windows
- Insulation of the structure
- Installation of a pedestrian-sized door to access the building.

5. Upper Garage

- Inspection and possible repairs to the roof
- Repair of eave supports and gutters
- Re-pointing of all brick work.

6. Clocktower Building

- Testing of the second floor for lead and asbestos
- Complete remodeling of both floors
- Possible upgrade of the heating, cooling, and electrical systems
- Roof repairs.

7. Police Station

- Major rehabilitation work.

8. Boilermaker's House (if not planned to be demolished)

- Inspection and repair of rotten sills
- Inspection and repair of the foundation.

Facilities Layout Options

Four layout options were considered to better utilize the yard area and consolidate DCR operations to meet the anticipated needs of DCR staff. Facilities Layout Options 1 and 2 include modifying traffic along George Washington Boulevard (i.e., Traffic Alternatives B or C) to create additional yard space for maintenance activities. Facilities Layout Options 3 and 4 are based on the No-build Traffic Alternative A.

Key features of each option are summarized in Table 1. Each option could be modified using elements from other options. Under each option at least two buildings would be available for lease to an outside party whose purpose and goals match that of the DCR mission at the Reservation. In all four options the Boilermaker's House, Small Garage and Laundry Building are recommended for demolition or relocation to increase yard area.

Description	Option 1: Full Build-out of Upper Garage	Option 2: Partial Build-out of Upper Garage	Option 3: No Build-out of Upper Garage	Option 4: No Action
Traffic Alternative	B or C	B or C	A	A
Dormitory Building	Lease	Lease	Lease	Office Space
Clocktower Building	Lease	Lease	Lease	Lease
Police Station	Lease/Office Space	Office Space	Office Space	Lease
Yard Area	On site	On site	Parking Lot 8	On site
Small Garage	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate
Boilermaker's House	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate
Laundry Building	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate	Demolish/Relocate
Upper Garage	10' expansion, 2nd story addition	10' expansion	No change	No change
Lower Garage	No change	No change	No change	No change
Additional Covered Storage	None	None	3-bay prefabricated garage	3-bay prefabricated garage

Table 1: Summary of Facilities Layout Options

Recommended Facilities Layout Option 2 – Partial Build-out of Upper Garage

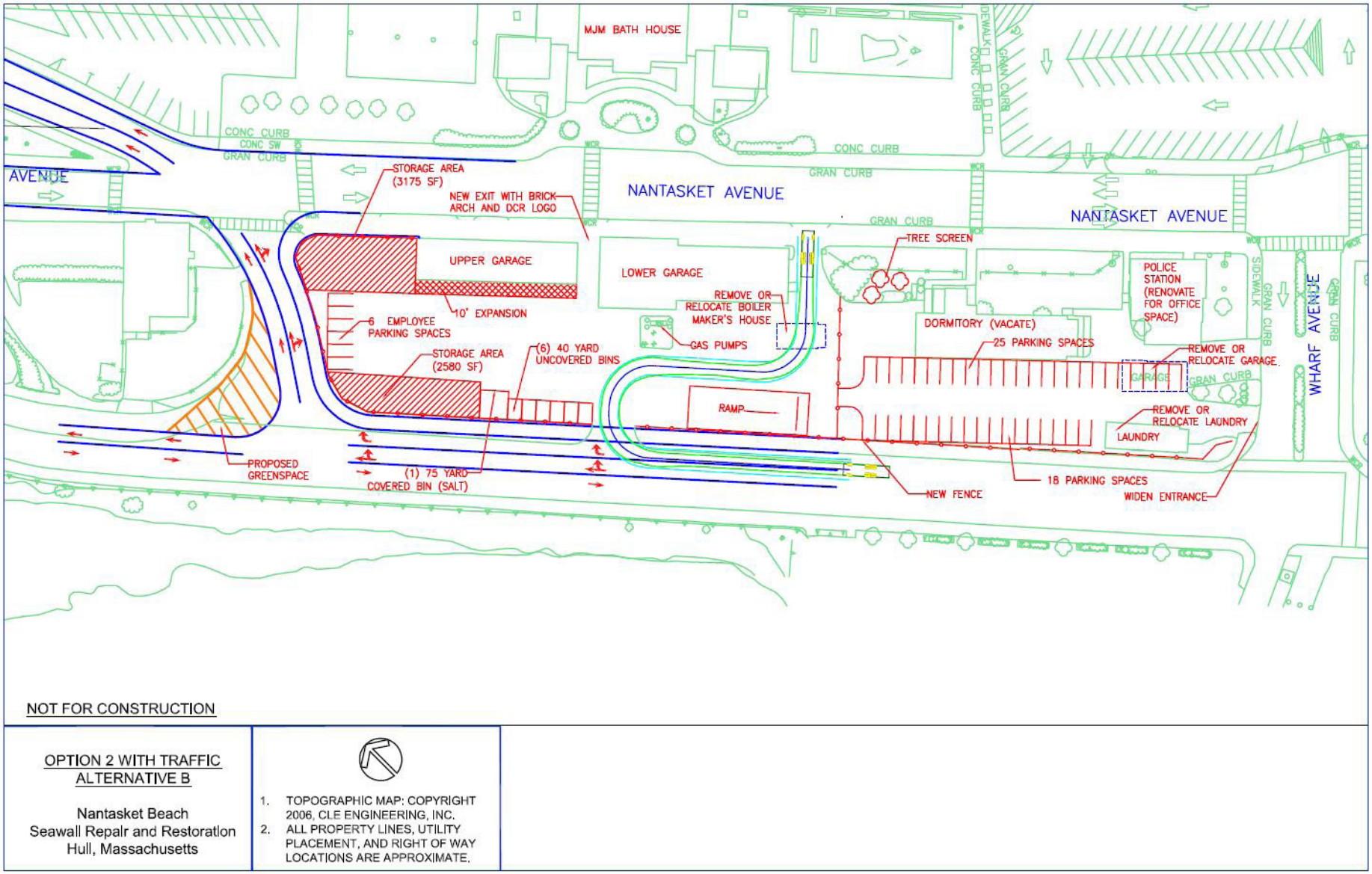
Layout Option 2 - because it provides an improved operations area, keeps all maintenance facilities on site, is consistent with Traffic Alternative B, and does not require adding a second floor to the Upper Garage - was selected as the option to be incorporated into the Master Plan illustrations in Chapter 5. The existing operations maintenance facility - bounded by Wharf Avenue, George Washington Boulevard, Hull Shore Drive and Nantasket Avenue – is 78,400 square feet (1.8 acres). Traffic Alternative B adds 11,400 square feet (0.26 acres) to this area, while changes to DCR's use of the area and buildings described below result in a 37,000 square foot (0.85 acre) decrease in the area used by DCR. The net result would be that DCR's operations maintenance facility would occupy 52, 800 square feet (1.2 acres), a net reduction of 25,600 square feet (0.6 acres). DCR's use of the Nantasket Avenue frontage of the site would be decreased by 200 feet.

Office Buildings and Uses

Option 2 utilizes the Police Station for office space. While the Police Station needs extensive repairs to serve this purpose, DCR staff agrees that the central location and ease of access make it an appropriate 'face' of DCR's operations on the Reservation. The building is also slightly removed from the brick garages and will aid in separating the public from the maintenance operations and equipment. The Dormitory Building will be available for lease to a user and use that aligns with DCR's mission. The Clocktower Building needs a stronger leasing agreement that includes substantial repair and upkeep of the building. Ideally the funds would come from a capital campaign by the Friends of the Paragon Carousel. The Small Garage, Boilermaker's House, and Laundry Building are recommended for removal or relocation to increase available yard space.

Maintenance Buildings

Due to the overall good condition of the brick Upper and Lower Garages, Option 2 suggests continued use of both with some improvements. Option 2 expands the back wall of the Upper Garage by 10 feet to the south (towards George Washington Boulevard) for additional storage. Garage doors should be included on the addition to create a convenient 'pull-through' area for the operators. This would eliminate the need



Facilities Layout Option 2.

for drivers to stop traffic on Nantasket Avenue to either back into or out of the garage. The Lower Garage should be improved as suggested earlier in this chapter. A brick arch between the two maintenance garages with the DCR logo is recommended to maintain the architectural intent of the original design.

Yard Area

Due to the current restrictions of yard space it is recommended that the dumpster and ramp be relocated to provide easier access during pickup and to avoid damage to the gas pumps. Additional yard space under Alternatives B and C can accommodate a truck entrance to the yard from George Washington Boulevard. Trucks will exit to Nantasket Avenue.

To improve the available area in the maintenance yard, Option 2 removes or relocates the Boilermaker's House, Small Garage, and Laundry Building. Forty-three parking spaces are located near the Dormitory Building.

For outside storage of materials and equipment, various locations around the site have been strategically chosen to leave sufficient open space for vehicle movement. One covered salt bin (capacity of 75 cubic yards) and six open bins (capacity of 40 cubic yards each) are located on the site for storage of materials throughout the year.

Six employee parking spaces are located at the north end of the site. Partial staff parking would be moved to Parking Lot G during the summer months.

For Traffic Alternative B, the entrance from Wharf Avenue should be reconfigured to increase the area for turning movements of large trucks. A new fence would surround the site to provide a visual screen.

Traffic Alternatives

Layout Option 2 under Traffic Alternative B increases the yard area substantially and "squares off" the yard.

Under Traffic Alternative C, even more yard area would be available. In addition to a truck entrance from George Washington Boulevard and additional parking spaces near the Dormitory Building, the storage bins under Traffic Alternative C are moved to the northern side of the yard. For Traffic Alternative C, the number of employee parking spaces within the yard area is increased to 10 (compared to 6 spaces under Traffic Alternative B). Traffic Alternative C also allows for some future expansion of the maintenance area, if needed.

Considerations for All Future Operations Area Options

A number of building and yard maintenance improvements discussed in the preceding sections are recommended for near-term consideration. The buildings on site are in need of fairly major repairs just to maintain the deteriorated conditions expected of buildings over 100 years old. Specifically, recommended improvements include the following:

- Build a temporary cover for the salt storage bin to meet environmental run-off regulations until a permanent structure can be constructed.
- Demolish or relocate the Laundry Building, Small Garage/Fire Safety Building, and/or Boilermaker's House to allow for additional yard space and to improve circulation.
- Re-route the current garage waste disposal drains to connect to the town sewer line under Nantasket Avenue.
- Install deep sump catch basins.
- Relocate the generator from the basement of the Dormitory Building to an area protected from flooding.
- Investigate options for a covered dumpster to reduce odors.

Uses of Available Buildings

Under all facilities layout options, at least two buildings are available to be leased to interested parties that will help to maintain the buildings and act within the intent of DCR's mission statement. If no satisfactory

lease candidates are selected for a building, DCR could use the buildings for internal programs. Possible options for either of these scenarios were discussed for each building by the DCR team and consultants. The resulting options are described in the following sections and are expected to be expanded upon in years to come.

Maintained and Operated by DCR

Maintaining the historic value and essence of all buildings on site is a priority of DCR. If maintenance and upkeep of selected buildings is not agreed to in a lease agreement, the repair and remodeling responsibility would fall to DCR. In this circumstance, appropriate uses for each building would need to be found.

The Dormitory Building could be used by DCR as a headquarters for the youth program Student Conservation Association (SCA). The first floor would be used as office space and the second floor would serve as rooming for students visiting the site to participate in the SCA program.

The Police Station could be used by DCR as a visitor center. It is centrally located and has extensive historical documentation that would be of interest to the public.

The Clocktower Building could be used by DCR for a variety of activities. The current ice cream stand within the building would make a convenient permit sales location. The adjacent first floor area could serve as a visitor center, office space, storage space, and/or a museum. The second floor would be better suited for office space or storage space.

Leased by DCR

The project team agreed that the first step in leasing any of the spaces vacated by DCR is to create a public forum to collect ideas on how visitors would like to see the spaces used in the future. All proposals submitted would be required to account for historic preservation and maintenance tasks while fitting within the DCR mission statement. Possible uses that the team felt were appropriate for the area and follow the mission statement have been documented for each building. The intent was only to brainstorm and inspire ideas, not to limit the proposals that are received.

The team felt that the Dormitory Building may be a suitable hostel for international youths visiting the area. The Clocktower Building is historically relevant so use as a museum was suggested to complement the existing Carousel. The Friends of the Paragon Carousel currently lease the Clocktower Building and use a portion as a maintenance area for the Carousel. The income from the ice cream vendor provides revenue to support the operation of the Carousel. However, the income is not sufficient to cover the cost of required building maintenance.. Alternatively, a new long-term lease could require that the lessee contribute more money to building maintenance. The historic Carousel is an important attraction at Nantasket Beach and both DCR and the Town, as well as The Friends of the Carousel, are interested in ensuring that the Carousel continues to operate. As discussed earlier, it is important that the funds required for much needed capital improvements and ongoing maintenance and operations of the building be generated by revenues from the lease of this building, or that an additional source of funding be identified.

The Police Station building also is historically significant and could be used as a visitor center, museum or perhaps as a studio for artists.

