Hurricane and Coastal Storm Damage Reduction Report
Feasibility Report and
Environmental Assessment
Draft

Brant Rock and Fieldston Areas Marshfield, Massachusetts

US ARMY CORPS
OF ENGINEERS
New England District

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EXECUTIVE SUMMARY

This Feasibility Report and Environmental Assessment for the Brant Rock and Fieldston areas of Marshfield, Massachusetts was prepared under Section 103 of the Continuing Authorities Program (River and Harbor Act of 1962, as amended). The program authorizes the Corps of Engineers to participate in the cost of investigations and projects for reducing coastal storm damages. This report was prepared in response to a request from the Town of Marshfield to investigate the flooding and erosion problems along the shorefront of Brant Rock and Fieldston and to present feasible solutions to those problems. This report is the product of detailed investigations conducted by the New England District of the Corps of Engineers in cooperation with the Town of Marshfield and other state and Federal agencies.

The study area encompasses the shorefront and backshore areas of Brant Rock and Fieldston in Marshfield, Massachusetts. The town of Marshfield is located in Plymouth County, Massachusetts, along the southern shore of Massachusetts Bay, about 13 miles north of Plymouth Harbor. Marshfield is located about where Cape Cod Bay meets Massachusetts Bay. Marshfield's 5-mile-long public seashore comprises nine villages. Two shorefront villages are being investigated by this study, Fieldston and Brant Rock. Both Fieldston and the Brant Rock comprise 1/2 mile of seashore.

Coastal storms have caused extensive damage to the Fieldston and Brant Rock shorefronts, its protective works and back-shore commercial and residential properties. Storm driven waves from the east contribute to the removal of sand, seaward of the concrete seawall, which has resulted in the lowering of the beach surface. At some locations, the footings of the publically owned concrete seawall are exposed by erosion and are at risk of failure. In March 2010, conditions deteriorated to such an extent that 650 linear feet (l.f.) of the Fieldston seawall collapsed after a period of moderate coastal storm activity. The seawall breach exposed the back-shore neighborhood to wave overtopping and flooding. In 2011 and 2013 the town replaced 1,600 l.f. of concrete seawall in Fieldston using both State and local funding sources. The reconstruction and improvements to the Fieldston seawall resulted in the continued protection of the backshore from storm driven wave overtopping and precluded the need for any further investigation of this area under the Section 103 program.

Further to the south along the Brant Rock seawall, damaging wave splash overtops the seawall and floods the back shore area. Assessment of the backshore topography of Brant Rock, it was determined that damaging floodwaters typically reach +8 feet NGVD; approximately equal to the 2-year flood event. The study determined that further reductions in flooding would not be achieved by increasing the height of the wall; since the area's drainage flows over Dyke Road and towards Green Harbor. Surveyed first floor elevations of structures in the Brant Rock backshore indicated that only 11 structures had the potential to be candidates for elevation (non-structural) above the 1% annual chance flood event or Base Flood Elevation (BFE). Since frequent storm events only contributed to minor flood damages, elevating the first floors above the BFE was also determined to lack sufficient benefits for a Section 103 project.

Although a Section 103 Hurricane and Storm Damage Reduction project could not be identified, protection of the Brant Rock seawall is needed. Protecting the seawall's toe would ensure the wall does not fail in the future and will continue to provide protection for all the backshore properties and its associated roads and other public infrastructure. It's proposed that a cobble/sand revetment be constructed to prevent further beach scour along the seawall beginning near Franklin Street and extending south, approximately 300 feet. The revetment will consist of coarse sand and rounded gravel fill. It should be noted that in January 2015, a coastal storm significantly damaged a portion of the seawall at the location of the proposed revetment. The storm caused the concrete seawall to shear/break off, and it was not a scour/overturning failure.. Subsequently, the town applied for a seawall reconstruction grant from FEMA. The grant would allow for the reconstruction of the damaged structure to pre-storm dimensions. The grant does not provide for any additional protection enhancements for the seawall e.g. rock toe protection, increase to the seawall's height or steel sheeting toe protection. If additional protection measures for the seawall are approved by FEMA, under the grant that the town applied for, a reassessment of the cobble sand revetment project may be warranted.

Further Federal involvement under the Section 103 program at Fieldston and Brant Rock Marshfield, Massachusetts is not warranted at this time. It is recommended that that a cobble sand revetment (coarse sand to cobble fill) project at Brant Rock be implemented under the Emergency Streambank & Shoreline Erosion authority (Section 14 of the Continuing Authorities Program). This alternative will protect 300 feet of the Brant Rock seawall from undermining. The project's estimated total cost is $794,000. The Corps will be responsible for 65% of this cost or $516,000 and the non-Federal sponsor will be responsible for the remaining 35% or $278,000. Annual O&M costs are estimated to be $5,000 and will be the responsibility of the non-Federal sponsor.

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ABBREVIATIONS

AEP	Annual Exceedance Probabilities
BCR	Benefit-Cost Ratio
BFE	Base Flood Event (**1% annual chance exceedance flood event)**
COE	Corps of Engineers, New England District
CRF	Capital recovery factor
CSDR	Coastal Storm Damage Reduction
cfs	cubic feet per second
cy	cubic yards
EGM	Economic Guidance Memorandum
EOEA	Executive Office of Environmental Affairs
ER	Engineering Regulation
ft	feet (foot)
FCSA	Feasibility Cost Sharing Agreement
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
HEC-FDA	Hydraulic Engineering Center – Flood Damage Analysis
LERRD	Lands, Easements, Rights-of-Way, Relocation, Disposal
LF	Linear Feet
MA-CZM	Massachusetts Coastal Zone Management
MA-DEP	Massachusetts Department of Environmental Protection
MHW	Mean High Water
MLW	Mean Low Water
NAVD88	North American Vertical Datum of 1988
NED	National Economic Development
NGVD	National Geodetic Vertical Datum
SF	Square Feet
SY	Square Yard

MAIN REPORT

1: INTRODUCTION

BACKGROUND

The study area for this Hurricane and Coastal Storm Damage Reduction investigation consists of the shorefront and backshore areas of Brant Rock and Fieldston in Marshfield, Massachusetts. These areas are located within Plymouth County, Massachusetts, along the south shore region of Massachusetts Bay, about 30 miles south-east of Boston. Marshfield is situated about where Cape Cod Bay meets Massachusetts Bay, see Figure 1. The town has about 12 miles of shoreline directly exposed to the Atlantic Ocean, with about 4 miles of it partially protected with shorefront coastal structures (e.g. seawalls, bulkheads and jetties). The Marshfield shorefront consistently experiences coastal flooding and storm surge hazards associated with hurricanes and nor'easter storms. Nor'easter storm damage to Marshfield's back shore community is more frequently significant as Cape Cod usually provides some protection to the town from the full force of hurricanes tracking north (Metropolitan Area Planning Council, 2011).

Figure 1

Storm driven waves from the northeast have caused extensive erosion loss of beach sand and cobble material seaward of Marshfield's concrete seawalls. The loss of beach material has left portions of the existing seawall vulnerable to damage and undermining. Additionally, the seawall has been subjected to increased risk of overtopping during coastal storms due to sea level rise, which has increased the flood risk to back shore public, commercial and residential properties.

The Town of Marshfield maintains the shorefront and its facilities, including its seawalls, revetments, and groins. Most of Marshfield's beach faces the north-east and is exposed to direct attack from ocean storms. The Town of Marshfield recognizes that when a seawall failure occurs, property in the backshore becomes more at risk due to storms. The town initially requested that the Corps of Engineers provide assistance to reduce coastal storm damages by enhancing or replacing the existing seawall sections. In 2011 and 2013 the town completely replaced a total of 1,600 linear feet (l.f.) of concrete seawall in the Fieldston area at a cost of $4.8million. The new structure was constructed two feet higher than the original seawall, +22 NAVD88. During the summer of 2012, the town dredged a portion of the Fieldston backshore drainage creek. The project entailed dredging a 10-foot wide channel approximately 3,200 l.f. in the upper reaches of Bass Creek, a tributary of the Green Harbor River. The dredging objective was to address backyard and street drainage issues that result when wave overtopping occurs. The channel was dredged to a minimum depth of -3.0 feet at the upstream end of the creek, adjacent to the Ocean Street culvert and to a maximum depth of -4.0 feet at the downstream extent. This dredging resulted in the removal of approximately 6,000 cubic yards of sediment. Due to local funding constraints the entire Bass Creek was not dredged. An additional 2,000 l.f. of downstream dredging and a pump station are planned by the town to complete the work. In January 2014, the Massachusetts Executive Office of Energy and Environmental Affairs provided the town of Marshfield $500,000 to conduct repairs to the Brant Rock seawall's concrete facing revetment. During a January 2015 coastal storm event an 80 foot section of seawall in the Brant Rock area collapsed due to beach erosion undermining the wall.

STUDY AUTHORITY

This investigation was conducted under Section 103 of the Continuing Authorities Program (River and Harbor Act of 1962, as amended). The maximum Federal expenditure for planning, design, and construction of any one economically justified project is $5,000,000.

STUDY OBJECTIVE AND SCOPE

The Town of Marshfield in participation with the United States Army Corps of Engineers, New England District (COE) conducted this investigation to reduce both the risk and severity of storm induced damages to the Fieldston and Brant Rock shorefronts. The objective of this Feasibility Study is to determine the most technically and economically feasible, and socially, environmentally and culturally acceptable storm protection project. The project's objective is to reduce damages caused by storm driven ocean flooding of back shore properties due to storm wave overtopping of the seawall along Marshfield's Fieldston and Brant Rock beach fronts (see Figure 2). The study scope for the Fieldston study reach extends southerly from Rexhame Road to Old Beach Road. The study scope for the Brant Rock area extends southerly from Hancock Street to South Street.

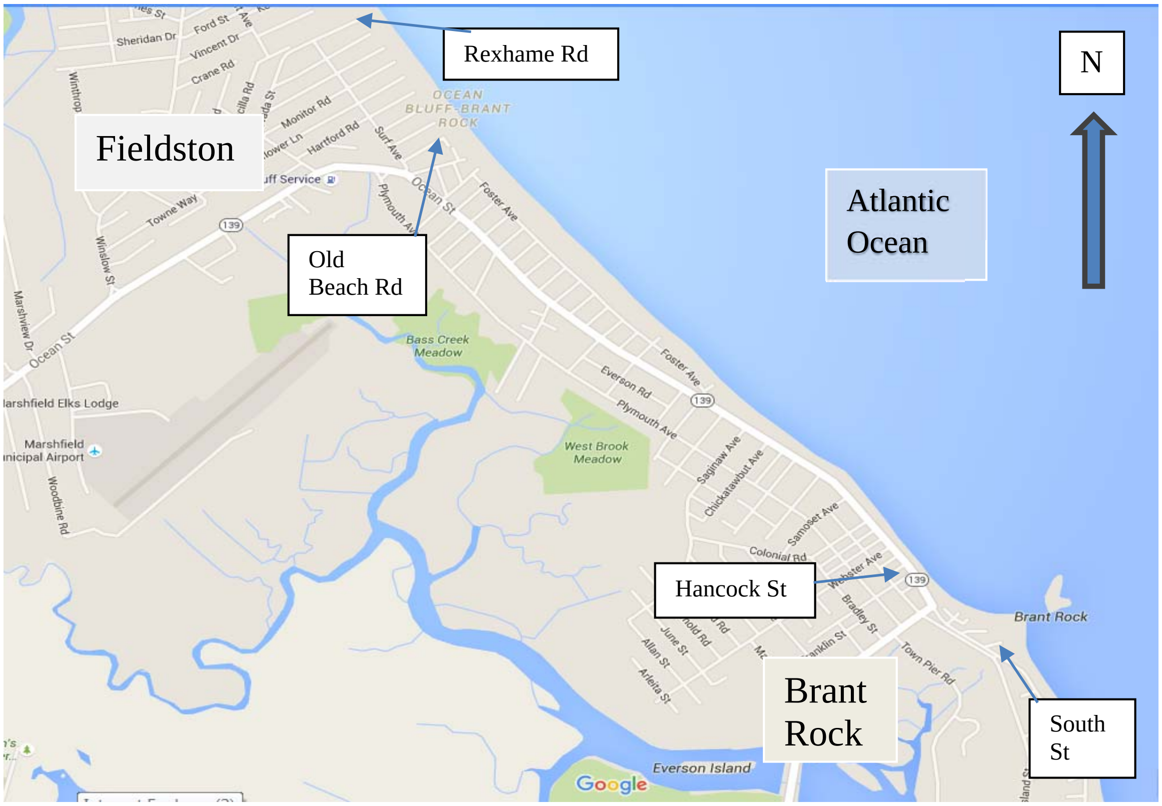

Figure 2

PRIOR STUDIES, REPORTS, AND PROJECTS (also used for Reference)

-Massachusetts Coastal Infrastructure, Inventory and Assessment Project
Massachusetts Department of Conservation and Recreation (DCR), Office of Waterways.
The Coastal Hazards Commission (CHC) was tasked with prioritizing coastal protection structures maintenance and repairs, October, 2009. 2

- Federal Emergency Management Agency, National Flood Insurance Program, Town of Marshfield, Plymouth County, June 16, 2006. 3

-Surf Avenue Seawall Revetment Construction, Marshfield, MA
Environmental Notification Form, August 2012. 4
http://www.env.state.ma.us/mepa/mepadocs/2012/090512em/nps/enf/14956.pdf

-Town of Marshfield
Environmental Inventory & Analysis, 2010. 5
http://www.townofmarshfield.org/Collateral/Documents/English-US/conservation/Open%20Space/4%20Environmental%20Inventory.pdf

-Town of Marshfield
Marshfield Hazard Mitigation Plan 2013
Metropolitan Area Planning Council.6

- Massachusetts Flood Plain Management Services, Green Harbor River and Bass Creek Flood Analysis, Marshfield, prepared by the COE for the Town of Marshfield, October, 2000.

- Green Harbor River, Tidal Hydraulics Study, Marshfield, Applied Coastal Research and Engineering, Inc. Completed for the Town of Marshfield, March, 2007. http://www.townofmarshfield.org/Collateral/Documents/English-US/conservation/Green-Harbor-River-Hydraulics-Report.pdf

2: EXISTING CONDITIONS

PHYSICAL SETTING

Marshfield's coastline varies from the barrier beaches at Rexhame and Fieldston; to the eroding coastal banks of Ocean Bluff, Brant Rock, and Blackman's Point; and to natural rock outcroppings in the Brant Rock area and one at Bluefish Point (Marshfield, 2010).

The study areas for this report consist of the shorefront and the adjoining back shore areas of Fieldston and Brant Rock (see Figure 2). The most significant existing shore protection feature in Marshfield are the concrete seawalls. Based upon available records, the concrete seawalls were originally constructed during the 1930s by the Commonwealth of Massachusetts. Residential homes in both the Fieldston and Brant Rock areas extend up to the seawall. Significant repairs to the existing seawalls have been made on numerous occasions by the town of Marshfield. Most recently, a 1,600 feet section of seawall was reconstructed by the town as a result of two sections of seawall in Fieldston collapsing. Throughout Marshfield's coastline, the seawalls continue to be the primary protection feature for the backshore houses and infrastructure.

Surveys have shown that significant seasonal erosion and some accretion occurs along Marshfield's shoreline. Erosion of the beach in winter contributes to the vulnerability of the seawall at the time of year when many significant storms occur, consisting predominantly of "Nor'easters. High wave impacts associated with splash over occurs along the shorefront during storm events.

GEOLOGICAL SETTING

The geology of Marshfield has created unique natural environments that are home to numerous sensitive and endangered plant and wildlife species. The bedrock underlying the northern portion of Marshfield, in the Fieldston and Brant Rock areas, is an assemblage of sedimentary rocks including sandstone, greywacke, and shale. The deposits overlaying this bedrock are sediments ranging from unsorted mixtures of sand, silt, and boulders to stratified sands and gravels. These deposits are dense, allowing little water to flow through and resulting in areas of high water runoff and high potential for coastal beach erosion (Marshfield, 2010).

ENVIRONMENTAL SETTING

Marshfield's extensive salt marshes, for which the town was named, are its most predominate natural characteristic. The town is comprised of approximately 18,600 acres, of which 3,400 are wetlands. The coastal area has six state designated barrier beaches totaling 235 acres with Rexhame the most northern and Brant Rock and Green Harbor in the south. As much as two-thirds of the town's salt marshes have been filled and lost to development over the years. Intertidal sand flats extend seaward from the beach along the length of both study areas. Site visits were undertaken in preparation of the COE 2009 Initial Appraisal Report and this feasibility report to determine the benthic community of the intertidal and sub-tidal areas. No dunes, beach grass, or other ecologically significant natural resources were observed. Benthic investigations conducted in November 2013 indicated a low number of species and individuals along the beach. No commercial shellfish were observed. A low benthic density would be expected considering currents, wave conditions and human disturbance. The waters offshore from Marshfield's beaches support a viable lobster (*Homarus americanus*) population. No eelgrass (*Zostera marina*) was found in the project area. The habitat of the proposed project area does not provide suitable habitat for Federally listed threatened or endangered species.

HISTORICAL/CULTURAL SETTING

Native Americans lived in Marshfield for thousands of years before English settlers arrived. These people included members of the Wampanoag Tribe of the Algonquin Nation and members of the Massachusetts Tribe. Pathways were well established in the region by the time of English settlement in the 17th century. These paths became the town's first roads and are still in use today.

A commercial fishing enterprise was first established in Marshfield in 1623, by William Green. The area was originally referred to as "Green's Harbor." When the area was formally set off as a town, it was named "Rexhame." Later, the name of the town was changed to "Marshfield." The town has extensive acreage of salt water tidal marshes along its three rivers: the Green Harbor River, the South River and the North River; hence the name "Marshfield".

Early industry in the town included farming, cattle, fishing and salt marsh haying. Shipbuilding grew in the town, and over 1,000 ships were built along the North River in town during the 19th century. The town is also the site of Brant Rock, where the first Trans-Atlantic voice radio broadcast was sent in 1907. Today, Marshfield is largely a semi-rural and suburban town, with many residents commuting daily into Boston. The town continues to have a large summer resort population.

3: PROBLEM IDENTIFICATION AND OPPORTUNITIES

Problems

Coastal storms cause extensive damages to the publicly and privately owned property along the Marshfield shorefront. Protective works along the shoreline were publically constructed and maintained by the town. Protection of Marshfield's back shore, between Fieldston and Brant Rock, is provided by mostly a continuous 5,400-foot long concrete seawall with a combination of revetments, groins, sand fill, and jersey barriers. Construction of the seawall was completed over a period of years by the Works Projects Administration, the Commonwealth of Massachusetts and the town of Marshfield. Storm driven waves from the east are responsible for the removal of sand in front of the seawall and the consequent lowering of the beach. At times seawall footings have been exposed and undermined.

At the Fieldston study reach ~~believed to be~~ the area is prone to interior flooding resulting from the low elevation of the area and poor local drainage. Area precipitation is trapped in the "basin" formed by the bowl shaped topography. There is an existing drainage swale/ditch that runs generally from north to south and exits Green Harbor to the south. A report prepared for the town titled "Rexhame Area Drainage Improvements" by Greene and Associates dated February 2005, states that portions of the ditch are overgrown, caved in, and poorly graded. The report determined that the existing capacity of the ditch is very small and that rainfall events smaller than a 2-year event overwhelm its carrying capacity. The report concluded that upgrading the ditch and the Ocean Street culverts could improve conditions to the point where the area would be "protected" from a 25 year fresh water storm event. However, the analysis did not take into account the additional water from wave splash over overtopping the seawall.

Another problem within the Fieldston study area is that the existing seawalls remain jeopardized by the continued loss of beach material, which in turn exposes the wall's toe that leads to wall rotation and subsequent failure. It should be noted that based on the recorded oceanographic/metrological data for the time period (March 2011) preceding the Fieldston seawall failure, there was no evidence that a specific wave, tide, or precipitation event caused or contributed to the wall's failure. All of the data gathered indicates that the conditions preceding the failure were not exceptional and, to the contrary, fairly benign. At no time during the preceding weeks to the wall failure was even a 1- year return period event recorded in any of the data sets gathered. In view of this, the loss of material at the wall's toe remains a great failure threat. The Fieldston redesigned replacement seawalls, constructed by the town, incorporates safety features, such as concrete footing base, steel sheeting tied into the footing and large bolderrs placed against the seawall. These improvements have reduced the risk of the structures shifting due to further beach erosion. Immediately south past the newly constructed seawall, the old seawalls appear not to be threatened from shifting since the beach elevation appears to be stable. The town reported that as funding is planned for further seawall rehabilitation and/or reconstruction.

The Brant Rock area is susceptible to fairly frequent coastal flooding due to the low elevations of the backshore, its proximity to both the ocean and Green Harbor, local drainage issues and storm wave overtopping the seawall. It was reported that the greatest flooding concern was from waves overtopping the seawall and water collecting in the low areas along Ocean Street. Brant Rock's eastern border is fronted by a seawall, to the south is an elevated headland type feature, to the west is a basin/salt marsh that is separated from Green Harbor by a dike and tide gates, and to the north there is a hill with significant land elevation increase. During storm events, the seawall is overtopped by splash-over from waves, which collects in the salt marsh/basin area to the west. However, once the basin is full, storm water then overflows and floods buildings and streets of the Brant Rock (Esplanade) area.

Flooding due to wave splash over in the Brant Rock area backs up septic tanks, inundates the Esplanade area, and damages dwellings and other properties. Town officials indicated that the Brant Rock (Esplanade) area receives storm splash-over flooding two or three times per year. The Esplanade floods to a depth up to two feet, affecting some 38 homes and retail businesses at the southern end of the peninsula. The existing seawall, with a top elevation of about 15.5 NAVD88, is the only coastal back shore protection for the Brant Rock study area. There are similar concerns with erosion failure of the seawall, similar to what has occurred in the Fieldston area, as a result of loss of material covering the toe.

Future Without Project Condition

The Fieldston area is subject to frequent flooding during rainfall events and splash-over of the seawall during coastal storms. Water collects in the backshore in the vicinity of Monitor and Mayflower Roads. The upper reaches of Bass Creek are heavily impacted by sediment and overgrown vegetation with minimal elevation change which limits drainage. The town plans to complete drainage improvements in 2017. Prior to the construction of the new Fieldston seawalls, approximately 18 homes would have been subjected to flood damages by associated 1-2 foot flood depths. Since the construction of the new Fieldston seawalls in 2015, minor splash-over continues to occur but to a lesser degree. Less frequent, higher water level storm driven waves will continue to threaten Fieldston properties. The new seawall includes sheeting driven at the base of the toe that should prevent future rotational failure.

It is anticipated that the town of Marshfield, along with occasional grants from the Commonwealth of Massachusetts and FEMA, would continue to maintain the seawall and other public infrastructure along Marshfield's shorefront in the Fieldston area. Despite the town's annual efforts to seal cracks and perform other surface repairs to the seawall, the position of the seawall is fixed, and its stability is subject to change when storm waves remove sand and cobble and subsequently expose its footing.

The town, utilizing a MA-CZM State grant, reconstructed the ocean facing armor stone revetment along a 580 linear foot portion of the Brant Rock seawall along Ocean Avenue. While providing stability protection for the seawall at this location, the stone was realigned to offer greater wave run up protection. The other areas along the Brant Rock seawall, about 1,700 l.f., are currently unprotected.

In January 2015, a coastal storm significantly damaged an 80 l.f. portion of the Brant Rock seawall opposite Dyke Road. The town has applied for a seawall reconstruction grant from FEMA. The grant would allow for the reconstruction of the damage structure to pre-storm dimensions. The grant does not provide for any protection enhancements for the seawall e.g. rock or sheeting toe protection, or an increase of the seawall's height to provide additional protection. Therefore, flooding of backshore properties will continue due to wave splash over and the seawall will continue to be at risk due to the loss of toe material.