Parties interested in the possible leasing of these sites would need to consider:

- The adjacent maintenance facility.
- Flood insurance would be required for leased occupants. The area is classified as a "high velocity" zone by FEMA and flooding is common.

5. THE PLAN

Illustrative Master Plan (see enlargement on pages 30-31).

As described in Chapter 2, creating a more attractive, greener environment, with better access to the beach and Reservation, and more amenities for visitors, are key goals of this master plan. The plan is designed to provide visitors with a great day at the Reservation from arrival to departure, while aiding the DCR in operating and maintaining the Reservation and supporting the Town's economic development goals. The recommendations described below were developed to achieve that vision, and respond to DCR's needs and concerns, as well as the concerns that were expressed by the community and the Citizens Advisory Committee throughout the master plan process.

Although it is anticipated that the peak season at the Reservation will continue to be the summer, when the beach is most heavily used, the Reservation has year-round visitors. The recommended improvements are designed to encourage visitation during the off-season through expanded opportunities for an array of activities and improved connections between the Reservation and adjacent commercial districts.

As described in the introduction, this master plan was developed in conjunction with the Nantasket Beach Seawall Repair Project. Recommendations (both design and phasing) have been coordinated with the remaining unfinished elements of that Project, including:

- Installation of a stone revetment to stabilize the existing seawall segment from the Mary Jeanette Murray Bath House north to Water Street (by the U.S. Army Corps of Engineers).
- Rehabilitation of the revetment at the northern end of the Reservation, near the David Cook Comfort Station (by the Hull Redevelopment Authority).

Recommendations are divided into the following categories:

- The Promenade/Boardwalk
- Open Space and Recreational Amenities
- Landscaping and Green Space
- Operations and Maintenance Area
- Vehicle and Pedestrian Access and Circulation
- Year-round Operations
- Interpretive Opportunities
- Wayfinding and Signage
- Phasing.

This Master Plan includes conceptual plans for recommended improvements. As individual recommendations are implemented, design will be taken to a much greater level of detail and a public review process will be conducted. All facilities will be designed to meet ADA accessibility standards, and layouts for new facilities (including the boardwalk, bike path and parking) were developed to accommodate those requirements. Specific modifications to existing facilities are noted in the text.

The Town of Hull has expressed an interest in using the redesign of portions of the Reservation as an opportunity to address ongoing flooding issues near the Reservation. As part of the design process, DCR is open to discussions with the Town regarding the specific causes and effects of flooding near the Reservation and the potential for design options to help mitigate the flooding.

Nantasket Avenue and Hull Shore Drive are listed on the National Register of Historic Places as part of the Greater Boston Metropolitan Park System National Register District. Changes to the alignment and streetscape will need to be reviewed by the Massachusetts Historic Commission during future design phases.

The Promenade/Boardwalk

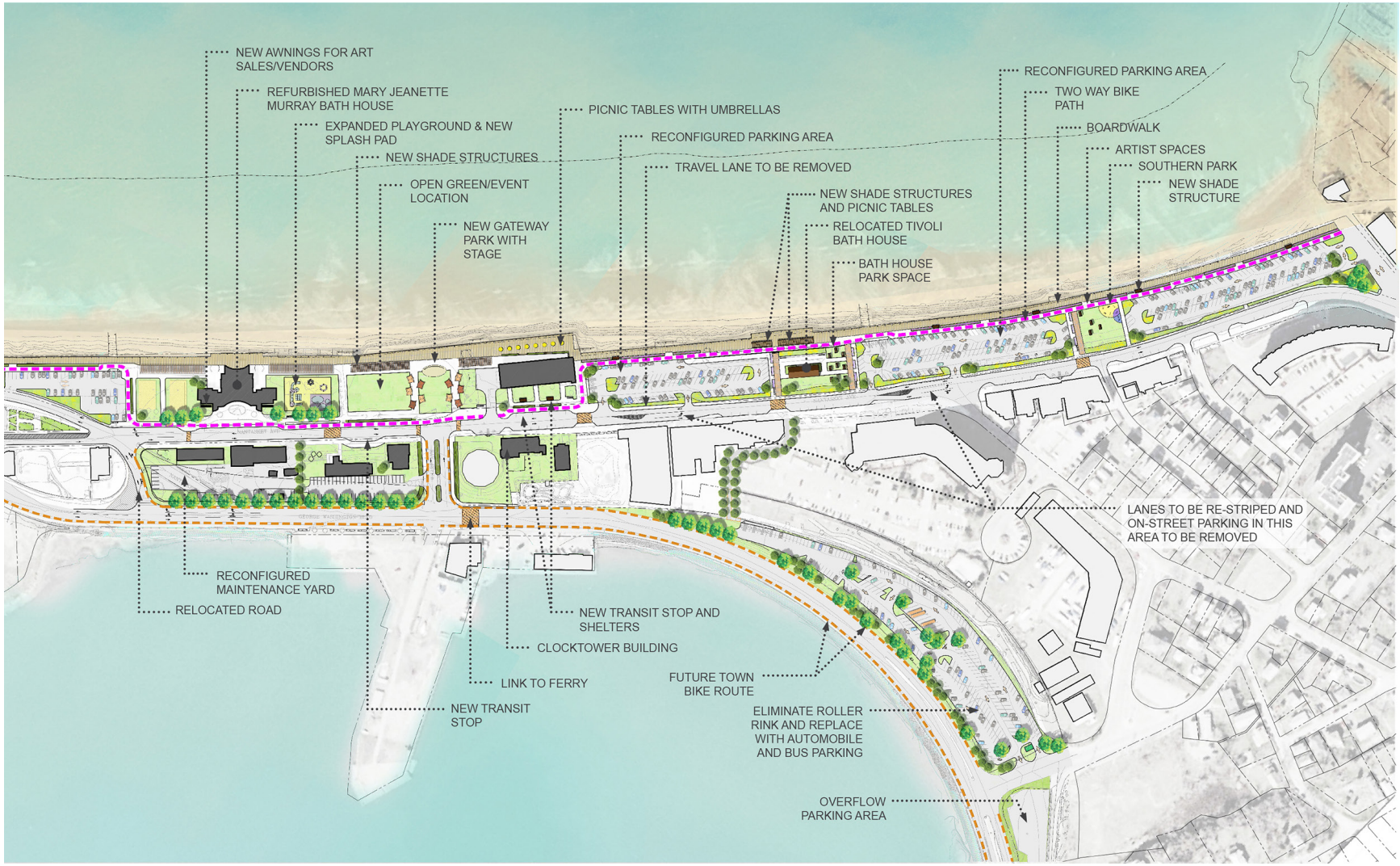
Most visitors to the Reservation walk along the beachfront promenade, whether to access the beach, to exercise or to enjoy the view. The promenade also provides a refuge for visitors during high tide, when the beach is underwater.

As with the existing promenade, the redesigned promenade will be continuous along the entire length of the Reservation.

For most of the length of the beach, the promenade is 16 feet wide. It widens to almost 20 feet behind the Mary Jeanette Murray Bath House. At the northern end of the beach, along Hull Shore Drive, it narrows

Above: Existing promenade and adjacent parking lot; rendering of boardwalk with shade structure, landscape buffer and bike path.

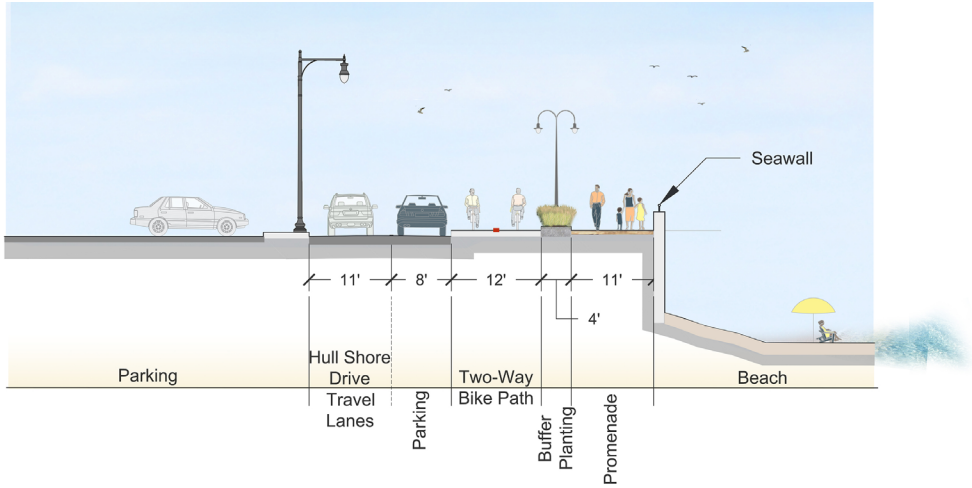
Illustrative drawing of Master Plan recommendations.


NEW AWNINGS FOR ART SALES/VENDORS
REFURBISHED MARY JEANETTE MURRAY BATH HOUSE
EXPANDED PLAYGROUND & NEW SPLASH PAD
NEW SHADE STRUCTURES
OPEN GREEN/EVENT LOCATION
NEW GATEWAY PARK WITH STAGE
PICNIC TABLES WITH UMBRELLAS
RECONFIGURED PARKING AREA
TRAVEL LANE TO BE REMOVED
NEW SHADE STRUCTURES AND PICNIC TABLES
RELOCATED TIVOLI BATH HOUSE
BATH HOUSE PARK SPACE
RECONFIGURED PARKING AREA
TWO WAY BIKE PATH
BOARDWALK
ARTIST SPACES
SOUTHERN PARK
NEW SHADE STRUCTURE
LANES TO BE RE-STRIPED AND ON-STREET PARKING IN THIS AREA TO BE REMOVED
RECONFIGURED MAINTENANCE YARD
RELOCATED ROAD
NEW TRANSIT STOP AND SHELTERS
CLOCKTOWER BUILDING
LINK TO FERRY
NEW TRANSIT STOP
FUTURE TOWN BIKE ROUTE
ELIMINATE ROLLER RINK AND REPLACE WITH AUTOMOBILE AND BUS PARKING
OVERFLOW PARKING AREA

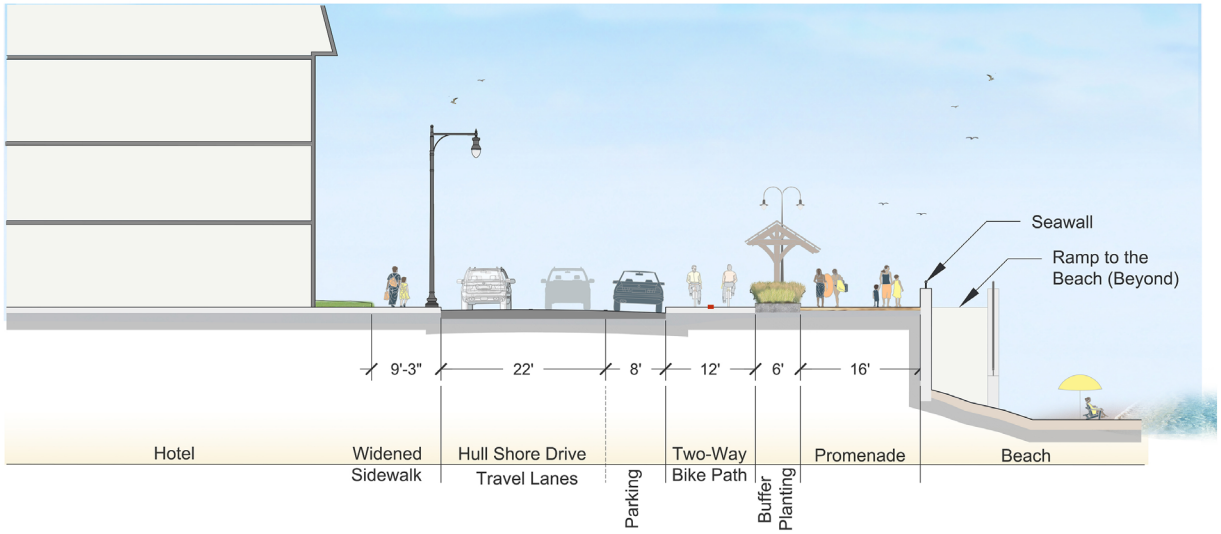
to 10 feet because of the limited land area available between Hull Shore Drive and the seawall. The promenade could be widened to 12 feet in this area if the promenade construction takes place during or after the Town of Hull's proposed roadway widening.

A six-foot wide planting buffer along the landside of the promenade separates the promenade from the bike path (described on page 48). The sides of the planters should be angled inward to avoid conflicts with cyclists. In a few locations, the buffer strip narrows to 4 feet. The exact width and juxtaposition of the boardwalk, planting buffer and sidewalks change as the available space differs over the length of the Reservation. The cross sections (pages 32 through 36) illustrate the different conditions.