Planning Considerations and Constraints

The formulated plans developed in this study 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. Local officials raised concerns that any recommended measures being assessed should protect the entire flood prone area for each study area. Additionally, during the progress of the study all plans identified for further assessment consider any threats to fishery and shellfish industries as well as private properties.

Consideration was provided to recent seawall improvements that the town accomplished. Between 2011 and 2015 the town replaced a total 1,600 linear feet (l.f.) of concrete seawall along the Fieldston shoreline. The new structures were constructed two feet higher than the original seawall, about +22 NAVD88. Completion of the seawall replacement extends from Old Beach Road to 9th Avenue. It is anticipated that with the ongoing backshore drainage improvements the town is implementing, future storm damages from the more frequent storm wave events will be reduced for the Fieldston study area.

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 selected alternative for construction (recommended plan) must be able to comply

with the COE responsibilities associated with Section 404(b)(1) of the Clean Water Act, and all other applicable laws and regulations, including but not limited to the Endangered Species Act, Clean Air Act, and Coastal Zone Management Consistency Act.

The following knowledge and information became known during the course of the study, and influenced the planning considerations via formulation of the alternatives that were considered:

- A characterization of Marshfield's beach material revealed it has a very bi-modal composition, consisting of very fine sand and cobbles. Marshfield beaches tend to be flatter with gentler slopes (between the high and low tide line). During periods of high tide, the exposed beach is reduced making access by visitors difficult. The beach front is the backshore's first line of defense against rising sea levels, erosion and storm waves. MA-CZM policy is that any implemented shorefront protection project ensure that the public have continued access to the shore during periods of high tide.

Due to the reconstruction of the new seawalls in Fieldston, that part of the community now has a much higher level of protection due to the new height of the seawall and the toe protection included in the design. With the new seawalls in place, the volume of water due to storm wave overtopping and wall failure risk along this reach are significantly reduced, thus impacting the planning considerations for this area. The focus of the study became how to further reduce damages due to residual storm splash over impacts and flooding along Fieldston and Brant Rock shorefronts and to protect the areas in Brant Rock where the seawall and beach levels remain vulnerable.

4: PLAN FORMULATION

For the purpose of formulating alternative plans this study addresses the need to protect Marshfield's back shore from damages due to coastal storms. For this effort, Marshfield's shoreline was divided into two study areas: Fieldston and Brant Rock. The objective is to assess viable alternatives that will develop the most technically and economically feasible and socially, environmentally and culturally acceptable project(s) to prevent backshore damages for the two coastal study areas of Marshfield.

Together with the no-action alternative, five alternatives were initially evaluated to reduce coastal storm damage for the two study areas. The study's objective is to avoid or reduce storm damages while avoiding or minimizing potential impacts to other uses such as: land use, marine and terrestrial ecosystem disturbance, and impacts on endangered and threatened species.

The following storm damage reduction alternatives were considered:

No Action Alternative: The no action alternative serves as a benchmark against which proposed Federal actions are evaluated. The no-action or future without project condition alternative refers to the continuation of existing conditions of the affected environment, without implementation of some proposed action. Under the No Action Alternative (providing no additional protection in the project areas), wave splash over backshore flooding will continue to occur. Considerable damage to the concrete seawall, stairs, riprap, and sidewalks as well as backshore flood damages to commercial, residential, and public properties will continue without intervention. Therefore, a no-action alternative was not acceptable to the community.

Between 2011 and 2015 the town replaced a total 1,600 linear feet (l.f.) of concrete seawall along the Fieldston shoreline. The new structures were constructed two feet higher than the original seawall, about +22 NAVD88. Completion of the seawall replacement extends from Old Beach Road to 9th Avenue. It is anticipated that with the ongoing backshore drainage improvements the town will be completing, future storm damages from the more frequent storm wave events will be significantly reduced for the Fieldston area.

Along the Brant Rock shorefront, the seawall's age (80 plus years) and current visible state along with the eroded beach indicates the structure may not provide continued reliable storm protection for the backshore community. The existing seawall at Brant Rock maintains a top elevation of at least 15.5 NAVD88. Due to the constant erosion of the beach and its age, the future reliability of the wall in protecting the backshore community is in jeopardy.

Groin Reconstruction Alternative: Groins were original constructed as part of the Brant Rock beach protection. Groins are sometimes effective at retaining littoral beach sediments. However, over the long term, groins prevent the natural migration of beach sand and are not consistent with the policies of MA-CZM. There are several existing concrete groins along the beach that have not sufficiently arrested beach erosion. Therefore, this alternative was eliminated from further consideration.

Seawall Replacement Alternative: The flood reduction benefits associated with a new raised seawall for the Fieldston study area lack economic justification since the town recently replaced 1,600 l.f. of the seawall. Town officials reported that the cost of the seawall construction was approximately $3,000 per l.f. Fieldston's drainage issues over the low areas are the predominate issues continue to plague rersidents. Due to the area's backshore elevation and reduced wave splash over damages, providing a new raised seawall further south beyond 9th Avenue was not warranted and was eliminated from further study consideration.

Consideration was then provided for the construction of a new raised seawall for the entire Brant Rock study area. The alternative would cost over $5.2 million. The new wall could be built two feet higher than the existing one to provide improved wave splash-over protection. Steel sheeting would also need to be driven below grade and/or a stone toe revetment be constructed to offer additional footing erosion protection. This alternative was kept for further consideration.

Revetment Alternative: The construction of a revetment for the Fieldston area would minimally reduce storm wave splash-over since the new wall was constructed 2 foot higher than the original wall. Additionally, the wall was constructed with a deeper footing and a steel sheet pile wall to provide for added erosion protection. Therefore, this alternative for the Fieldston area was dropped from further consideration.

For the Brant Rock study area the revetment alternative would consists of providing additional protection for the existing seawall. A stone slope revetment or a mixed cobble and sand revetment placed in front of the unprotected seawall can be effective in reducing beach toe scour and may provide greater wave run-up protection. Currently, storm driven waves create scour at the base of the seawall, as some of the energy is deflected downward. Scour contributes to the loss of beach material and exposes portions of the seawall's footings. Due to the current condition of the beach, overtopping and sometimes failure of portions of the seawall have occurred. The following picture shows the January 2015 seawall breach near the corner of Beach Street and Dyke Road that the town subsequently filled with rocks and concrete rubble. In view of the foregoing, this alternative was retained for further analysis.

Fieldston Bass Creek Ditch Improvements: The Fieldston area is subject to frequent flooding during rainfall events and wash over of the seawall during coastal storms. Flood water collects in the backshore in the vicinity of Monitor and Mayflower Roads. Due to the area's low elevation, it is also subject to a high water table and restrictions in the drainage ditch into Bass Creek. The flow in the upper reaches of Bass Creek are heavily affected by sediment and overgrown vegetation with minimal elevation change reducing downstream drainage. Due to funding constraints the Town completed two-thirds of the needed drainage improvements for Bass Creek (Marshfield, 2013). The town reported that the remaining drainage improvements of Bass Creek (channel excavation and pump station) will be accomplished during Phase 2 of their mitigation plan, scheduled to commence in 2017. Due to the ongoing improvements completed and planned for the area, this alternative was eliminated from further consideration.

Elevating Structures (non-Structural) Alternative: Non-structural measures do not control flooding but rather reduce the impact of flood damages. Elevating affected backshore structures for both study areas was considered. By elevating vulnerable flood prone properties, much of the structure and contents damage can be eliminated. The first floors of structures have to be elevated to at least 1foot above the 1% annual chance exceedance flood event or Base Flood Elevation (BFE). This alternative merited further evaluation for both the Fieldston and Brant Rock areas.

Evaluation of Alternative Plans

Fieldston area

The study area for Fieldston consists of 94 single family houses protected by a concrete seawall. There were several openings in the seawalls in the Fieldston beach area that allowed water to pass through the structures and flood backshore neighborhoods during storm events. During the course of this study, the town secured State grant funding, and replaced 1,600 linear feet of concrete seawall along the Fieldston shorefront. The seawall was constructed with a top elevation of 24 Feet NAVD making it 2 feet higher than the original seawall.

For the Fieldston area the current without-project conditions reflect the new seawall in place and the reduced risk of flooding from failure or splash over during coastal storm events. As identified in the Economic Appendix C, Existing Conditions Section, when the improved conditions with reduced water surface elevations were analyzed using the HEC-FDA tool, results indicated minimal expected annual damages ($1,000) and the Fieldston area was dropped from consideration. As stated previously, two-thirds of the drainage ditch leading to Bass Creek has been cleared and widened by the town, with the remaining dredging improvements scheduled for 2017. No further wall improvements (either increased height or revetment) were found to be effective in reducing flooding. In view of the foregoing the study alternatives assessed indicate that there are no justified improvements under Section 103 for the Fieldston area.

Brant Rock area

Seawall Replacement Alternative: Reconstructing or raising the elevation of Brant Rock seawall two feet higher, along with providing toe sheeting with revetment protection, would only achieve minimal flood reduction benefits from overtopping storm splash over. Flood depths from wave splash over would reach +4.2 NAVD88, which would equal a storm water depth of 2 feet. Due to the area's topography, if a larger event occurred, overtopping volume/depth would overwhelm the back shore area and pass over Dyke Street. The area's storage volume in relation to its corresponding flood elevation and total storm overtopping volumes are provided in Tables 8 and 9 of the Coastal Engineering Appendix. Although frequent flood damage events (< 2-year storm) would be reduced, a 15-year storm event would fully inundate Brant Rock's backshore by storm splash over. Significant reductions in flooding would not be achieved by increasing the wall's height (either by reconstruction or by raising the seawall's elevation). Due to the alternative's limited flood reduction benefits versus the estimated $5.2 million cost of this alternative, it was dropped from further consideration.

Revetment Alternative: Placing a full height rock rip rap or a cobble sand revetment has been shown to be effective in breaking waves, extending the seawall's life and reducing beach front erosion. Two methods of toe protection were analyzed to address erosion failure of the seawall in Brant Rock: placing either a rock or cobble/sand revetment in front of the seawall. Due to the beach's elevation and alignment, a revetment would need to begin opposite Franklin Street (tying into the existing town revetment) and extend about 300 feet southeast. The revetment would be built to elevations potentially sufficient to protect the wall from erosion contributed wave attack and meet sliding and overturning criteria of the seawall.

The full height rock rip rap revetment would consist of armor stone, filter stone, and bedding layers extending out from the seawall 56 feet, with a cobble beach placed at a 5H: 1V slope on top of the revetment (See. Diagram1: Rip Rap Toe Protection – Appendix B). The other alternative analyzed was the cobble/sand revetment. The cobble/sand alternative (shown below, Diagram 2: Cobble Berm – Appendix B) would consist of a 5 foot think coarse sand to rounded cobble fill extending towards the water about 5 feet and then beginning a shallow slope towards the water until it meets the existing beach. The height of the revetment would be constructed to 10 NAVD88. Maintenance of the top berm must be carried out every 5 years with 20% of initial fill replaced, to be confident that the berm provides the required toe protection. Both revetments would provide similar erosion protection for the Brant Rock seawall. Both revetment alternatives could be carried under the Section 14 authority, Shoreline/Streambank Emergency Erosion protection.

The total project cost for the rock rip rap alternative would be $1,262,000 (cost not include additional beach sand nourishment requirement). The total project cost for the cobble/sand revetment alternative is $794,000. The revetment erosion protection for the Brant Rock area is to prevent damaging beach erosion from continuing and threatening the seawall infrastructure. It should be noted that the sand cobble revetment would maintain an exposed beach during high tide, thus providing public beach access to the community. Utilizing the MA-CZM Morris Mapping Tool, it is predicted that the Fieldston/Brant Rock beaches historically experience six tenths of a foot of annual beach loss due to erosion. Conservatively a 5-year maintenance of the sand/cobble revetment should be anticipated.