Shade structures with benches, as well as locations for artist spaces, are interspersed in the planting strip along the length of the promenade. Artist spaces will provide opportunities for artists to set up easels, as well as to display and sell their work. The boardwalk can become an Arts Walk - strolling the boardwalk to look at art displays will become another activity attracting and engaging visitors during high tide and the off-peak seasons. The Arts Walk also will help to support Hull's strong arts community. Vendor stalls or pavilions to accommodate umbrella, beach chair and/or bicycle rentals are located near the northern and

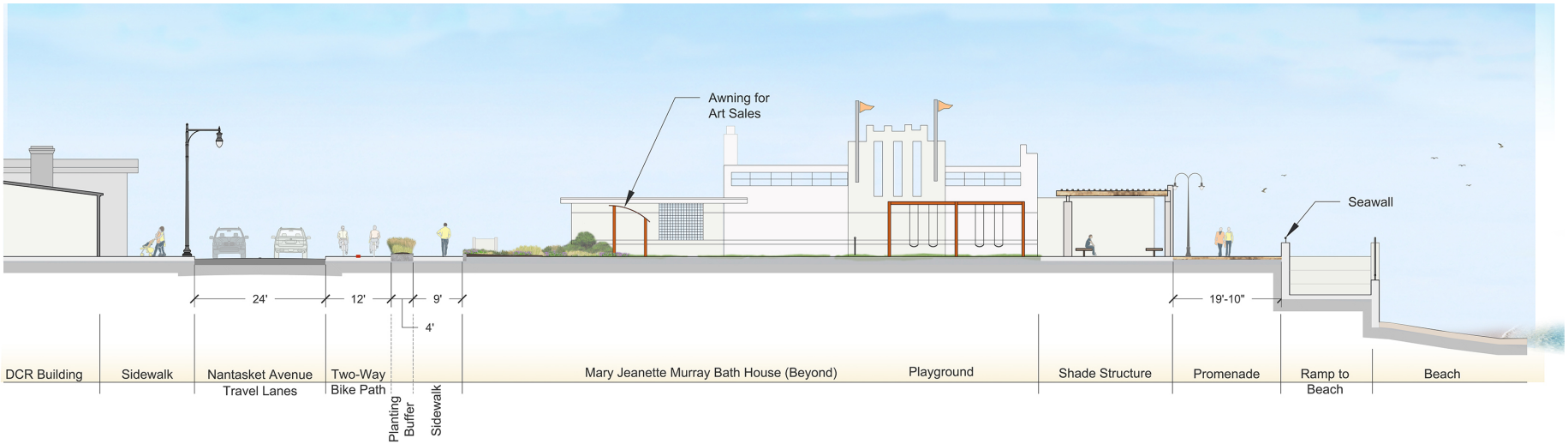


SECTION 1- 20' TOTAL WIDTH @ HULL SHORE DRIVE, REDUCED BUFFER ZONE WIDTH (4')



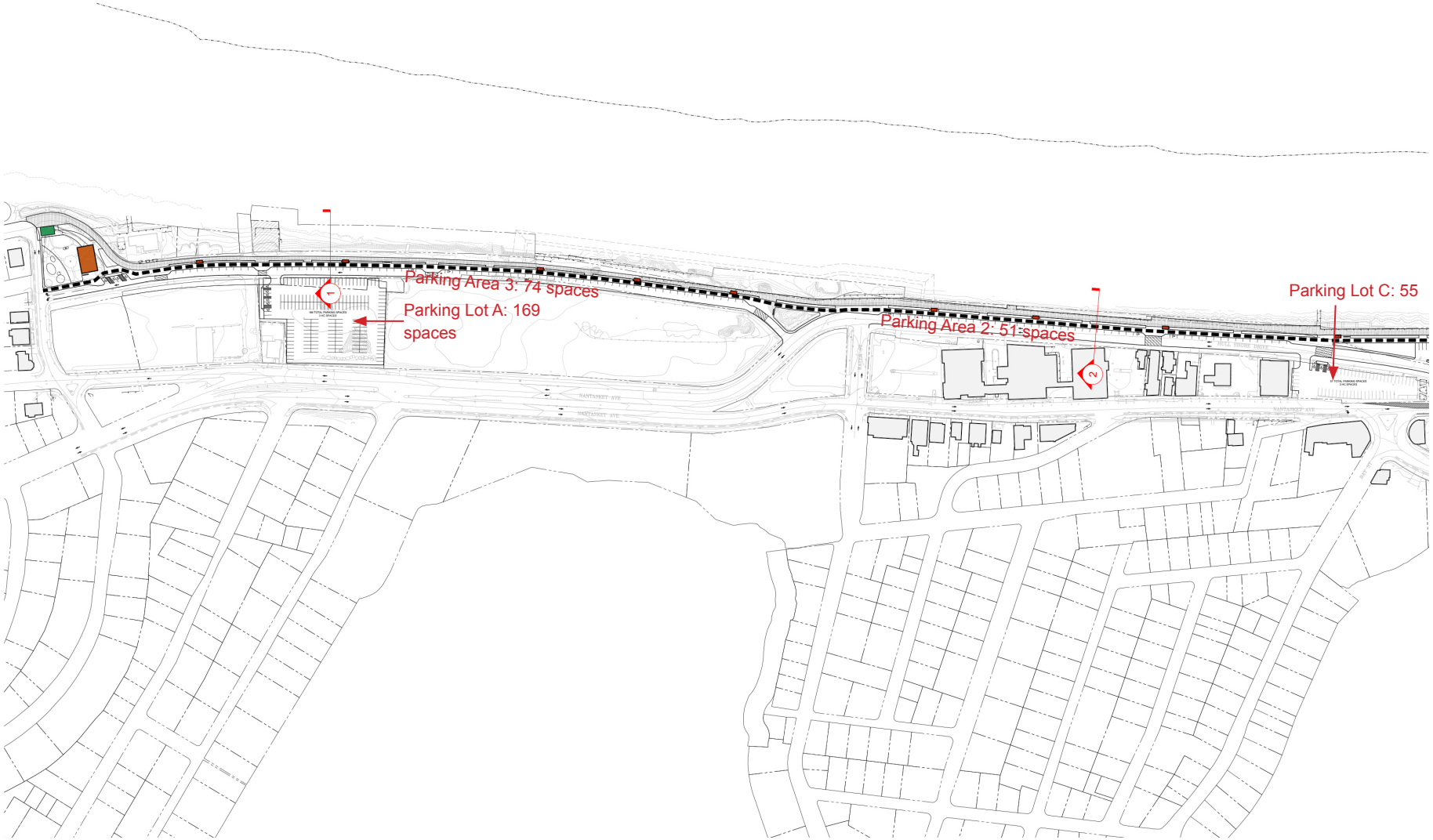
SECTION 2- 12' BIKE LANE ALONG PROMENADE, 30' TOTAL WIDTH @ HULL SHORE DRIVE

Above and facing page: Cross sections indicating juxtaposition and width of promenade, bike path and other amenities at various locations (cross section locations are shown on pages 34-35).

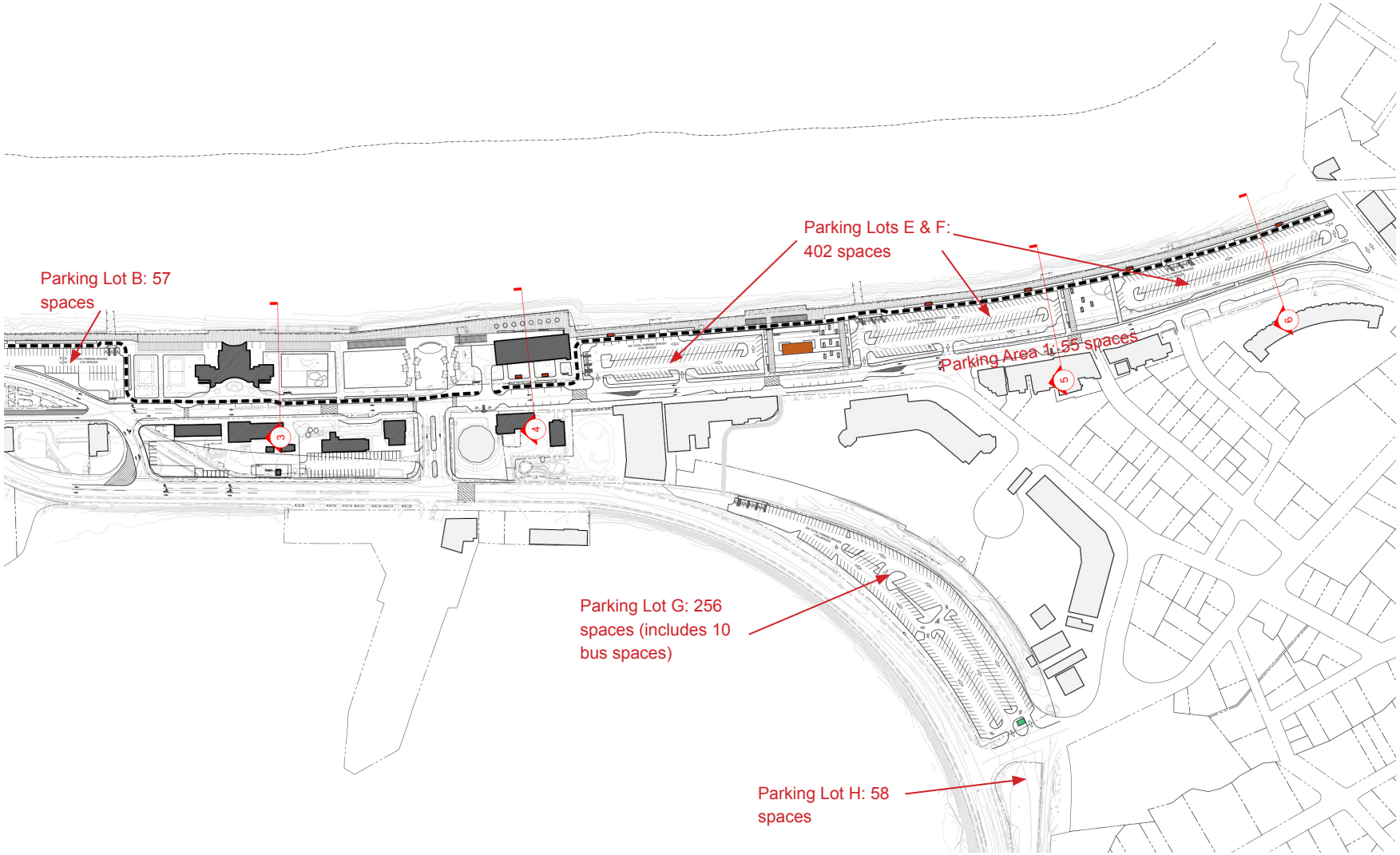


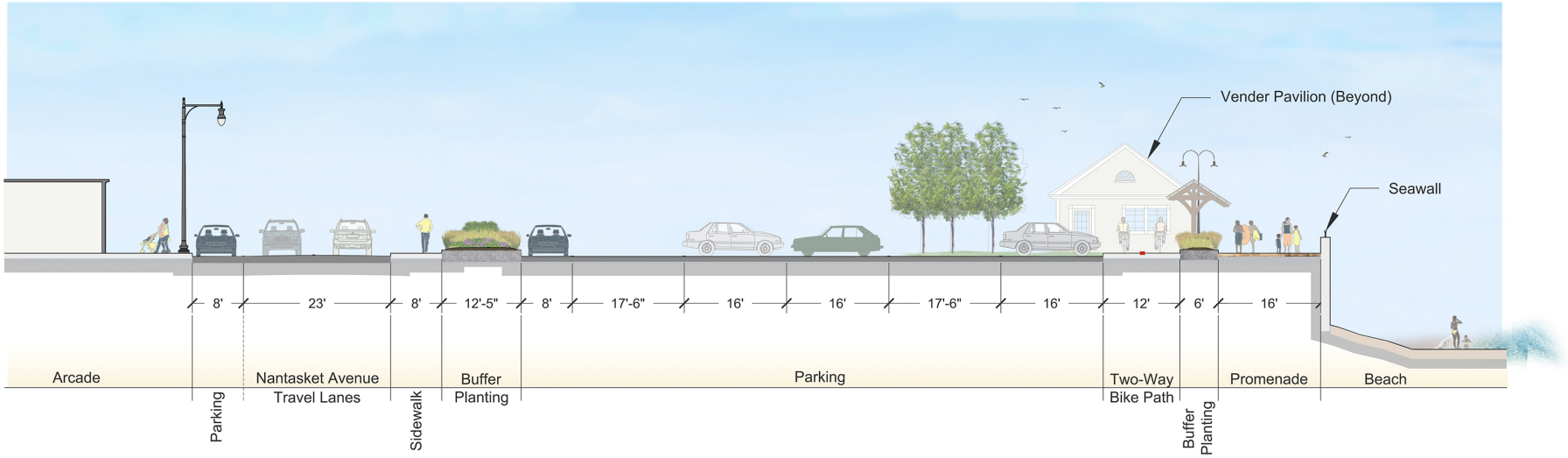
SECTION 3- 12' BIKE LANE ALONG SIDEWALK, 24' TOTAL WIDTH @ NANTASKET AVENUE

SECTION 4- 12' BIKE LANE ALONG SIDEWALK, 42' TOTAL WIDTH @ NANTASKET AVENUE

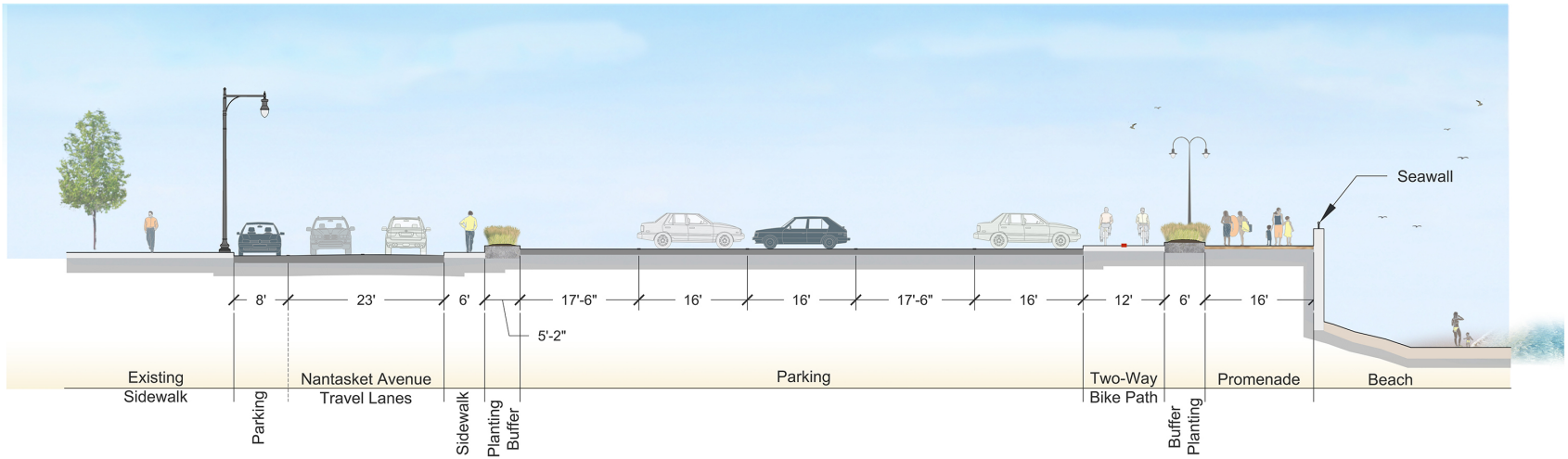


Above and facing page: Location of cross sections on pages 32, 33 and 36 and parking facilities discussed on page 48.


Parking Lot B: 57 spaces
Parking Lots E & F: 402 spaces
Parking Area 1: 55 spaces
Parking Lot G: 256 spaces (includes 10 bus spaces)
Parking Lot H: 58 spaces



SECTION 5- 12' BIKE LANE ALONG PROMENADE, 31' TOTAL WIDTH @ NANTASKET AVENUE



SECTION 6- 12' BIKE LANE ALONG PROMENADE, 31' TOTAL WIDTH @ NANTASKET AVENUE

Cross sections indicating juxtaposition and width of promenade, bike path and other amenities at various locations (cross section locations are shown on Pages 34-35).

southern end of the beach. These stalls could be operated as "branches" of existing beachfront businesses.

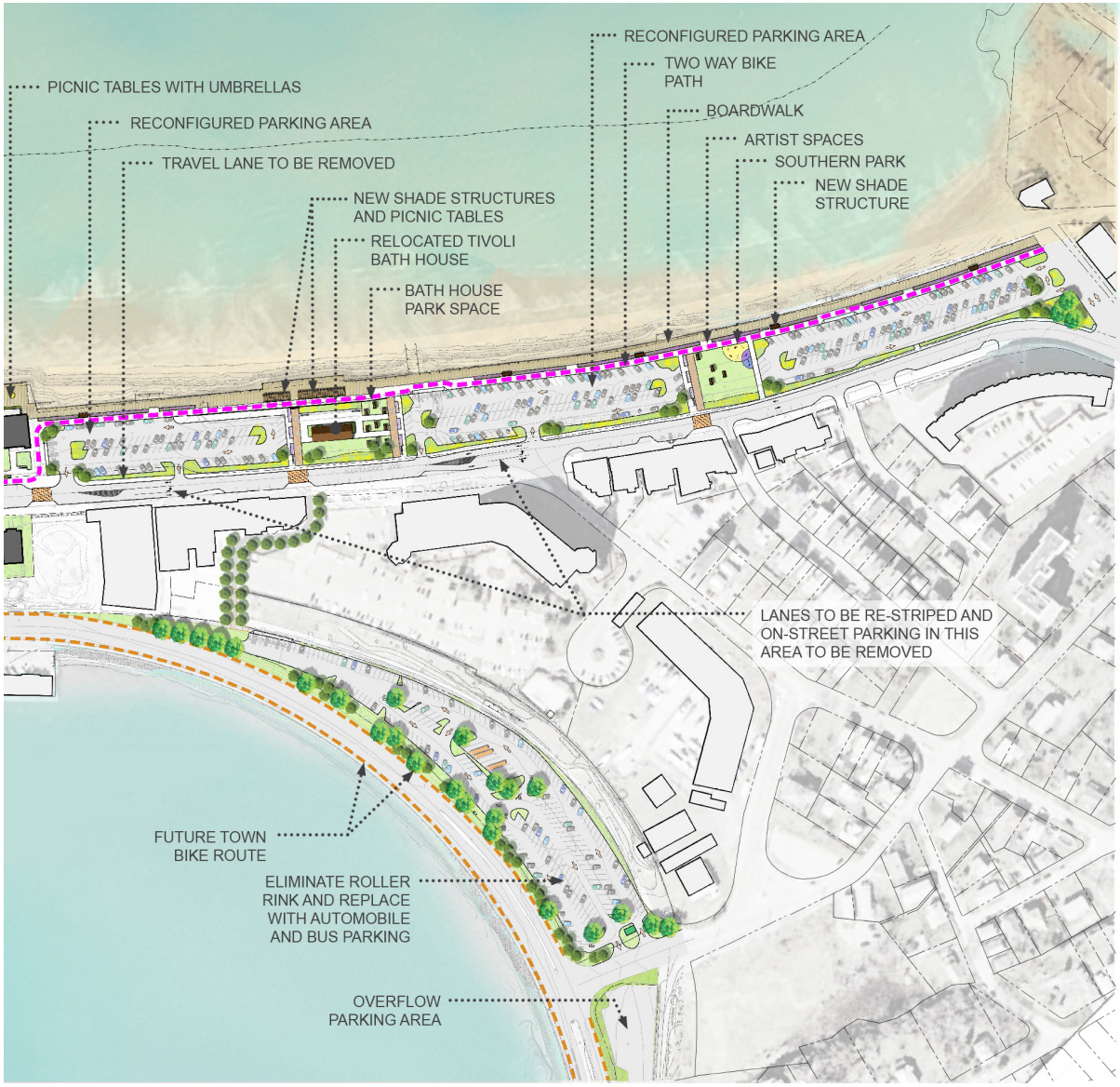
Lighting is incorporated into the design for the promenade and is shown as double pendant lights, similar to those used at other DCR Reservations. Where possible, the lights are placed to illuminate both the promenade and the bike path or adjacent seating areas. Lighting should be energy-efficient; the use of solar-powered lights should be explored during the next design phase.

Open Space & Recreational Amenities

While the beach is, of course, the major recreational amenity and the reason most visitors come to the Reservation, many visitors come for the day and are looking for other opportunities to extend the season, to limit sun exposure, to create a more varied experience and to "wait out" the loss of the beach during high tide. The recommendations on the following pages are designed to provide a range of amenities and activities for visitors.

South Area

Recommended changes to the southern portion of the Reservation are designed to "break up" the existing large parking area that extends from the



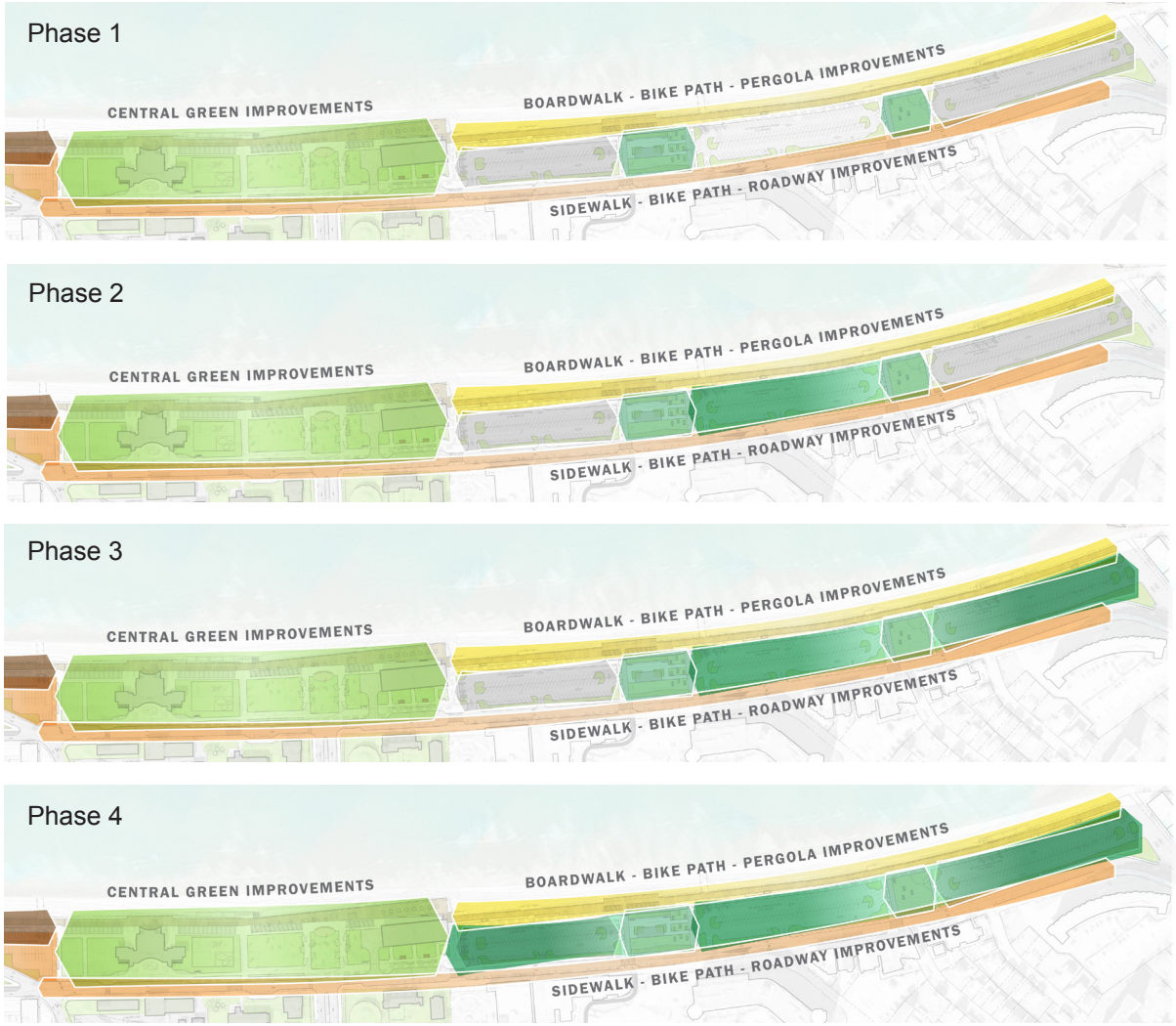
Close-up of the South Area.

Bernie King Pavilion to the southern end of Nantasket Reservation. Two new open spaces will create additional locations for visitors who want to be near the ocean but not necessarily on the beach, as well as provide more attractive views from the retail establishments and restaurants on the west side of Nantasket Avenue. The size of the two parks is dependent upon the need for parking in this location – it is anticipated that the parks will be expanded over time as transit service improves and fewer visitors arrive by car.

The northerly park connects to the wide portion of the boardwalk and is linked via a crosswalk to the pedestrian path leading to the parking lots on George Washington Boulevard. The conceptual design includes picnic tables, a plaza area and bike racks. The Tivoli Bath House is relocated further back from the beach to provide more protection from wave damage. The design of the new bath house should include an analysis of the potential for including solar powered hot water heaters.

The second park connects to the crosswalk at Berkley Road. This park could be designed to resemble an upland beach with a large sandy area and a splash pad play area. Picnic tables are also shown in this park.