Elevating Structures Alternative: A preliminary analysis of the costs and benefits for protection of the Brant Rock backshore indicated that elevating selected structure's first floors above the Base Flood Elevation (BFE), was a potential alternative that warranted more detailed consideration to reduce storm flood damages. The Brant Rock seawall experiences frequent seawall storm overtopping, (1 to 5 year events). The overtopping coupled with low backshore elevations results in frequent residential and commercial property losses. Flooding is caused almost entirely by wave seawall splash over. This is expected when examining the surrounding topography and noting the relatively small drainage area. The controlling flood depth elevation is 8 NAVD88 at the northwest corner of the area located near Dyke and Town Pier Roads. Once flood waters reach this elevation, water overflows this location and flows to Green Harbor. Since structures in the flood zone would not receive greater flooding or approaching the BFE, a lower level of protection would need to be examined. A first floor elevation survey indicated that due to the limited flood reduction benefits realized only 11 structures were eligible to be candidates. The 11 structures identified (3 residential and 8 commercial/retail) would require one foot or more elevation increase to reach the full FEMA required BFE protection.

In the Economic Summary-Appendix C, Table 3, it is shown that the Total Investment Cost of elevating these 11 structures is $1,547,647. The annual cost for this alternative would be $65,982. The estimated annual benefit is $58,800. Since the annualized cost for structure elevation is greater than the estimated annualized flood reduction benefit, this alternative was not economically justified. Therefore, any consideration for increasing first floor elevations of individual structures is not warranted. Due to the lack of flood damage project benefits, a Section 103 project for the Brant Rock area is not economically justified.

During the course of this study, consideration was given to providing protection for the Brant Rock seawall, thus maintaining the seawalls' protection. The wall provides the primary protection to the Brant Rock backshore community. As originally constructed, the seawall was not provided with a full toe revetment or steel sheeting extending into the beach below the foundation to mitigate scour action and potential subsequent overturning. Due to the crescent shape of the beach, protection of the seawall the critical (exposed) reach extends opposite Franklin Street and extends 300 linear south towards North Street. A cobble sand revetment was selected as the most economical, publically acceptable, protection for the seawall. The revetment would be designed to resist erosion forces acting on the beach surface along the seawall's toe. The protection plan meets economic, engineering, cultural criteria for Section 14 implementation as well as being publically acceptable with local town officials. Upon project approval, under the Section 14 authority, the Federal government may participate in its final design and construction. The cobble sand revetment's cost of implementation falls within the expenditure limits for Section 14 authority. The estimated costs associated with the plan implementation are presented in the following Table.

Table 1
Revetment Cobble Sand Revetment
Protecting the Brant Rock Seawall

PLAN IMPLEMENTATION PHASE COSTS

Activity	Total Cost	Federal Share (65%)	Non-Federal Share (35%)
Construction Cost (with 18% contingency)	$612,000	$398,000	$214,000
Engineering and Design (E&D)	$132,000	$86,000	$46,000
Construction Management (S&A)	$50,000	$32,000	$18,000
Total Project Cost	$794,000	$516,000	$278,000

The seawall protection plan will entail approximately three (300) hundred linear feet of coarse sand to cobble fill be placed as a berm at an estimated cost of $794,000. The seawall protection plan calls for the placement of a 5 foot wide crest at an elevation of 10 NAVD88 (14 NGVD) and a 1V:6H slope to the beach terminating above MLLW. Figures 3 and 4 depicts the proposed cobble berm location and cross section.

For the seawall to remain stable the northerly end section would need to be tied into the town's revetment. To the south the natural crescent shape of the beach could accept the southerly end of the project. The toe of the wall needs to be buried beneath the beach surface. To ensure that the toe remains buried, the cobble/sand berm will be placed along the seawall to resist erosion. Beginning at Franklin Street and extending 300 ft. south, the revetment will be built to elevations sufficient to meet potential seawall sliding failure from future beach erosion. The revetment will consist of a 6-foot thick coarse sand to rounded cobble fill extending towards the water about 5 feet and then a shallow slope (6 horizontal: 1 vertical) towards the water eventually terminating at the existing beach surface (at or above MLLW). It is anticipated that maintenance would be carried out (every once every 5 years) to be confident that the berm and revetment continues to provide sliding protection from erosion.   The town of Marshfield would be responsible for the entire costs and implementation of periodic cobble sand fill nourishment replacing cobble sand fill for both the berm and revetment that is lost to erosion and tidal wave forces. The town also understands that the cobbles could become projectiles in significant storm events.

5: CONCLUSIONS AND RECOMMENDATIONS

Conclusions: Due to the condition of the beach and seawall at Brant Rock, emergency shoreline protection for the seawall merits consideration under the Section 14 authority. The town owns and maintains the seawall which provides protection for backshore properties, associated roads and other public infrastructure. Due to beach erosion, sections of the seawall are currently in jeopardy of being undermined and failing. Two revetments were analyzed for the Brant Rock seawall (coarse sand and cobble berm, and a cobble berm underlain by armor stone). Since both berms would equally protect the seawall and increase the beach level, the study team selected the lower cost option, course sand and cobble revetment. The cobble sand fill in front of the wall would increase the stability of the sea wall against overturning. The cobble sand revetment would guard against scouring at the toe of the sea wall and possible undermining of the sea wall footing.

If the benefits attributable to the Section 14 protection project, to construct a cobble sand revetment seaward of the sea wall, are to be realized, minor repairs to the sea wall must continually be made by the sponsor as prerequisite to the construction phase of the project.

Recommendations: Under the Section 14 authority, it is recommended that in the Brandt Rock section beginning near Franklin Street and extending south approximately 300 feet (Figure 3), a cobble/sand berm be constructed to prevent further beach erosion. Although some wave splash-over would still occur, the continued reliability of the wall would be maintained thus protecting the backshore community from direct attack by frequent coastal storm events.

No further Federal involvement under the Section 103 program at Fieldston and Brant Rock Marshfield, Massachusetts is warranted at this time.

The recommended cobble berm project for the Brant Rock seawall be implemented under the Emergency Streambank & Shoreline Erosion authority (Section 14 of the Continuing Authorities Program). This alternative will protect from erosion approximately 300 linear feet of the seawall from undermining. The project's fully funded total cost is estimated to be $794,000. The COE would be responsible for 65% of this cost or $516,000 and the non-Federal sponsor would be responsible for the other 35% or $278,000. Annual O&M costs are estimated to be $5,000 and will be the responsibility of the non-Federal sponsor. During the preparation of the revetment's plans and specifications a detailed estimate of potential maintenance costs will be completed. 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 protection 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.

Coordination with Federal and State agencies has occurred during this study's formulation phase. The U.S. Fish and Wildlife Service concurs with the project's Environmental Assessment that the cobble sand mix berm as proposed would have only minimal effect of fish and wildlife resources in the project area. In addition, the NMFS indicated that there is no Endangered or Threatened species in the project area. The NMFS recommends that project activities be conducted during periods of low tide to minimize elevated levels of sediment in the water column be adopted to follow EFH conservation recommendations. In formulating our recommended plan, coordination with MA-CZM and Massachusetts Department of Environmental Protection (MA DEP) was conducted. During the Engineering and Design phase of this project, 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.

The Brant Rock shoreline erosion protection cobble/sand berm will be constructed on town property. Space for construction staging and access will be necessary for the implementation of the recommended plan. There are no private 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 local traffic as trucks deliver materials to the construction site.

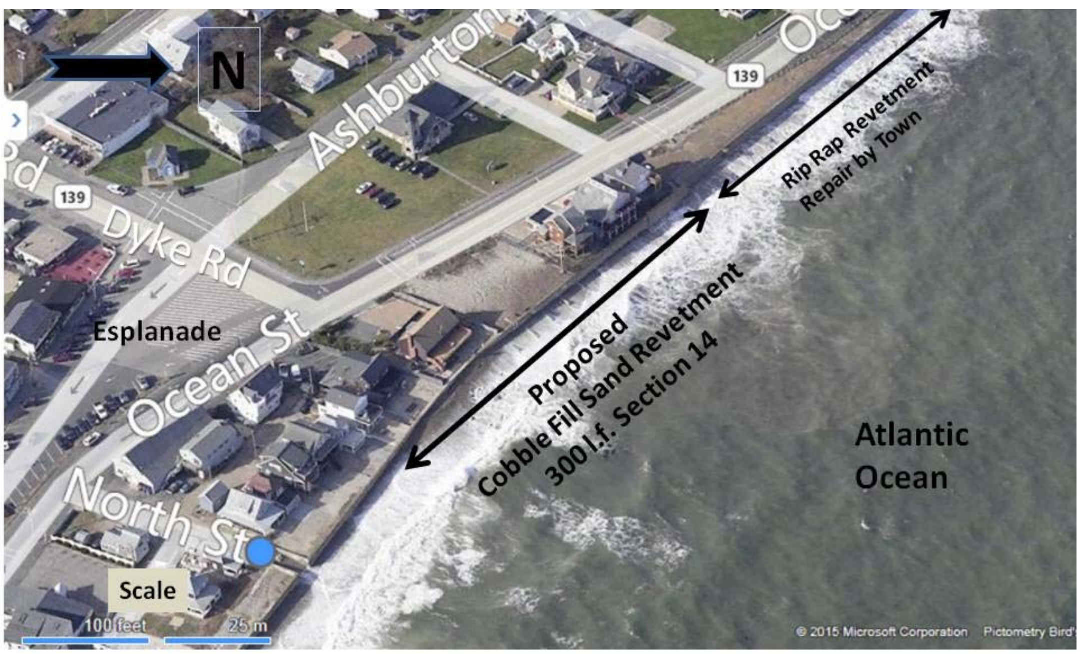

Figure 3: Cobble Berm Location

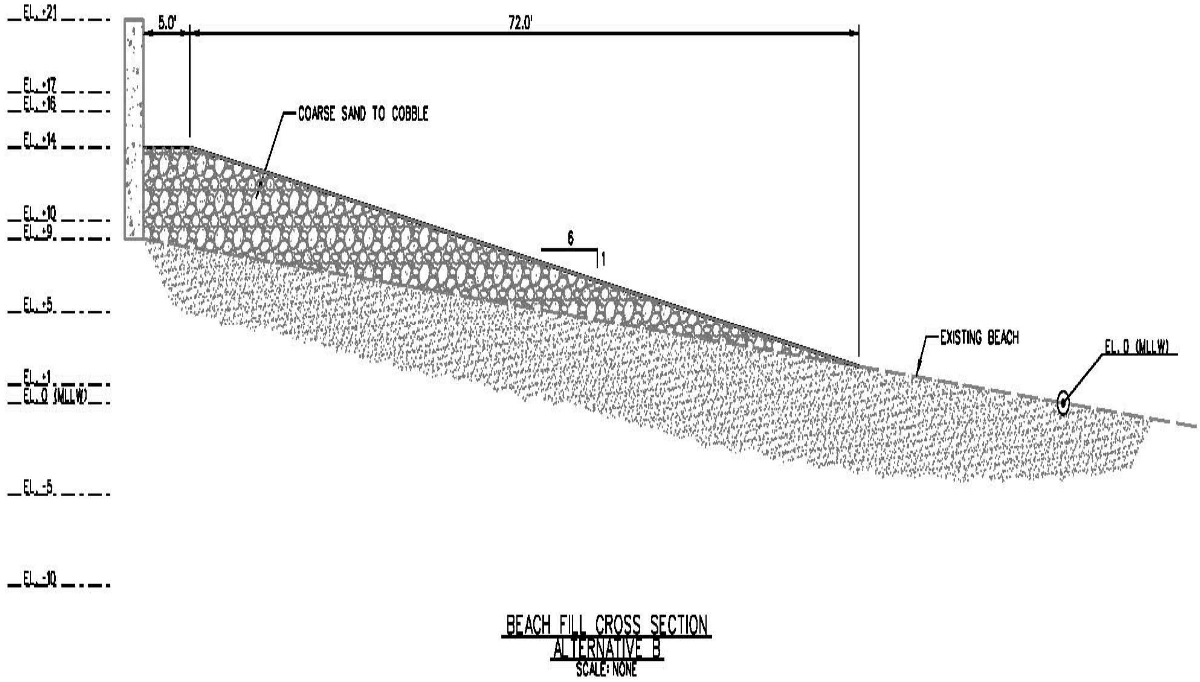

Figure 4: Cobble Berm Cross Section

Marshfield, MA Section 103 (revised)
Section 14
Feasibility Study

Coastal Analysis

Appendix A

Marshfield Storm Damage Reduction Study
Section 103
Coastal Engineering Analysis
New England District
Water Management Section
January 05, 2006
Updated June 13, 2014

1.0 Purpose

Study efforts focused on determining the potential for a Continuing Authorities Program (CAP), Section 103 storm damage reduction project. The analysis took into account the existing site's topography and seawall structures in Marshfield, MA to determine if potential alternatives exist that could be recommended with a positive benefit to cost ratio that would merit further Corps participation in a flood reduction project for the back shore coastal properties along the Fieldston and Brant Rock coastline.