Long term, the two southern parking lots could become open space if there is not demand for the

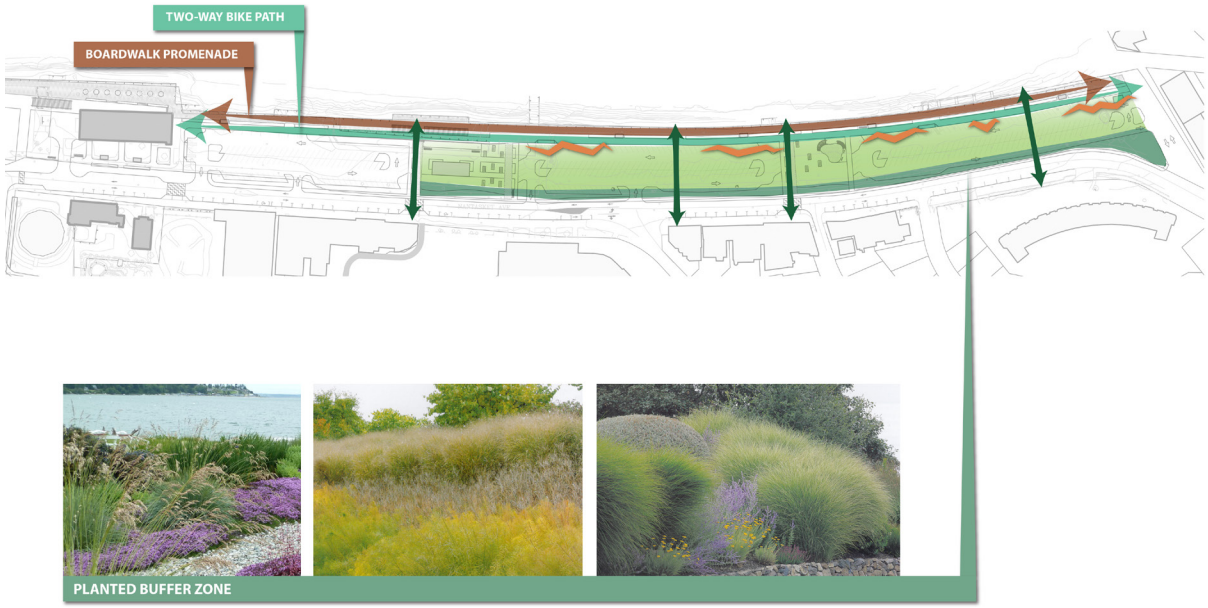


The diagrams above illustrate potential phasing for converting the southern parking lots into parks as parking demand decreases. Phase 1: two small parks with three large parking lots; Phase 2: the central lot becomes a park; Phase 3: the southernmost lost becomes a park; Phase 4: the northernmost lot becomes a park.

Playful windbreak structures.

Elevated beach zone.

Diagrams and photographs illustrate potential design features to be used when and if the southern parking lots are converted to park use. The two-way bike path and boardwalk/promenade would be built prior to any conversion.



Planted buffer zone.

Connections from Nantasket Avenue to the beach.

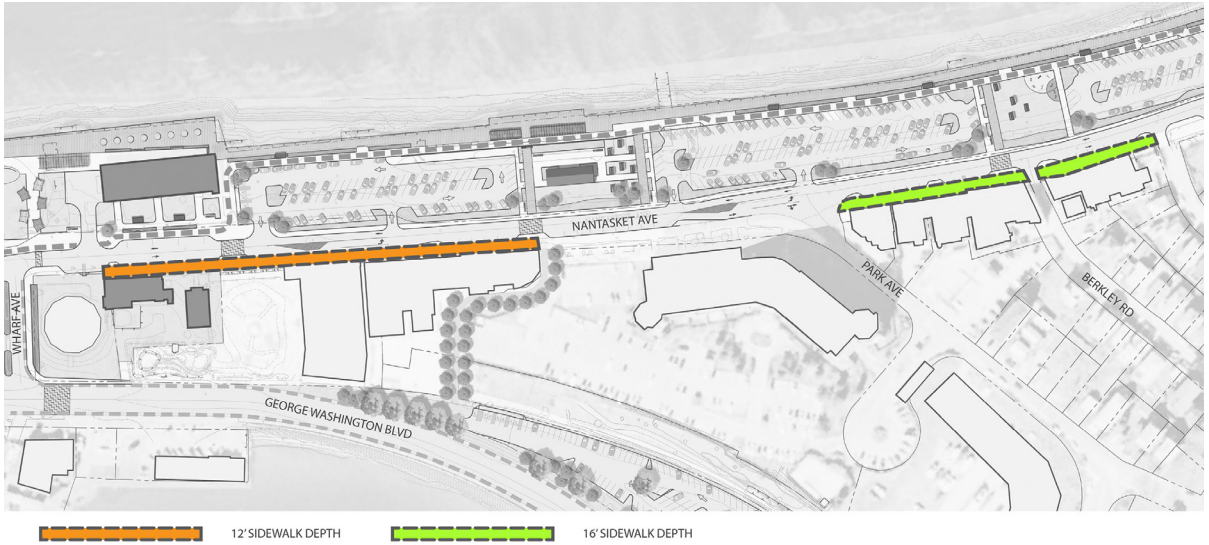
Diagrams and photographs illustrate potential design features to be used when and if the southern parking lots are converted to park use. The two-way bike path and boardwalk/promenade would be built prior to any conversion.

parking. The northern parking lot, shown as parkland in Phase 4, will most likely remain to provide accessible parking for events at the Bernie King Pavilion, the Mary Jeanette Murray Bath House, Nantasket Green, the Carousel and businesses along Nantasket Avenue. DCR should re-evaluate the need for parking on an approximately five-year schedule. The parks should be designed so that they can easily be expanded as parking demand decreases.

At the existing plaza between the south side of the Bernie King Pavilion and the Tivoli Bath House, new shade structures are added.

Accessibility: The promenade in this location will require regrading to eliminate the steep slopes at either end of the plaza.

Many people expressed an interest in accommodating sidewalk cafes in front of restaurants on this section of Nantasket Avenue. The existing sidewalk is 12 feet wide from the Clocktower Building to the southern end of the adjacent commercial strip, and 16 feet wide in front of the commercial strip from Park Avenue south to Atherton Road. Both widths will accommodate outdoor seating. Parking is limited to the southbound (west) side of the street, to provide unobstructed views to the parks and beach.



Top: locations where sidewalk cafes could be accommodated. Left: existing view from sidewalk cafe location. Right: Rendering of potential view from same location, with sidewalk cafe and new small park in the southern parking lot.

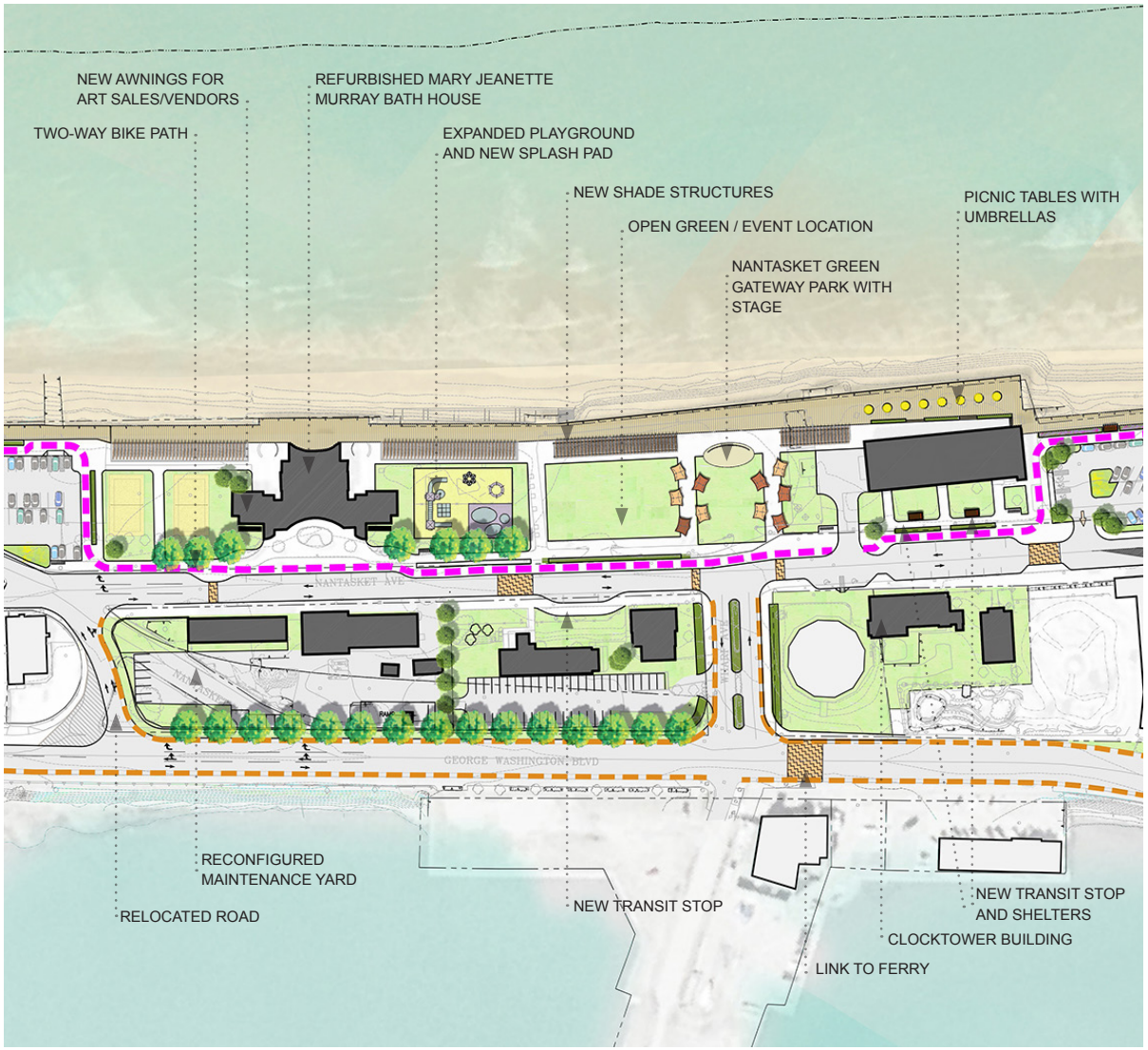
Central Area

The area from the MJM Bath House to the Tivoli Bath House encompasses many of the existing key visitor amenities and gathering spots, including the MJM Bath House, a playground and the Bernie King Pavilion. This area is located close to much of the parking and is very visible for visitors arriving via Wharf Avenue. It also is directly across Nantasket Avenue from the Carousel and Clocktower Buildings, as well as the DCR operations and maintenance yard A number of improvements are recommended for this area.

Nantasket Green

Just to the south of the MJM Bath House and directly across from Wharf Avenue, a key feature will be Nantasket Green, a new gateway that will welcome visitors to the Reservation.

Nantasket Green replaces the existing parking lot and creates an attractive gateway to the Reservation. More importantly, replacing the parking lot with parkland in this location will create a centrally located, continuous open space from just north of the MJM Bath House to south of the Bernie King Pavilion. The space will be able to accommodate a variety of large events such as the 24-hour Cape Relay, arts fairs, the Polar Plunge, Endless Summer, radio station/band broadcasts, car shows, Swim Across America,



Close-up of the Central Area.

triathalons, and kite festivals - some of which take place already but could be accommodated more effectively, and some of which have chosen not to come to Nantasket Beach because of limited space.

Combined with the MJM Bath House, Nantasket Green will be able to host events requiring a mix of indoor and outdoor space. Event participants will be able to use the restrooms at the MJM Bath House, rather than setting up port-a-johns, making this a very desirable location for event planners. The large gathering space may also eliminate the need to close down Nantasket Avenue for large events such as the car show and Endless Summer. Creating a centralized focal point for events will help to attract more events, bringing visitors to local businesses and reflecting the spirit of the original destination Paragon Park.

Nantasket Green also will be able to host smaller, community oriented events such as farmers markets, yoga/tai chi classes, volleyball tournaments, community concerts, and outdoor movies. The event space could provide opportunities for additional community gatherings and more programming partnerships between DCR, the Town and local schools. Clustering the major facilities also helps to simplify operations from a DCR management perspective.

Nantasket Green will serve as a "front yard" for the reuse of the Dormitory Building and Former Police

At left: Examples of community events that could be hosted on Nantucket Green, including outdoor movies, yoga classes and the staging area for the Polar Plunge. Above: larger events such as the Cape Cod Relay could be hosted on the Green without closing Nantasket Avenue.

Existing conditions photo and rendered view of Nantasket Green, with stage and shade structures, from Wharf Avenue.

Station, enhancing the potential reuse of those two buildings. Increased activity in this portion of the Reservation will bring more visitors to the Carousel, helping to support that facility as well as new and existing businesses along Nantasket Avenue. The area will be served by existing parking lots to the north and south, as well as transit stops along Nantasket Avenue.

The conceptual design for Nantasket Green includes a gateway park with a stage that could be used for a variety of performances and events. The structure, as shown in rendering, reflects the shape of the former Paragon Park roller coaster; smaller shade structures provide a sculptural element to the park. A large open lawn will provide space for picnics, Frisbee throwing, etc. and can accommodate a tent for larger gatherings and events. Long shade structures are shown parallel to the boardwalk. Community members liked the idea of open lattice roofs so that the benches are not in full shade. Benches are shown along the sides of the large lawn area.

Bernie King Pavilion

On the ocean side plaza adjacent to the Bernie King Pavilion, new plantings and picnic tables with permanent umbrellas will provide a more attractive and better protected picnic area adjacent to the beach. The design and installation of these umbrellas will need to allow for potential removal during strong storm conditions. The planters and tables will help to better define the picnic area which currently feels somewhat open and desolate. The exact location and size of these planters and tables will be studied during the design phase to avoid interference with those visitors viewing and/or participating in the dances at the pavilion.