The focus of this effort consisted of updates to existing wave overtopping calculations, which when combined with interior flood volumes, would develop estimated interior flood stage frequencies. Simplified assumptions and basic calculations were applied in the wave overtopping calculations, flood depths, and flood frequency analysis. Considerations for sea level rise are also discussed in this analysis.

2.0 Problem/Project Description

The study area is located in the town of Marshfield, MA, which is located between Boston and Cape Cod on Cape Cod Bay (Figure 1). The updated analysis of two sites (Fieldston and Brant Rock areas) within Marshfield was conducted and they are shown in Figure 2. The areas are the Fieldston/Rexhame area (referred to as Fieldston in this report) and the Brant Rock area

Figure 1. Marshfield location Map

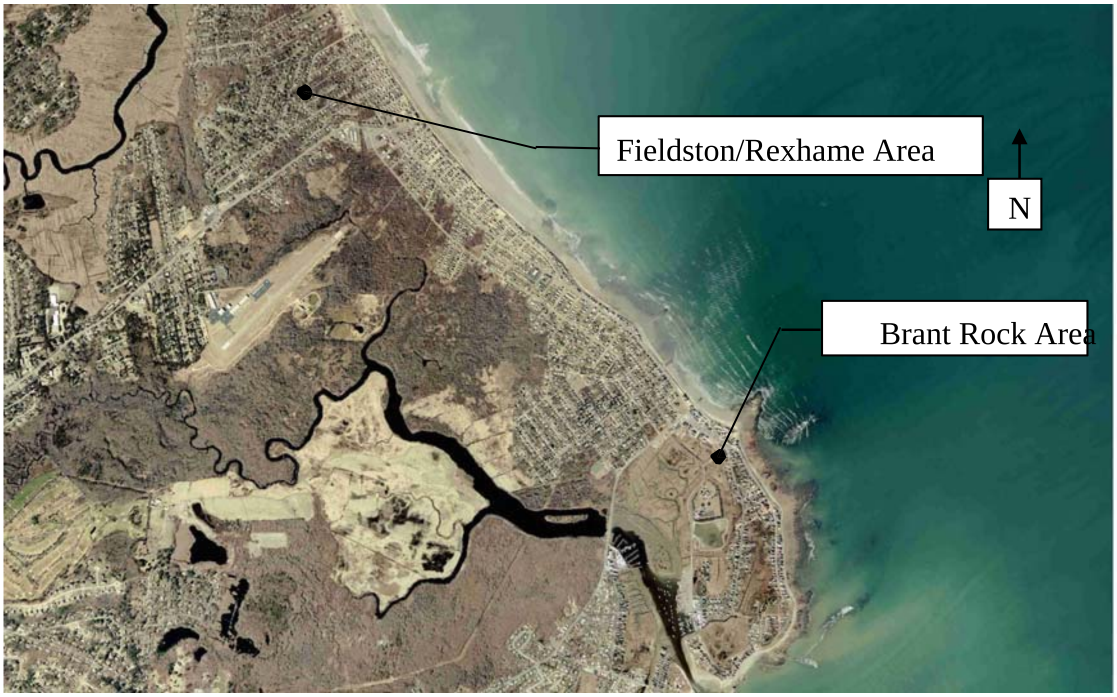

Figure 2. Fieldston and Brant Rock locations

The Fieldston and Brant Rock locations are low lying areas. Typical flooding in these areas is due to extra tropical winter storms, known better as Nor'easters, overtopping the coastal seawalls. In Figures 3 and 4 the contoured elevations are shown for each area and in Table 1 the ocean tidal regime has been provided to demonstrate the elevation issues of each site.

The 1 foot contour data was provided by the Town of Marshfield's GIS department. The Boston tidal benchmark data was provided due to: 1) the proximity of Marshfield to Boston, and 2) the minor differences noted on the NOAA tidal benchmark/prediction web pages between the two areas. Additional sources of tidal elevation data was explored including statistical analysis completed by Nadal-Caraballo and Melby (2013). This data was used to verify the benchmark data used in the analysis and used as a source of data for more extreme water levels not provided by tidal benchmark data (less frequent than the 100 year event).

As seen in Figure 3, Fieldston has ground elevations that are lower than Mean High Water (MHW) and the Brant Rock area has elevations that are lower than the annual high tide/return period water level. Recently the seawall at Fieldston was reconstructed and increased by the town to elevation +24' MLW, or +18.5' NAVD88. The Brant Rock area is protected by an older seawall with an approximate crest elevation of +21' MLW or +15.5' NAVD88. In addition to the seawalls, high ground exists between the low areas and the ocean.

Table 1. Boston, MA Bench Mark Data

	MLLW	MTL	NGVD29	NAVD88
Datum	**feet**	**feet**	feet	**feet**
100-Year Return Period Water Level (adjusted to 2006)[1]			10.47	9.66
50-Year Return Period Water Level (adjusted to 2006)[1]			10.17	9.36
25-Year Return Period Water Level (adjusted to 2006)[1]				8.90
15-Year Return Period Water Level (adjusted to 2006)[1]				8.60
10-Year Return Period Water Level (adjusted to 2006)[1]			9.17	8.36
5-Year Return Period Water Level (adjusted to 2006)[1]				8.05
2-Year Return Period Water Level (adjusted to 2006)[1]				7.56
1-Year Return Period Water Level (adjusted to 2006)[1]			7.57	6.76
Max. Annual Predicted Tide (2005 to 2023)[2]	12.50	7.41	7.80	6.99
Max. Annual Predicted Tide (average)[3]	12.23	7.14	7.53	6.72
MEAN HIGHER HIGH WATER	10.27	5.18	5.57	4.77
(MHHW) MEAN HIGH WATER (MHW)	9.83	4.74	5.13	4.32
NORTH AMERICAN VERTICAL DATUM-1988	5.51	0.42	0.81	0.00
(NAVD) Mean Sea Level (MSL)	5.20	0.11	0.50	-0.31
MEAN TIDE LEVEL	5.09	0.00	0.39	-0.42
(MTL) NGVD29	4.70	-0.39	0.00	-0.81
Mean Low Water (MLW)	0.45	-4.64	-4.25	-5.06
Mean Lower Low Water (MLLW)	0.00	-5.09	-4.70	-5.51

LENGTH OF SERIES: 19 Years

TIME PERIOD: January 1983 - December 2001

TIDAL EPOCH: 1983-2001

[1]The elevations were adjusted using the sea level rise rate provided by NOAA for Boston Harbor. The elevations were corrected from 1988 (study completion date) to 2006 by applying the 0.87 feet/century rise rate over the 19 year time period or a correction of 0.17 feet.

[2]The elevation was determined using Tides and Currents Pro software to find the maximum annual predicted tide and then taking the maximum from that list (19 years of tidal predictions used)

[3]The elevation was determined using Tides and Currents Pro software to find the maximum annual predicted tide and then the average was taken (19 years of tidal predictions used)

3.0 <u>Site Specific Flooding</u>

The Fieldston area is believed to be prone to two types of flooding resulting from the low elevation of the area and poor local drainage. Fresh water (rain and snow) that falls in the immediate area is trapped in the “basin” formed by the bowl shaped topography and Ocean St., which acts a weir or small dam. As shown in Figures 3 and 11, there is an existing drainage swale/ditch that runs generally from north to south and exits the area under Ocean Blvd to the south. However, as seen in the field, and highlighted by the report titled “Rexhame Area Drainage Improvements” by Greene and Associates dated February 2005, the drainage ditch is over grown, caved in, and poorly graded. The report also found that the existing capacity of the ditch is very small and that events smaller than a 2 year fresh water event would overwhelm its capacity. The analysis developed several alternatives and concluded that upgrading the ditch and Ocean Street culverts could improve conditions to the point where the area would be “protected” from a 25 year fresh water event. However, the analysis did not take into account water from wave overtopping the seawall and flowing down into the basin, which will be considered in this analysis

The Brant Rock area is susceptible to fairly frequent coastal flooding due to the area’s low elevation, their proximity to the ocean/Green Harbor, and local drainage issues. The town reported that the largest flooding issue is from waves overtopping the seawall and the ocean water collecting in the low areas along Ocean Street. The topography around this area is complex. As shown in Figures 4 and 12, the eastern border of this area is fronted by a seawall, to the south is an elevated headland type feature, to the west is a basin/salt marsh area that is separated from Green Harbor by a dike and tide gates, and to the north there is a hill with a significant elevation increase. As the seawall is overtopped the water initially collects in the salt marsh/basin area to the west. However, once these basins are full, the water overflows and floods the buildings and streets of the Brant Rock area.

4.0 Coastal Flooding Analysis

As discussed in the previous analysis, both the Fieldston and Brant Rock areas are prone to both freshwater and coastal flooding. The purpose of this analysis was to determine the frequency of interior flooding at a basic level due to coastal flooding at each site. Since the Corp’s CAP Section 103 Study Authority was the motivating authority for this investigation, (all projects must be formulated for hurricane and storm damage reduction and not for local drainage issues), only the flooding due to coastal flooding in each area was assessed in this report. Given the complexities of the drainage for each area a simplistic approach to the flooding potential was taken. The supporting calculations/information along with a list of the key assumptions has been provided in the next section.

4.1 Site Condition Calculations and Overtopping Analysis Assumptions

1. The first assumption was that all of the volume of water that entered each area during a storm stayed in that area until it overflowed the site’s topography and eventually drained into Green Harbor. For the Fieldston area the maximum flood elevation was controlled by the elevation of Ocean Street at the southern end of the area. The elevation of the road was 4.5 feet NAVD88 and as such once the water elevation reached that elevation, water would overflow the road and enter Bass Creek/Green Harbor. For the Brant Rock area the controlling elevation was 8 feet NAVD88 and was located at the northwest corner of the flood area (Dyke Road and Town Pier Road). Once flood waters reached this elevation, water would overflow this point and enter Green Harbor. Due to the Brandt Rock area having a very complex flood profile due to the low elevations of the land, tidal gates on Green Harbor, tidal gates on the salt marshes at Brant Rock, and the storm/tidal dynamics of Green Harbor our drainage assumptions are general in nature.

2. Further clarifying assumption #1 was that the water entering each area did not leave the area via storm water culverts or channels. As discussed and shown in Figure 3, the Fieldston area currently has an incomplete drainage ditch and due to the poor condition of the upper reaches of the channel (as discussed in Section 2.0), and the fact it is overwhelmed from just the fresh water storm runoff, the assumption of no “ocean” water draining being able to be carried was considered reasonable. For the Brant Rock area the salt marsh/upper basin area is cut off from

the lower Green Harbor River by tidal control gates that are closed during storms to prevent tidal surges from flowing into the upper basin area (upstream from the tide gates located at Dyke Road, Route 139). As such no street and property drainage is available except for the overflow at the corner of Dyke Road and Town Pier Road. Once again for this level of study, and this water flow situation, the assumption of no water flowing out of from this area was assumed to be reasonable.

3. Infiltration of the overtopped water was also assumed to be negligible and was not considered for this level of study. In the Fieldston area this is certainly believed to be a valid assumption due to the high water table and the local flooding from the freshwater runoff. At Brant Rock, the elevation is slightly higher so there may be more potential for infiltration, but due to the high water table it is likely low and too insignificant for this study.

4. The storm events of various return frequencies were "created" for the sites due to the lack of existing processed data. The 1 through 100 year Storm events were generated using the elevations in the New England Tidal Profiles Study from 1988. As the 1/500 year event was required for the analysis at Fieldston, an estimated offset from the Nadal-Caraballo and Melby analysis was applied to the New England tidal profiles to estimate this data value.

The storms were generated by taking a spring tide tidal profile from a predicted tide for the area and adding a "surge" to the tidal profile so that it would equal the return frequency tidal elevation. Each storm was assumed to last over two high tide events. While it is realized that this is less than ideal, it would be difficult to perform a comprehensive return period analysis with the associated tidal profiles that would provide a greater level of accuracy. The 1, 5, and 10 year created storm tidal profiles for example, are shown in Figure 6. In this way, return period tide hydrographs were created.

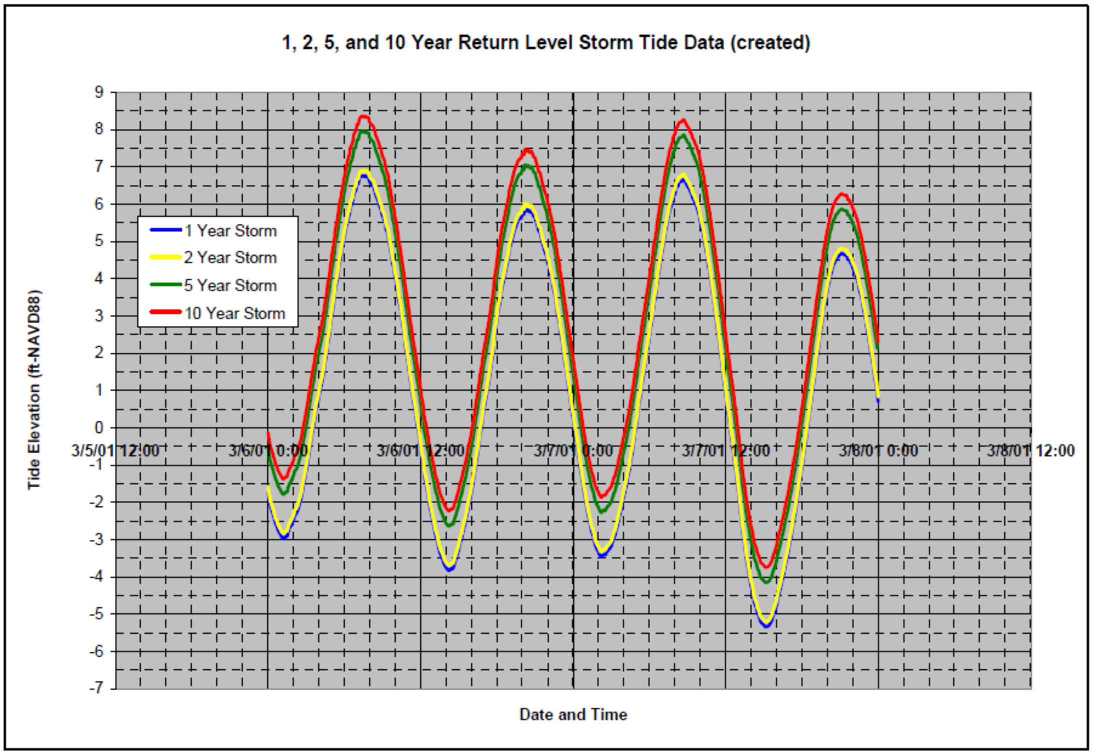

Figure 5. Created return period tide hydrographs

5. The storm waves were calculated using the water depth in front of the seawall since depth limited conditions apply at this site. This means the water depth in front of the seawall directly controls the size of the waves in front of the seawall. Significant wave height, or H_s, was calculated by multiplying the depth limiting factor of 0.60 times the water depth. This factor was taken from the CEM and can be found in Sections (II-4-2-a-4) and (II-2-2-b-3). Water depth was determined by using the NOAA LIDAR data from 2000 (Figures 7) and the storm water elevation. Based on the NOAA LIDAR data it was assumed that the beach elevation in front of the seawall at both locations was
4 feet NAVD88. (This has been verified with more recent (2012) Lidar).

6. In order to calculate the overtopping volumes the formulation provided in the Wave Overtopping of Seawalls Design and Assessment Manual HR Wallingford Ltd February 1999 R&D Technical Report W178 was used. Based on the cross section of the Seawall (Figure 8) this formula was thought to be the most applicable. The equation and the necessary inputs have been provided below as Table 2. To calculate the overtopping volume throughout the storms a Microsoft Excel spread sheet was developed. A portion of the spread sheet for the 5 year event at Fieldston was included as Table 3. As shown in the spreadsheet the tidal elevation is provided every six minutes. The water depth changes with each water surface elevation change, and therefore the depth limited wave height is changed as well. This information was fed into the overtopping formula which results in the overtopping volume at that point in the storm. The overtopping rate was initially reported as cubic feet per linear foot of wall length per second. This was converted to cubic feet per second per 1,000' of seawall (Figure 9 and 10) and then totaled to reach a total overtopping volume from the storm. The same procedure

was followed for both Fieldston and Brant Rock, with the only difference being the length of seawall that is overtopped (1,000 feet and 1,500 feet respectively). The total overtopping volume for each storm can be seen in Tables 4 and 6 in the next section.

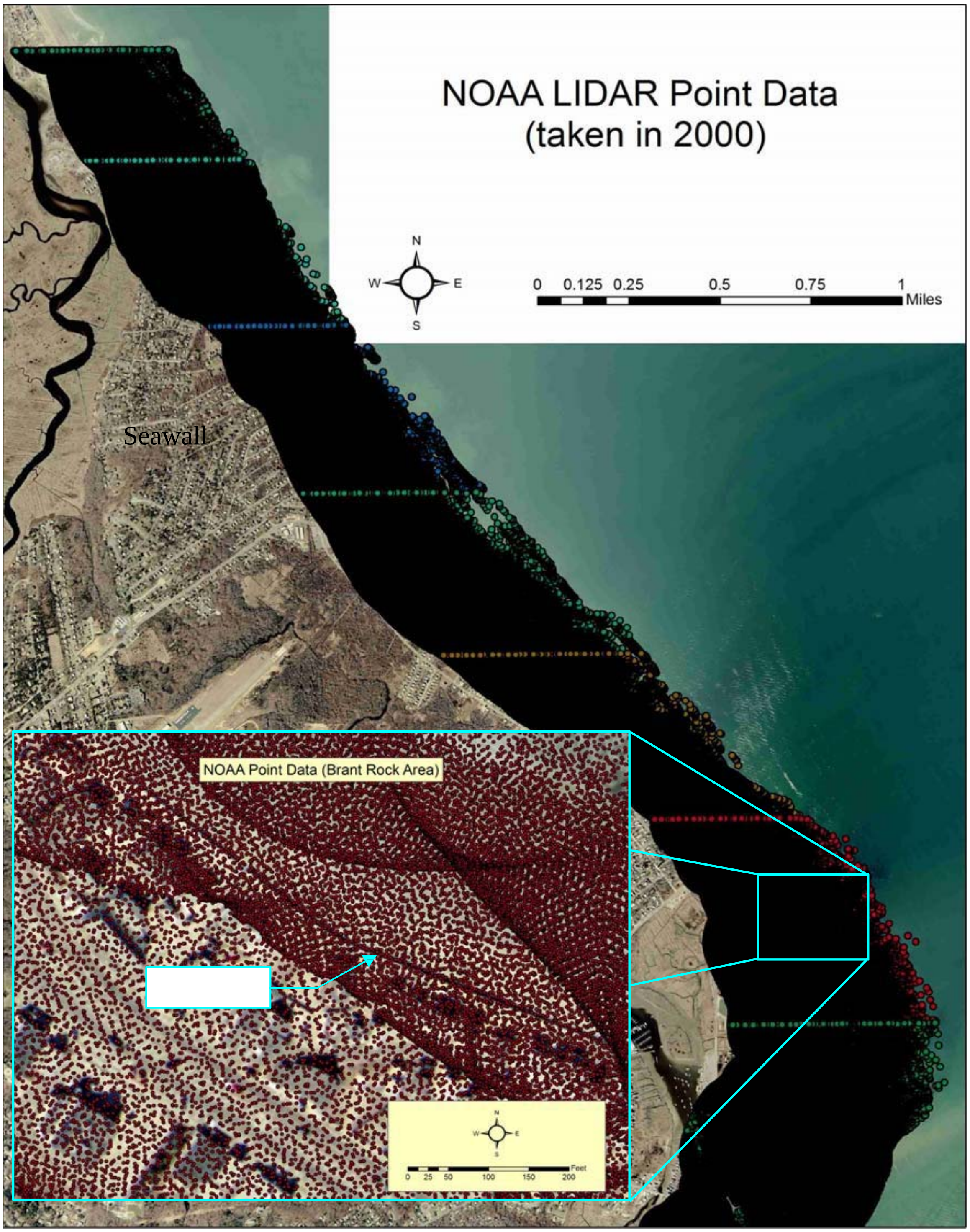

Figure 6. NOAA LIDAR point data from 2000

Figure 7. Photo of representative seawall cross section

Table 2. Seawall overtopping formulation (HR Wallingford Technical Report W178)

BOX 3.7
PLAIN VERTICAL WALLS
MEAN OVERTOPPING DISCHARGE

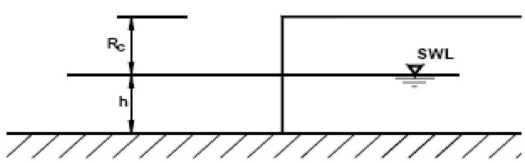

Figure 3.11 Plain vertical wall

NORMAL WAVE ATTACK
First calculate h_* to determine whether the waves are predominantly impacting or reflecting.
The parameter h_* is given by :-

$$h_* = (h/H_s)(2\pi h/(gT_m^2)) \qquad (22)$$

where h is the water depth at the toe of the structure (m)
H_s is the significant wave height at the toe of the structure (m)
g is acceleration due to gravity (m/s^2)
T_m is the mean wave period at the toe of the structure (s)

Impact waves predominate when $h_* \leq 0.3$, in which case the following equation applies:-

$$Q_h = 0.000137\ R_h^{-3.24} \qquad (24)$$

where Q_h is the dimensionless discharge, given by :-

$$Q_h = \{Q/(gh^3)^{0.5}\} / h_*^2 \qquad (25)$$

and R_h is the dimensionless crest freeboard, given by :-

$$R_h = (R_c/H_s)h_* \qquad (26)$$

Equation 26 is valid for $0.05 < R_h < 1.00$

Table 3. Example of Excel spread sheet used to calculate overtopping rates and volumes