A transit stop with shelters is located along Nantasket Avenue in front of the pavilion.

Existing conditions photo and rendering of recommended improvements to plaza behind the Bernie King Pavilion.

Accessibility: The existing promenade is widened at the southwest corner of the Bernie King Pavilion, by the stairs to the beach, to eliminate the pinch point in that location.

Mary Jeanette Murray Bath House

As discussed in Chapter 2, the Mary Jeanette Murray Bath House is underutilized, with the main space being closed for much of the time. While no maintenance repairs are needed at the MJM Bath House, a number of changes were suggested for the near future:

- Hang historical pieces and artwork in the open meeting space to create a more inviting atmosphere.
- Improve acoustics for more inviting meeting space.
- Open the doors and invite the public in during normal operating hours, rather than just during special events.
- Create a station in the open meeting space to sell DCR parking permits during the summer; this will require a phone line for credit card transactions.
- Add windows to the utility rooms in each wing of the building to create office space for the rangers and the lifeguard supervisor.
- Reconfigure the currently empty room in the women's wing with the large door to the outside to be a break room for the lifeguards. The inside door will need to be secured to prevent access to the women's room – lifeguards will be allowed access through the large outer door. The room has a large door that opens directly to the beach and a number of lockers that could be used for storage. This layout will allow the rangers and lifeguards to stay closer to the beachfront to serve visitors.
- Repurpose the Manager's office for storage of materials that are currently located in the utility rooms proposed for other uses (see above).
- Provide awnings along the front of the MJM Bath House for artists/vendors.
- Assess the potential for installing solar powered hot water heaters.

The plan includes expanding the existing playground on the south side of the MJM Bath House to accommodate more children and includes a new splash pad that would be visually attractive and provide a popular play/cooling off spot during high tide. Play structures should be designed for a variety of ages.

From top: Existing views of the Mary Jeanette Murray Bath House and adjacent playground.

Bay Street to Water Street

North of the Mary Jeanette Murray Bath House, between Bay and Water Streets, the narrow width of the Reservation limits facilities to the promenade, buffer strip and bike path.

As part of the ongoing Seawall Stabilization Program, a stone revetment is planned to be constructed between the MJM Bath House and Water Street. Recommendations for this area should not be constructed until after the revetment is in place.

Close-up of the Bay Street to Water Street area.

North Area

Changes at the northern end of the Reservation at Phipps Street are designed to make this area more attractive and user-friendly. Currently, amenities and opportunities for purchasing food and drink are very limited at this end of the Reservation.

It is recommended that Manomet Avenue, which separates the beach from adjacent Reservation property, be closed to create a larger area contiguous to the boardwalk. The expanded area includes a new playground as well as a vendor pavilion for selling food, beverages and other beach items, or for bicycle rental. A right-turn only lane for drivers turning from Hull Shore Drive onto Phipps Street would help to prevent Hull residents heading north from being impacted by beach traffic turning left onto Phipps Street to head back south.

A portion of the revetment needs to be rehabilitated in this area. It is recommended that the David Cook Comfort Station be relocated to the land side of the boardwalk to allow for dune reclamation, and that this area serve as an early pilot project for the beach nourishment program. As with the Tivoli Bath House, the use of solar powered hot water heaters should be evaluated.

Close-up of the North Area.

It is recommended that the David Cook Comfort Station be relocated to the landside of the boardwalk.

An accessible route down to the beach and a ramp to accommodate both DCR and Town-owned beach maintenance vehicles will need to be built in this location.

Landscaping & Green Space

A key concern expressed during this project was the overall lack of green space throughout the Reservation. In addition to the landscape buffer and new open spaces described in this chapter, recommendations include:

- Planting a row of trees along George Washington Boulevard to help screen the Operation and Maintenance area.
- Adding landscaping to parking lots.
- Enhancing plantings at entry points, such as along Wharf Avenue.

It has been DCR's experience at Nantasket Beach that the harsh beachfront environment makes it difficult for trees to flourish. With the exception of the trees noted above, it is recommended that landscaping include primarily shorter, hardy plants that can withstand the strong winds and sea spray.

Operation & Maintenance Area

Recommendations for the Operation and Maintenance area are described in detail in Chapter 4.

Vehicular & Pedestrian Access & Circulation

Pedestrian Access

Pedestrian access to and through the Reservation is provided via the sidewalks and promenade described above. Buffer planting will provide a more attractive pedestrian environment. Twenty six crosswalks provide access to the beach. The plan includes the introduction of bump-outs at a number of the crosswalk locations to shorten the crossing. It is recommended that temporary raised crosswalks be used to slow traffic during the summer. The temporary raised crosswalks can be removed between the fall and spring to provide good traffic flow and to avoid conflicts with snow plows.

Recommendations for push-button activated flashing beacons and warning signs are discussed in Chapter 4.

A wide crosswalk on George Washington Boulevard (outside of the Reservation) will provide a safe pedestrian crossing, should ferry service to the Town Pier be established.

Bicycles

Nantasket Beach is popular with cyclists and this master plan greatly improves cycling amenities. As shown on the plan on pages 30 and 31, and the sections on pages 32 through 36, a two-way 12-foot wide bike path runs the entire length of the Reservation. For most of that length, it is at the same height as the boardwalk and sited to allow cyclists to ride close to the beach, separated from the boardwalk/promenade by the planted buffer strip. The 12-foot width provides adequate width for a curb/bumper between the bike path and on-street parking. The bike path moves to the street in front of the MJM Bath House

and the Bernie King Pavilion, where beach side access is limited by the buildings. The bike path will connect with the Town's proposed bike lanes at either end of the Reservation, and with the George Washington Boulevard bike lane at Wharf Avenue.

The bike path is designed to provide a protected and attractive beach side route for families and other recreational riders. It is likely that some cyclists, particularly commuters and others traveling long distances, will continue to ride in the street.

Bicycle racks are provided throughout the Reservation and vendor pavilions near the north and south ends could be designed to accommodate bicycle rentals.

Transit

The plan is designed to accommodate transit access to the Reservation, and it is recommended that DCR work with the MBTA to coordinate ferry, train and bus schedules to allow for easy transfers between modes. It is also recommended that a consolidated schedule be developed each summer so that potential visitors can easily plan a transit route to and from the Reservation.

Recommended transit-related improvements include:

- On Nantasket Avenue, new pull-outs are provided for buses and trolleys in front of the Bernie King Pavilion (on the northbound side) and the Dormitory Building (on the southbound side), in addition to the existing pull-out in front of the MJM Bath House. Covered waiting areas have been included in front of the Bernie King Pavilion.
- Parking at the George Washington Boulevard lot (Lot G) has been reconfigured to accommodate 10 buses (see plan on pages 34 and 37).
- A wide crosswalk has been added on George Washington Boulevard near Wharf Avenue (outside of the Reservation) to provide a safe pedestrian crossing should ferry service to the Town Pier be established, as stated above.

As the north and south areas of the beach become popular destinations and transit use increases, on-street parking spaces can easily be converted to transit stops.

Parking

While much attention has been paid to bicycle, pedestrian and transit access, it is likely that the majority of visitors will continue to arrive by car for a number of years. The following recommendations are intended to improve the efficiency of parking operations:

- **Installation of an intelligent parking system utilizing Variable Message Signs.** The system should count entering and exiting vehicles from each DCR lot and report the "Percentage Full" to each message board. Message board displays should feature a map of the Reservation as well as Lot designations and the number of available spaces or, if the lot is full, the word "CLOSED". If placed at each major entrance roadway these signs will allow patrons to proceed directly to a lot with capacity and avoid circling which will in turn alleviate traffic delays within the immediate region. Particularly important will be the addition of a sign just south of the entrance to the George Washington Boulevard lots (Lots G and H). Drawing visitors into those lots will reduce traffic on Nantasket Avenue and Hull Shore Drive. Similarly, a sign on Route 228/Nantasket Avenue, south of Rockland Road, will direct drivers to open lots and keep them off of Nantasket Avenue when the lots there are full. A sign in this location will be more difficult to implement because it will not be on DCR property. Signage indicating the letter designation of each lot also should be installed.
- **Introduction of an on-line and/or radio broadcast service to provide real-time parking information.** The system would allow potential

visitors to check on parking availability prior to beginning their trip or while enroute. Information provided should include updates on current parking availability and, when parking is at capacity, when parking is likely to be available. On days when parking demand exceeds capacity (see the discussion below) it is only for a portion of the day and is dependent on time of day, weather, and the timing of high tide.

- **Introduction of a "Park and Pay" system, in which drivers park their cars and purchase a ticket from a vending machine to place on their windshield.** This type of system will eliminate queuing to get into the parking lots and will eliminate or reduce the need for parking attendants.

As discussed earlier, the new park areas adjacent to the southern lots on Nantasket Avenue could be expanded over time as the demand for parking decreases. Currently, income from parking is used to support ongoing maintenance and operations for the Reservation. If parking revenues are reduced as a result of a decrease in the number of spaces, the lost revenue will need to be made up through another revenue source.

During the summer of 2015, DCR and Louis Berger conducted a parking study to determine the feasibility of reducing the number of parking spaces at Nantasket Beach in the immediate future and to provide goals to determine the number of spaces that could be removed in years to come as travel patterns and private vehicle usage patterns change. Daily data were collected from June 15 through September 7, and a site visit was conducted by the Louis Berger team on Saturday, July 11 to observe parking operations. The day was a prime summer beach day - 90°F and sunny, low tide at 1:00, and the Reservation was hosting an event, allowing the team to witness operations on a very high parking demand day.

The following observations were recorded during the summer, both by DCR staff and during the Louis Berger site visit (see following page for lot locations):

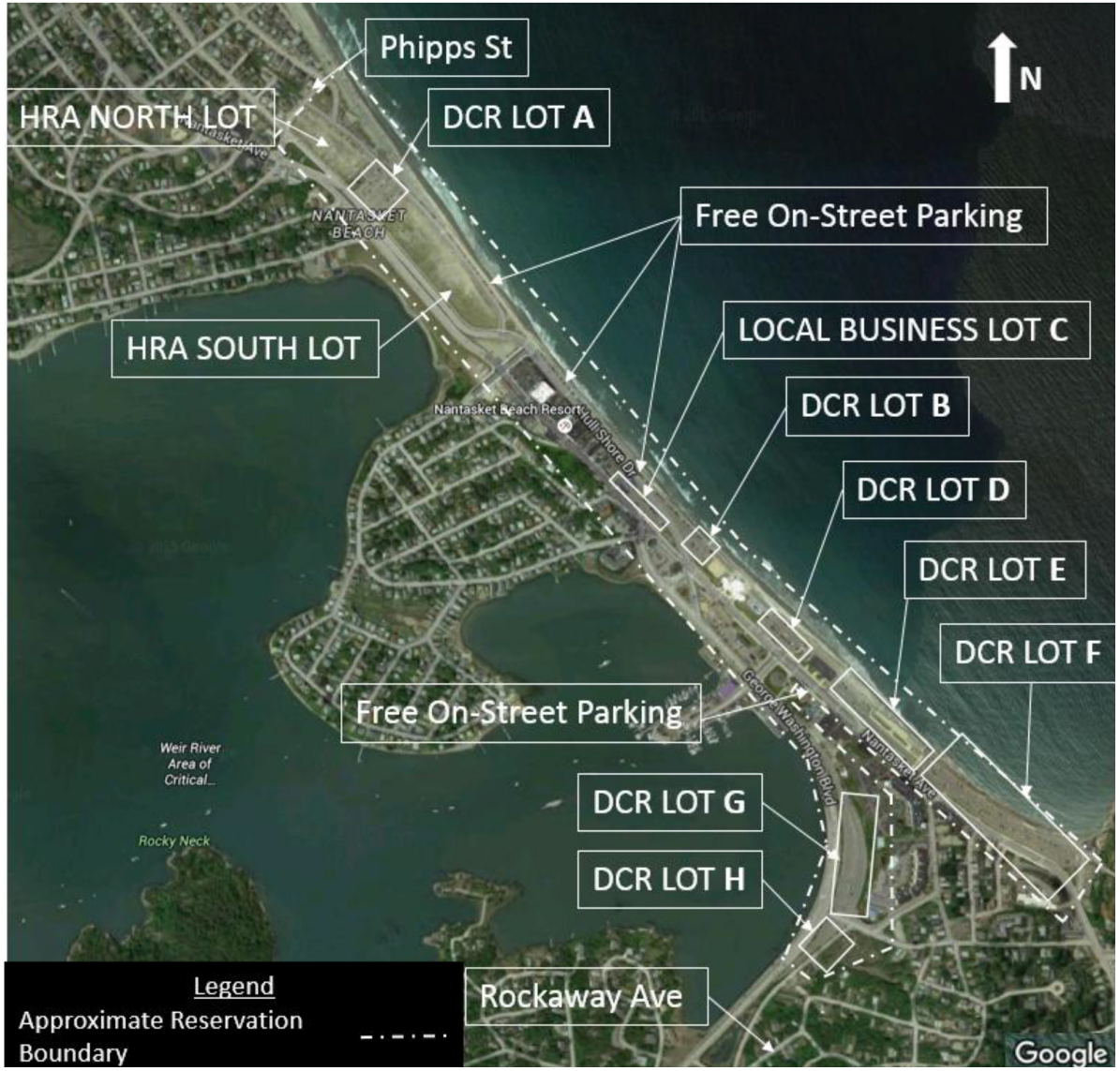
- Existing parking includes 1,003 spaces in DCR lots, 200 on-street spaces and 900 spaces in Hull Redevelopment Authority lots (2,103 total)
- Lot C is utilized by the nearby businesses and parking there is free. It was generally at capacity throughout "Beach Days" (defined as sunny and over 70°F, or humid and/or overcast and over 80°F) and turnover was high due to the enforced two-hour limit.
- On-street parking is free and was generally at capacity throughout Beach Days.
- Lots B and D are centrally located. These lots were the first of the staffed DCR lots to reach capacity. The combined 147 spaces at these two lots reached capacity by 9 AM on Beach Days. The lots generally started to have open spaces around mid-afternoon
- Lot A is located in the northern part of the Reservation. The beach is wider at high tide in this location than it is to the south, which is attractive to beachgoers. Lot A has 122 spaces and generally reached capacity by 10 AM on Beach Days. The lot also generally started to have open spaces around mid-afternoon.
- Lot E/F contains the majority of the DCR capacity with 428 spaces. This lot generally reached capacity around noon on Beach Days and started to have open spaces again by mid-afternoon.
- Lots G and H are removed from the beachfront and considered by patrons to be the least desirable of the DCR lots. A "Pay and Display" machine allows for these lots to be unstaffed a majority of the time. Data from these lots is limited but records show that they reached capacity on at least five summer days. Lots G and H have a combined 251 spaces.
- The HRA lots in the northern region of the Reservation add 900 spaces of capacity for Nantasket Beach patrons. The fee for parking at these

lots is variable and dependent on demand. Generally, these lots reached capacity at the same time of day as Lot E/F on Beach Days.

- The demand met or exceeded capacity at some point in the day during 19 of the 85 summer days studied, or 22 percent of the summer. By considering only days that met the "Beach Day" conditions during any time of the week, the percentage of days during which the demand met or exceeded capacity increased to 37 percent. By considering only Beach Days on weekends, the percentage of days when demand met or exceeded capacity at some point during the day was 62 percent of the days.

The master plan includes reconfiguring a number of the DCR lots to accommodate the boardwalk, bike path and landscape buffer, as well as to provide more efficient layouts. Landscaping has been added to most of the parking lots. Parking locations and counts are indicated on the drawing on pages 34 and 35 and in Table 2. Location-specific changes include the following:

- George Washington Boulevard lot north of Rockland Circle (Lot G): The skating rink has been removed and the lot is reconfigured to accommodate bus parking. DCR should continue to negotiate with the private property



Existing parking lot locations.

owner to allow completion of the pedestrian path adjacent to the north edge of the Horizons Condominiums parking lot. This path will provide a direct link from the DCR parking lots to the beach, which will increase the attractiveness of these underutilized lots. This parking lot is designed to accommodate covered parking with solar panels that can be used to supply power to the Reservation. The cover also will shade parked vehicles, increasing the desirability of the parking lot. The layout shown for this lot is similar to the one developed by the Town's consultant Nelson\Nygaard Consulting Associates. However, the layout shown in this master plan was designed to accommodate parking for ten buses, as well as internal bus circulation. Providing adequate lane width and area for cars and buses to turn around eliminates a row of cars at the northern end of the lot and two rows of cars in the central portion of the lot, reducing the number of parking spaces from the 360 shown in the Nelson/Nygaard plan to 286.

- George Washington Boulevard lot south of Rockland Circle (Lot H): The lot will continue to be used for overflow parking on busy days.
- South of the Bernie King Pavilion (Lots E and F): The lots have been reconfigured as three separate lots, as described earlier on page 38.

Location	Existing Spaces	Future Spaces (including Accessible Spaces)
Parking Lots		
Lots E & F: Nantasket Ave., south of Tivoli Bath House to Bernie King Pavilion	428	402
Lot D: Nantasket Ave., Bernie King Pavilion to MJM Bath House	81	0 (open space)
Lot C: Between Nantasket Ave. and Hull Shore Drive, south of Red Parrot Restaurant	55	55
Lot B: Nantasket Ave., North of MJM Bath House	66	57
Lot A: Between Hull Shore Drive and Nantasket Ave., south of Quincy Street	122	169
Subtotal Parking Lots	*752*	*683*
Remote Lots		
Lot G: George Washington Boulevard, north of Rockland Circle	193	256 (includes 10 bus spaces)
Lot H: George Washington Boulevard, south of Rockland Circle	58	58
Subtotal Remote Lots	*251*	*314*
On-Street Parking Areas		
Area 1: Nantasket Avenue south of Bernie King Pavilion	66	55
Area 2: Hull Shore Drive south of Water Street	89	51
Area 3: Hull Shore Drive extension	50	74
Subtotal Parking Areas	*205*	*180*
TOTAL	**1,208**	**1,177**

Table 2: Existing and future parking availability (see plan on pages 34 and 35 for parking locations).

** Number of spaces may change due to ongoing streetscape improvements by Town of Hull.*

Example of covered parking lot with solar panels.

One or more of these lots could be converted to open space over time as the demand for parking declines.

- South of the MJM Bath House (Lot D): The lot is eliminated to accommodate the Nantasket Green open space.
- North of the MJM Bath House (Lot B): The lot is reconfigured to accommodate roadway changes and additional landscaping.

On-street parking is also modified, as shown on Table 2. In particular, parking on Hull Shore Drive Extension has been changed from angled to parallel parking to allow sufficient width for a bike path.

These changes result in a total of 2,022 spaces (942 spaces in DCR lots, 180 on-street spaces and 900 spaces in the HRA owned lots).

Using the summer 2015 demand and assuming that Lot H will be staffed on Beach Days, the impact of this change will result in no additional days per summer when demand will be greater than capacity.

The Town of Hull is currently soliciting bids to develop both HRA lots. Development of the lots will result in a net decrease of 900 spaces. If this change had been implemented during the summer of 2015, demand would have exceeded capacity during an additional 17 summer days, nearly doubling the percentage of days with such exceedance from 22 percent to 42 percent. In addition to increasing the number of days when demand exceeds capacity, the loss of the HRA lots will also substantially increase the demand in comparison to capacity. For instance, on a day during the summer of 2015 when the DCR lots were at 100 percent capacity it was assumed that the HRA lots were also completely full. If this same situation were to occur once the HRA lots were removed, the result will be 900 additional vehicles circling the Reservation in need of a parking space.

The DCR mission statement reads, in part, that "The health and happiness of people across Massachusetts depend on the accessibility and quality of our green infrastructure - our natural resources, recreational facilities, and great historic landscapes." Removing parking capacity prior to reducing private vehicle demand will directly contradict this statement by limiting accessibility. Additionally, excess demand creates traffic congestion and corresponding vehicle emissions on the Reservation. Thus, milestones should be considered to balance available parking capacity as demand changes, without limiting the number of beachgoers. Potential changes to demand will result from changes in the modes of transportation beachgoers use to access the Reservation - away from private vehicles and towards mass transit, bicycles, and ferries. These changes require shifts in both the public mindset and in the attractiveness of transit options, both of which will take time to develop. Trends should be monitored and recorded annually to understand the percentage of demand versus capacity on Beach Days.

It is recommended that the Town of Hull and DCR consider and discuss additional decreases in parking capacity once the following milestones are met during a summer time period:

1. Demand exceeds capacity during fewer than 25 percent of Beach Days during any day of the week (one in every four Beach Days a patron will be turned away until spaces become available), or
2. Demand exceeds capacity during fewer than 50 percent of Beach Day weekend days (one

in every two weekend Beach Days a patron will be turned away until space becomes available). Ideally, the transportation programs implemented will work well and this number could be lowered over time to 25 percent.

These milestones may be modified as additional traffic and parking data and information become available from further monitoring and analysis.

Traffic Circulation

Changes in traffic circulation related to the realignment of the George Washington Boulevard/Nantasket Avenue intersection are described in Chapter 4.

Year-Round Operation

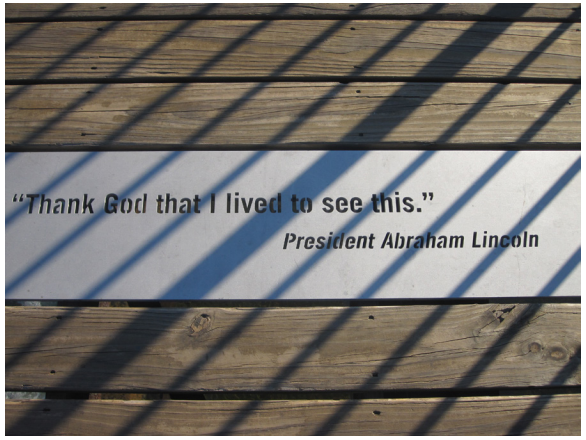
The busiest time of year at Nantasket Beach Reservation is between Memorial Day and Labor Day when warm weather draws a lot of beachgoers. However, the Reservation also is utilized during the other nine months of the year by visitors walking along the beach and enjoying the view. Improvements proposed in the master plan are designed to benefit visitors during all seasons through the introduction of more upland areas and opportunities for larger events on Nantasket Green. The improved promenade and the new bike path can be used year-round. Potential new uses discussed for the Dormitory, Clocktower and Police Station Buildings, as well as interpretive exhibits in the Mary Jeanette Murray Bath House, are designed to encourage year-round activity. The use of hardy plants and sturdy weather-proof materials will enhance the year-round use of the Reservation.

Wind breaks proposed for the parks south of the Bernie King Pavilion will help to protect visitors from ocean spray during cooler weather.

Interpretive Opportunities

Interpretive opportunities at Nantasket Reservation include both historic and natural resources. Key elements could include the former Paragon Park, former uses of the buildings within the operations and maintenance facility, as well as an explanation of the evolution of the beachfront from a natural seashore to a constructed seawall. The former Police Station, Clocktower Building and MJM Bath House all provide opportunities for displaying historic photos and artifacts.

Potential outdoor interpretive signage locations include the plaza behind the Bernie King Pavilion, the new parks between the southern parking lots on Nantasket Avenue and the new park at the northern end of the Reservation. The northern end, in particular, will provide a prime location for explaining sand dunes and natural wave action.



Examples of interpretive elements inserted in boardwalks and embedded in pavement.

At left and above: Examples of interpretive elements attached to railings and low walls, and free standing.

Above: Examples of interpretive elements attached to indoor building walls and within shade shelters; typical DCR wayfinding signage.

Wayfinding & Signage

A wayfinding and signage program will help visitors to navigate the Reservation and the important destinations scattered throughout. Maps in key locations, including arrival spots such as parking lots and transit stops, will better enable visitors to plan their visit. Signage should clearly identify bath houses, picnic areas, vendor pavilions and the Carousel. Signage should also identify the location for pass sales.

Phasing

It is anticipated that full implementation of the master plan recommendations, including beach nourishment, could take more than 20 years. However, as shown on Table 3, it is recommended that much of the design work take place during the next three years, with construction of many of the visitor amenities taking place in Years three to five.

The schedule is laid out to ensure that the design and construction of related and/or adjacent elements can happen in a coordinated and cost-effective manner, and that design and construction packages have realistic budgets based on potential DCR funding availability.

Year	Activity	Description
1-3	Design	Nantasket Green Boardwalk, shade structures, planting buffer, lighting Seating area behind Bernie King Pavilion Open Space and expanded playgrounds Bike lane Relocated bath houses (Cook and Tivoli) Vendor pavilions Nantasket Avenue Transit stops Parking lots
	Design & Construct	Parking signage program Bike lane striping on Wharf Avenue Seawall stabilization north of Mary Jeanette Murray Bath House Early improvements to operations/maintenance area and MJM Bath House Renovations to Upper Garage, Dormitory and Police Buildings
	Other	Continue monitoring parking demand Work with transit agencies to improve service & route timing
3-5	Design & Construct	Pedestrian link from George Washington Blvd. to Nantasket Avenue Continue improvements to operations/maintenance area Renovate/remodel MJM Bath House and Clocktower Building Traffic alternative and expanded operation and maintenance area
	Construct	Nantasket Green Expanded playground at MJM Bath House South, Central & Water Street Areas, including boardwalk, shade structures, planting buffer, lighting, bike path Relocated Tivoli Bath House

Table 3: Phasing Schedule

Year	Activity	Description
5-10+	Construct	North of Water Street area, including boardwalk, shade structures, planting buffer, lighting, bike path Relocated Cook Comfort Station Vendor pavilion Nantasket Avenue and remote parking lot improvements Southern parking lot and 2 parks Beach Park 1
	Design & Construct	Beach Parks 2 and 3 Beach renourishment

Table 3: Phasing Schedule (continued)

APPENDIX: SUMMARY OF COMMENTS

A draft plan was presented at a Public Meeting on September 22, 2014. The list below summarizes a number of issues raised during and after the meeting, and the way in which the current master plan responds to those issues:

- "The southern parking lot occupies too much land": Two new parks have been added, with the possibility of 3 additional parks if parking demand decreases over time.
- "Nantasket Green was not designed to be flexible and interesting": The Green was redesigned with flexible open areas as well a performance space and additional shade structures. The water feature was eliminated.
- "The closing of Manomet Ave. will have a negative impact on traffic flow going north": A new right turn lane was added to the intersection of Hull Shore Drive and Phipps Avenue to improve traffic flow.
- "Reuse of historic buildings": DCR open to variety of uses, acknowledging the need for additional financial resources for maintenance
- "The conversion of the parking lot to Nantasket Green would negatively impact the Paragon Carousel": DCR representatives met with the Friends of the Carousel and they are supportive of Nantasket Green.
- "Amenities for use during high tide and the 'shoulder season' should be expanded": Parks and other amenities have been added.
- "Vendor areas along the boardwalk would compete with local businesses": Vendor areas were changed to artist areas to support the local arts community.