25 Year Storm Event

time	Water Elev.	Bottom Elev.	Elev. of Seawall	T_p	Depth (h)	Rc	H_s	T_m	h_*	Rh	Qh	Q	Q	Q (Brant Rock)	Total Volume
date and time	feet	feet	feet	sec.	meters	meters	meters	second				$M^3/s/m$	$ft^3/s/ft$	$ft^3/s/1000'$	ft^3
3/6/01 0:00	0.41	4	15.5	13	0.00	4.599	0.00	10.66	9.39E-11	0.071974	0.690978	0.0000	0.00	0.00	8.13691E-26
3/6/01 0:06	0.22	4	15.5	13	0.00	4.657	0.00	10.66	9.39E-11	0.072881	0.663525	0.0000	0.00	0.00	7.81363E-26
3/6/01 0:12	0.03	4	15.5	13	0.00	4.715	0.00	10.66	9.39E-11	0.073787	0.637483	0.0000	0.00	0.00	7.50696E-26
3/6/01 0:18	-0.08	4	15.5	13	0.00	4.749	0.00	10.66	9.39E-11	0.074312	0.623015	0.0000	0.00	0.00	7.33659E-26
3/6/01 0:24	-0.18	4	15.5	13	0.00	4.779	0.00	10.66	9.39E-11	0.074788	0.610233	0.0000	0.00	0.00	7.18607E-26
3/6/01 0:30	-0.31	4	15.5	13	0.00	4.819	0.00	10.66	9.39E-11	0.075409	0.594125	0.0000	0.00	0.00	6.99638E-26
3/6/01 0:36	-0.44	4	15.5	13	0.00	4.859	0.00	10.66	9.39E-11	0.076029	0.578569	0.0000	0.00	0.00	6.81319E-26
3/6/01 0:42	-0.49	4	15.5	13	0.00	4.874	0.00	10.66	9.39E-11	0.076267	0.572728	0.0000	0.00	0.00	6.7444E-26
3/6/01 0:48	-0.61	4	15.5	13	0.00	4.910	0.00	10.66	9.39E-11	0.076839	0.55902	0.0000	0.00	0.00	6.58299E-26
3/6/01 0:54	-0.68	4	15.5	13	0.00	4.932	0.00	10.66	9.39E-11	0.077173	0.551222	0.0000	0.00	0.00	6.49116E-26
3/6/01 1:00	-0.73	4	15.5	13	0.00	4.947	0.00	10.66	9.39E-11	0.077412	0.545739	0.0000	0.00	0.00	6.42659E-26
3/6/01 1:06	-0.8	4	15.5	13	0.00	4.968	0.00	10.66	9.39E-11	0.077746	0.538182	0.0000	0.00	0.00	6.3376E-26
3/6/01 1:12	-0.84	4	15.5	13	0.00	4.980	0.00	10.66	9.39E-11	0.077936	0.533925	0.0000	0.00	0.00	6.28747E-26
3/6/01 1:18	-0.82	4	15.5	13	0.00	4.974	0.00	10.66	9.39E-11	0.077841	0.536048	0.0000	0.00	0.00	6.31247E-26
3/6/01 1:24	-0.77	4	15.5	13	0.00	4.959	0.00	10.66	9.39E-11	0.077603	0.541404	0.0000	0.00	0.00	6.37554E-26
3/6/01 1:30	-0.77	4	15.5	13	0.00	4.959	0.00	10.66	9.39E-11	0.077603	0.541404	0.0000	0.00	0.00	6.37554E-26
3/6/01 1:36	-0.65	4	15.5	13	0.00	4.923	0.00	10.66	9.39E-11	0.07703	0.554547	0.0000	0.00	0.00	6.53031E-26
3/6/01 1:42	-0.55	4	15.5	13	0.00	4.892	0.00	10.66	9.39E-11	0.076553	0.56582	0.0000	0.00	0.00	6.66306E-26
3/6/01 1:48	-0.49	4	15.5	13	0.00	4.874	0.00	10.66	9.39E-11	0.076267	0.572728	0.0000	0.00	0.00	6.7444E-26
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3/6/01 2:00	-0.34	4	15.5	13	0.00	4.828	0.00	10.66	9.39E-11	0.075552	0.590487	0.0000	0.00	0.00	6.95354E-26
3/6/01 2:06	-0.21	4	15.5	13	0.00	4.788	0.00	10.66	9.39E-11	0.074932	0.606466	0.0000	0.00	0.00	7.1417E-26
3/6/01 2:12	-0.18	4	15.5	13	0.00	4.779	0.00	10.66	9.39E-11	0.074788	0.610233	0.0000	0.00	0.00	7.18607E-26
3/6/01 2:18	-0.11	4	15.5	13	0.00	4.758	0.00	10.66	9.39E-11	0.074455	0.619144	0.0000	0.00	0.00	7.291E-26
3/6/01 2:24	0.01	4	15.5	13	0.00	4.721	0.00	10.66	9.39E-11	0.073882	0.63482	0.0000	0.00	0.00	7.4756E-26
3/6/01 2:30	0.12	4	15.5	13	0.00	4.688	0.00	10.66	9.39E-11	0.073358	0.649649	0.0000	0.00	0.00	7.65022E-26
3/6/01 2:36	0.24	4	15.5	13	0.00	4.651	0.00	10.66	9.39E-11	0.072785	0.666347	0.0000	0.00	0.00	7.84686E-26
3/6/01 2:42	0.45	4	15.5	13	0.00	4.587	0.00	10.66	9.39E-11	0.071784	0.696946	0.0000	0.00	0.00	8.20719E-26
3/6/01 2:48	0.6	4	15.5	13	0.00	4.542	0.00	10.66	9.39E-11	0.071068	0.719936	0.0000	0.00	0.00	8.47791E-26
3/6/01 2:54	0.78	4	15.5	13	0.00	4.487	0.00	10.66	9.39E-11	0.07021	0.748852	0.0000	0.00	0.00	8.81843E-26

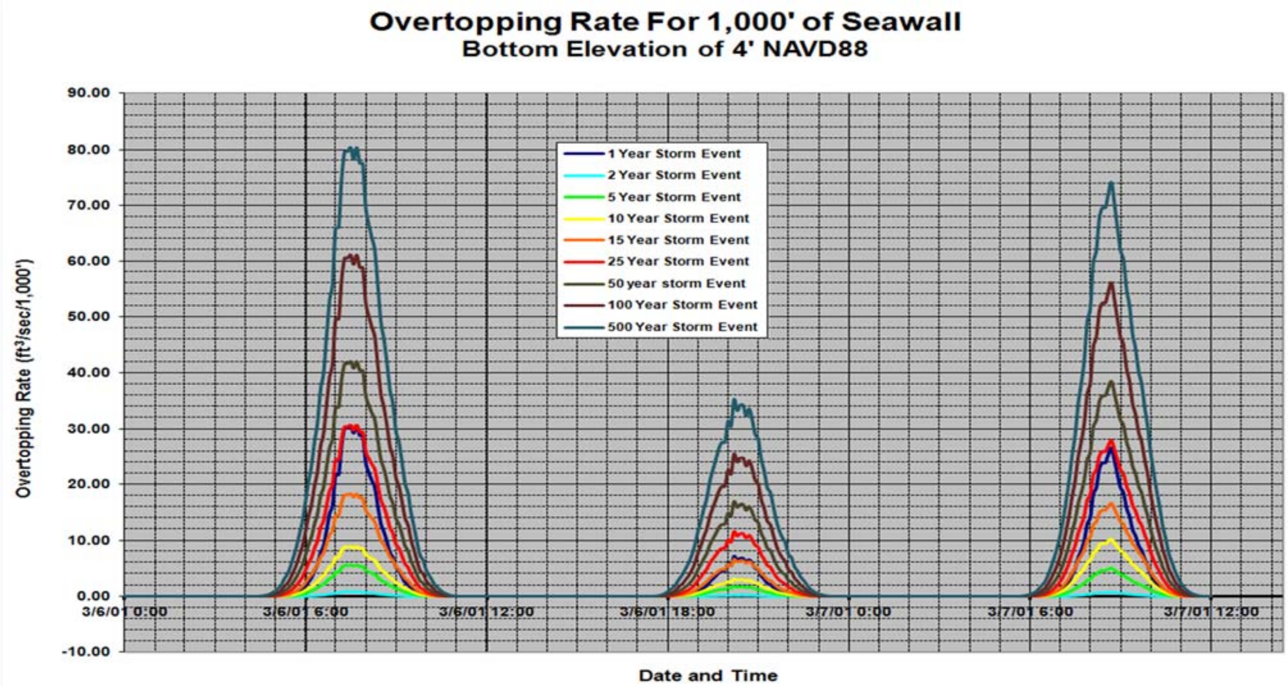


Figure 8. Overtopping rate for the Fieldston area seawall.

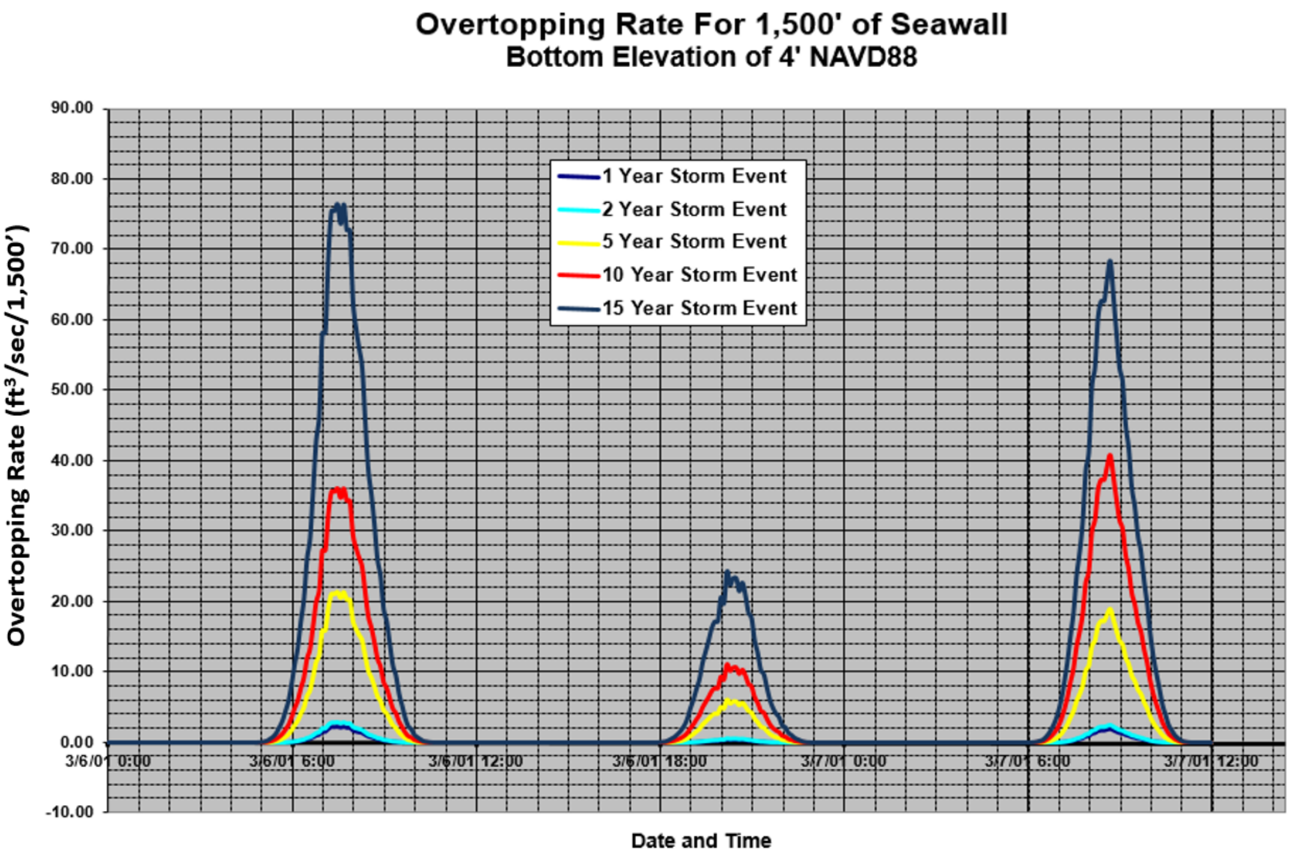


Figure 9. Overtopping rate for the Brant Rock area existing seawall.

4.2 Flooding Depth Determination

4.2.1 Existing Conditions

Once the total volume of overtopped water was determined for each storm the flooding depth for each area was mapped in ArcMap GIS. The maximum elevation of the water was determined by calculating the volume below each elevation for each area using digital terrain models developed from the Marshfield contour data and using the volume calculator in the ArcMap 3-D Analyst extension. The digital terrain models used for each area can be seen in Figures 11 and 12. With that information, the flood elevation that would be reached during each storm was determined. Tables 4 through 7 show the "storage" volume vs. elevation for each area and show the total storm overtopping volumes. This established existing conditions for Fieldston, and for both the existing condition and with a 2-foot wall increase for Brant Rock. To clarify how this information was used, examples for Brant Rock and Fieldston were provided. Flooding depths for both areas are shown in Figures 13 through 17. For more extreme interior flood depths of the Brant Rock area, FEMA BFE (Base Flood Elevation's) informed the interior flood stages.