The current plan was presented at a Public Meeting on January 27, 2016. The table on the following page summarizes the comments received following that meeting.

Name	Comments
Patricia Abate, President Hull-Nantasket Chamber of Commerce	The Board of Directors of the Chamber of Commerce is pleased with the plan and likes the idea of allowing sidewalk café space. All parts of the plan calling for activities and areas that encourage visitors to lengthen their stay at the beach are most welcomed. Would like to see the Reservation embrace and integrate the business community.
Joann Capone	Supports this beautiful Master Plan that will create a public place of seaside enjoyment and whatever else DCR is doing to protect this beautiful state property and keep it open to the public.
Marie Schlieff, President, Friends of the Paragon Carousel	Board of Directors applauds the efforts of the DCR and feels the planners have offered excellent ideas for much needed improvements to the historic beachfront. The Paragon Carousel and Clocktower Building must be an integral piece of the Master Plan.
Paul Hiltz	Does not want: to replace parking lot with Nantasket Green; to expand the playground; to add the umbrellas or planters at Bernie King Pavilion, lighting, parallel parking, or a separate bike lane.
Marianne Buckley Curran	The ideas for revamping and extending green space is on the right track. The plan is well rounded, pulling in natural resources, beautiful scenery, access for walking and biking, circuit training, active playground. Removing parking is a plus. Concerned with funding and commitment to follow through on plans.
Sheila Connor	Would like to see the proposed amenities ASAP. Should have pick-up/drop-off spaces along Nantasket Avenue to encourage use of remote lots or a shuttle. Work with MBTA to use their parking lot and institute a shuttle.
Martha Walsh	Consider parking needs for handicapped with access to the ramp near the bathhouse. Walking on sand and swimming in the sea should be the priority.
Paul Hiltz	Do not replace the parking lot with Nantasket Green. The promenade at the Bernie King Pavilion needs improvement, but lights and umbrellas are impractical. Should just add tables and benches.
Andrea White	Hopes that improvements to the bath houses include heated showers.
Michael Fleming	Is extremely pleased with the concept and would love it to move forward. Would like to see a trolley from Pemberton Point.
Jerry Seelen	Is concerned that improvements to the Reservation will exacerbate the parking scarcity. Existing lots could be reconfigured to increase efficiency.
Jennifer Fleming, Hull resident	This is a terrific plan that will capitalize on Hull's natural attributes for the good of the area and community.

Above and following page: Summary of comments received following January 27, 2016 Public Meeting.

Name	Comments
Philip Lemnios, Town Manager on behalf of Hull Board of Selectmen	The following elements are improvements: expanded boardwalk, bike lane, shade structures, pedestrian path to parking lots, improved transit stops, relocated comfort stations, sidewalk cafes. Agrees with converting parking abutting the beach to active recreational land, but is concerned with having adequate parking for commercial interests. Prefers 2-way road system and parking layout as proposed in town sponsored Nelson/Nygaard Study. Encourages the expansion of transit options, including a trolley to the remote parking lots, and introduction of ferry service. Is concerned with loss of parking to create Nantasket Green. Likes the introduction of artist spaces rather than vendor areas. Opposes the continued use and expansion of the Maintenance Facility in its current location. The plan should ensure that the Clocktower building continues to support the Carousel. The plan should include beach nourishment as early as possible. The Town and DCR should acknowledge that the successes of both parties are interdependent and continue to work together on improvements.
Robert Fultz, Director Hull Community Development and Planning Department	The Town and DCR should work together on a plan for conversion of parking into parkland and to initiate outdoor seating on Nantasket Avenue. DCR's first priority should be to enhance the Reservation's ability to provide recreation and storm and flood protection, and act on beach nourishment and other wetland restoration opportunities. Does not support phasing of the revetment in years 0-2, with other amenities not added until years 3-5; the enlarged maintenance area; Nantasket Green. Master Plan should incorporate Resiliency by Design principles. 75% of the south parking lot should be converted to recreation area. The maintenance area should be relocated to the remote parking lot, allowing the Town to reuse the existing maintenance site. Should support the Paragon Carousel by investing in the Clocktower Building. Supports sidewalk cafes, artist spaces, wayfinding and signage, boardwalk, bike lanes, crosswalks, sidewalks, shade structures, variable message signs, remote parking lot covered with solar panels. Wants to institute the 2-way road system and parking layout studied by Nelson/Nygaard and TEC, and expand transit options, including a trolley and ferry..
Jennifer Constable, Chairwoman Hull Planning Board	Board endorses goals to "provide an enhanced natural and recreational experience" and proposed boardwalk, bike lane, shade structures, sidewalk and crosswalk improvements and pedestrian link. Would like to see design and demonstration of the Resiliency by Design Concept "more park less parking" on the front beach; beach nourishment moved to an early implementation phase, utilization of Reservation properties for their "highest recreational and sustainable economic development values"; multi modal transportation and reconfiguration of parking.
Hull Conservation Department	Supports the Town's proposals for beach nourishment and a park in the south parking lots, not a revetment. The conversion of the south parking lot to park should be implemented earlier. Supports the landward relocation of the bathhouses; the north area should include space for a dune landward of its current location and there should be no ramp in this location.
Town of Hull Beach Management Committee	Does not support the revetment; prefers beach nourishment and/or moving the seawall landward. Important for DCR to work with Town at all stages of development. Should replace parking south of MJM with green space and build parking garage behind Horizons. Supports sidewalk cafes, bike paths and improved transportation options. There should be no free parking or changes to the Clocktower. DCR operations facility should be relocated to remote lot. Does not support current road reconfiguration plan.
Chris Lofgren, resident and member of the Paragon Carousel Board of Directors	Supports the Plan. The concepts presented represent improvements to the function and vitality of the Reservation and the loss of parking spaces is not a concern.
Priscilla Beadle, Past President, Hull Artists	Strongly urges introducing the amenities to the boardwalk as soon as possible and supports the artist space.
Jordan Trundy	Is thrilled with the plan and feels that the majority of comments seen through social media have been very positive and supportive.

Summary of comments received following January 27, 2016 Public Meeting (continued).

Appendix I

Relevant Past Agency Communication

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Office
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

June 26, 1996

Mr Joseph Ignazio, Chief
Planning Directorate
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

ATTN: Evaluation Division

Dear Mr. Ignazio:

This letter constitutes our response to the Nantasket Beach Coastal Storm Damage Reduction Project, Hull, Massachusetts. The investigation examines the feasibility of reducing coastal storm damage for the Metropolitan District Commission's Nantasket Beach Reservation. The following comments are provided in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661, et seq.) and constitute our Fish and Wildlife Coordination Act Report on the project.

Natural Resources of Project Area

The study area included in this feasibility investigation is approximately 6,700 feet long. The beach is composed mostly of brown/grey-colored sand with some cobble. There is little sand in the backshore area and the upper beach is unstable and inundated during most high tides. At low tide, the beach is approximately 400-600 feet wide.

No vegetation is established on Nantasket Beach from the subtidal zone to the seawall. The combination of the shifting sand substrate, tidal fluctuations and wave action do not provide suitable habitat for aquatic vegetation to become established.

A benthic invertebrate survey was conducted on May 10, 1996 for the Corps at Nantasket Beach. No species were found in high numbers along the five transects. At high tide, the most abundant species was the amphipod Haustorius canadensis; at mid-tide, Amphiporeia virginiana and Parahaustorius longimerus were predominant; and at low tide, Paraonis fulgens and Amphiporeia virginiana were the most abundant species.

There are no known eelgrass (Zostera marina) beds located off Nantasket Beach (personal communication, G. Mannesto and C. Costello). Lobster (Homarus americanus) and surf clams (Spisula solidissima) are located offshore in Massachusetts Bay. Surf clams are found below extreme low tide.

Wildlife resources in the project vicinity are predominately birds in the shorebird and waterbird groups. The beach and nearby waters have the potential to support migrating and wintering populations of waterfowl, shorebirds, and seabirds. The area is a potential migratory stopover site for the federally-threatened piping plover (Charadrius melodus). The beach receives high levels of recreational use, which diminishes its value as shorebird habitat during the summer period.

Storm Damage Reduction Alternatives

The following discussion describes the potential impacts of the alternatives proposed by the Corps:

The Offshore Breakwater Alternative consists of a 7,000-foot-long rubble-mound breakwater placed 900 feet offshore with a crest elevation of either 10 or 11 feet (NGVD). This alternative would permanently displace subtidal habitat. The high energy of the waves would be dissipated by the breakwater, and this might provide suitable habitat for eelgrass to grow behind the breakwater. The establishment of eelgrass would improve the fish and shellfish habitat of the project area. However, the wave energy deflected by the breakwater has the potential to increase coastal storm damage at other locations on the beach.

The Revetment Alternative involves constructing a 6,700-foot-long revetment along Nantasket Beach. This alternative would cause short-term impacts to the beach system during construction. A long-term monitoring study would be needed to determine its impact on the beach system.

The Seawall Reinforcement Alternative involves reinforcing the existing 5,400-foot-long seawall by providing toe protection, thereby preventing the collapse of the seawall. This alternative would cause short-term impacts to the beach system during construction. A long-term monitoring study would be needed to determine its impact on the beach system.

The Sandfill Nourishment Alternative consists of placing approximately 310,000 to 435,000 cubic yards of sand seaward of the seawall. This would protect the toe of the seawall and cause the storm waves to break farther offshore. Periodic nourishment would be required. Although the placement of the sand would kill invertebrates unable to move, this alternative would have only temporary and minor impact on wildlife. This alternative could have larger negative impacts on the intertidal and nearshore zones because of increased sedimentation. To reduce impacts, the deposited sand should be of a larger grain size than sand currently on the beach. This would reduce offshore drift and turbidity. All the material should be placed

well above the high tide line in order to minimize the amount of material which may drift into the bay and cover invertebrates and shellfish beds, as has happened in some past beach nourishment projects. There should be contingency plans for keeping the sand on the beach. The new beach areas should be planted with beach grass and crisscrossed with snow fencing to improve stabilization. If offshore sources of sand are used, additional studies are needed to determine the impacts of dredging. We recommend that our agencies cooperatively develop a beach nourishment management plan.

The Nonstructural Alternatives reduce the vulnerability of private and public properties to flooding, but do not reduce the flooding itself. The two alternatives consist of moving vulnerable properties from flooded areas and raising and/or floodproofing structures. These alternatives would have only minor short-term impacts on wildlife resources during construction and would not impact the beach or intertidal zones.

Endangered Species

Based on information currently available to us, no federally-listed or proposed threatened and endangered species under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area, with the exception of occasional transient endangered bald eagles (Haliaeetus leucocephalus), peregrine falcons (Falco peregrinus anatum), or piping plovers (Charadrius melodus). However, we suggest that you contact Pat Huckery of the Massachusetts Natural Heritage Program, Division of Fisheries and Wildlife, 100 Cambridge St., Boston MA 02202, (508)792-7270 for information on state-listed species that may be present.

Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act is not required. Should project plans change, or additional information on listed or proposed species becomes available, this determination may be reconsidered.

Conclusions

We recommend that the Corps avoid alternatives involving structural changes to the beach system because the beach ecosystem is dynamic and structural changes frequently cause negative impacts to areas located outside the project. We recommend nonstructural alternatives be used to reduce coastal storm damage. If beach nourishment is proposed, we recommend that the sand come from an existing extraction site or a previously-filled area such as the I-95 embankment in Revere. This project should include an extensive long-term monitoring plan for whatever alternative is implemented.

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We appreciate the opportunity to provide these comments. If you have any questions concerning this letter, please contact Greg Mannesto of our Rhode Island office at (401) 364-9124.

Sincerely yours,

for Michael J. Bartlett
Supervisor
New England Field Office

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930

DEC 21 1995

Joseph L. Ignazio, Director
Planning Division
New England Division, Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

This is in response to your letter of November 22, 1995 requesting information on endangered and threatened species on Nantasket Beach in Hull, MA. There are no threatened or endangered species under NMFS jurisdiction present on Nantasket Beach. Therefore, no further consultation pursuant to Section 7 of the Endangered Species Act of 1973 is necessary. However, should project plans change or new information become available that changes the basis for this determination, then consultation should be reinitiated.

Sincerely,

Laurie Allen Silva
Protected Species