Looking at Table 5, it can be seen that the total overtopping volume for the existing condition at Brant Rock seawall during a 2 year storm is calculated to be 37,000 cubic feet. Looking at Table 4 it can be seen that this volume will "fill up" the Brant Rock area to an elevation of roughly 4.2 feet. It can also be seen that for anything greater than roughly a ten year storm, the overtopping volume would overwhelm the area and pass over Dyke St. which is at elevation 8 feet NAVD88.

Tables 4 and 5. Brant Rock storage volume vs. elevation and storm overtopping volume

Brant Rock Area Storage Capacity and Storm overtopping Volumes

Volume vs. Elevation

Elevation ft-NAVD88	Volume ft^3
4	27,850
4.5	49,178
5	80,069
5.5	126,720
6	180,489
6.5	269,970
7	382,133
7.5	535,913
8	710,897

Overtopping Volume vs. Storm Event existing

Storm Return Period Year	Volume of Overtopping ft^3	Resulting Flood Stage Elevation (ft)
1	28,705	3
2	37,105	4.2
5	345,184	6.8
10	673,470	7.9

In the same way we can see that the total overtopping volume for the existing condition at Fieldston during a rare 500 year event would produce a volume of 1,543,000 ft^2. Table 6 shows that this corresponds to an interior flood elevation of less than 4.5 feet NAVD88. At this point it is assumed the water would then overflow and enter Bass Creek/Green Harbor. Thus an extreme event would not fill the system.

Tables 6 and 7. Fieldston storage volume vs. elevation and storm overtopping volume

Fieldston/Rexhame Area Storage Capacity and Storm overtopping Volumes

Elevation vs. Volume

Elevation ft-NAVD88	Volume ft^3
1	5,360
1.5	67,985
2	163,141
2.5	323,514
3	525,626
3.5	827,635
4	1,181,530
4.5	1,630,414

Overtopping Volume vs. Storm Event		
Storm Return Period	Volume of Overtopping	Elevation
Year	ft^3	(ft)
1	7640	1.02
2	9800	1.04
5	82700	1.58
10	154500	1.97
15	295231	2.43
25	511,284	2.98
50	740,000	3.38
100	954,000	3.75
500	1,527,950	4.39

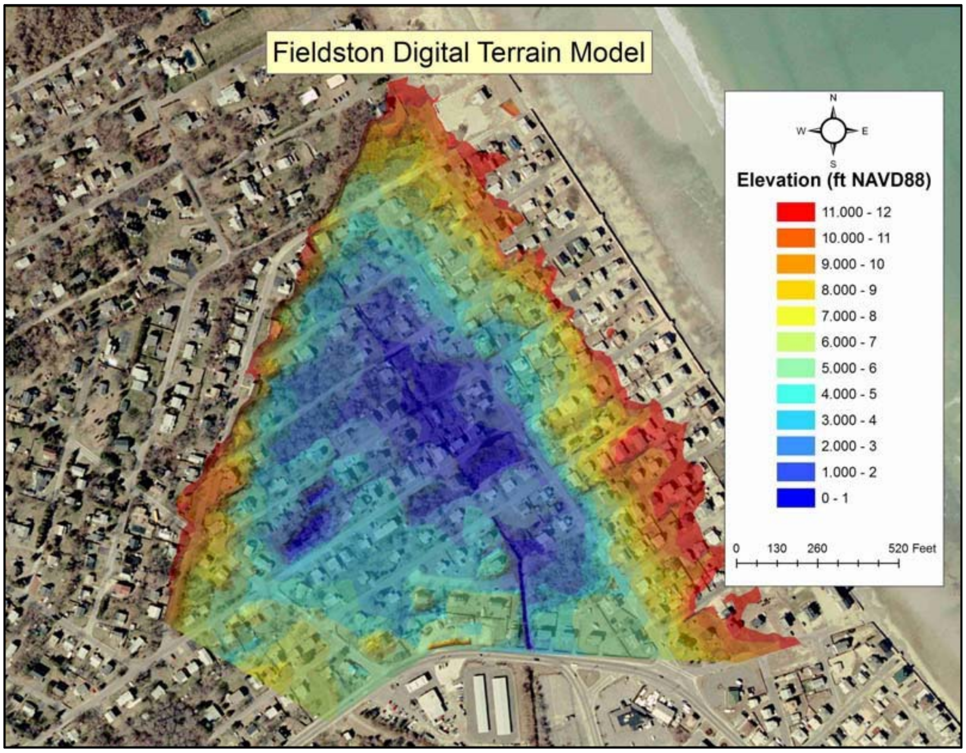


Figure 10. Fieldston digital terrain model.

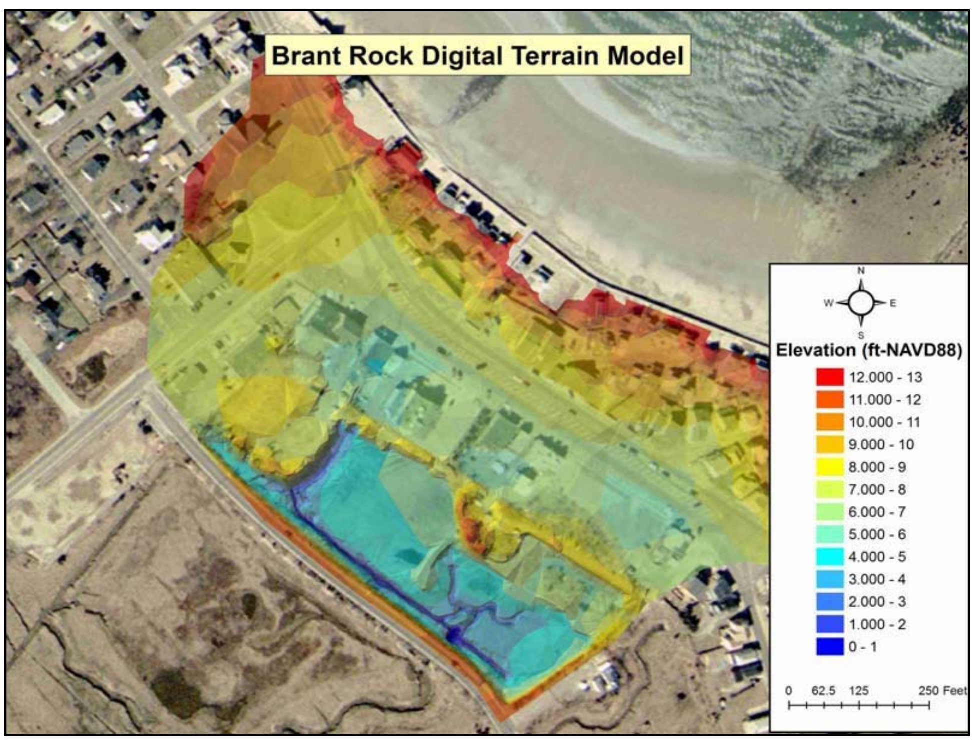


Figure 11. Brant Rock digital terrain model.

Figure 12. Fieldston Inundation for 2 year storm - existing conditions

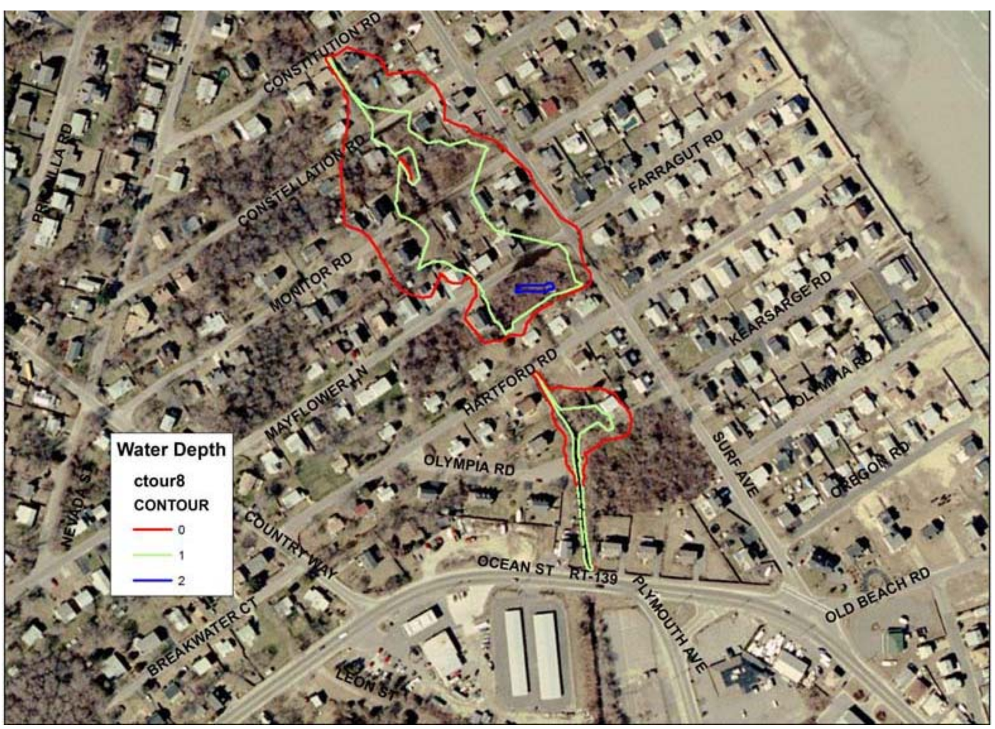


Figure 13. Fieldston Inundation for 10 year storm - existing conditions

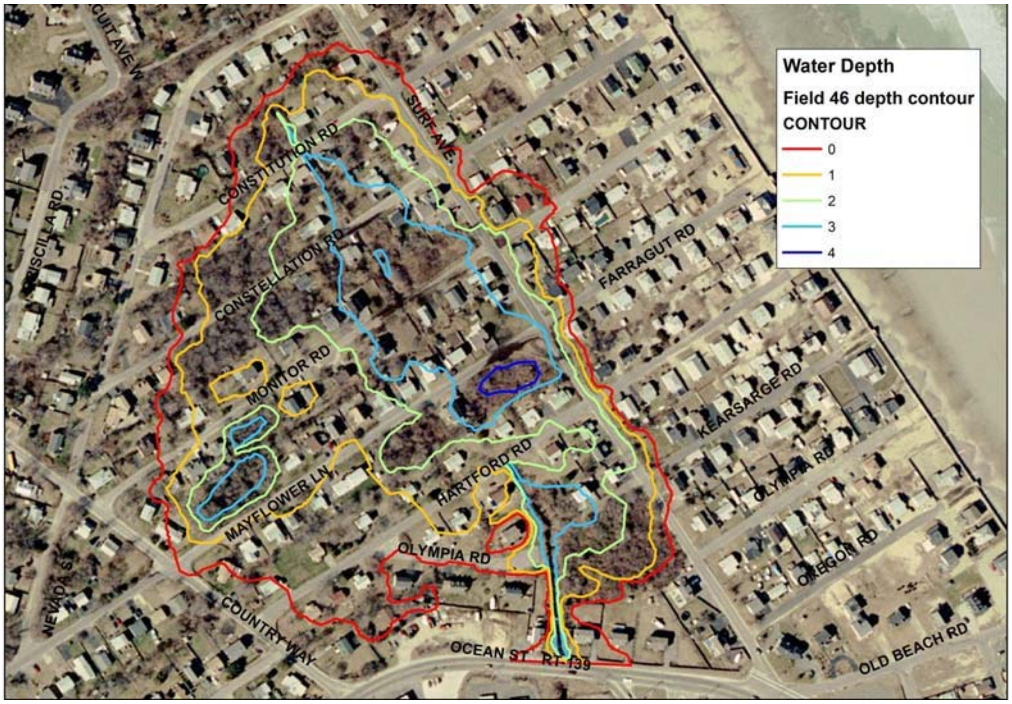


Figure 14. Fieldston Inundation for 500 year storm - existing conditions

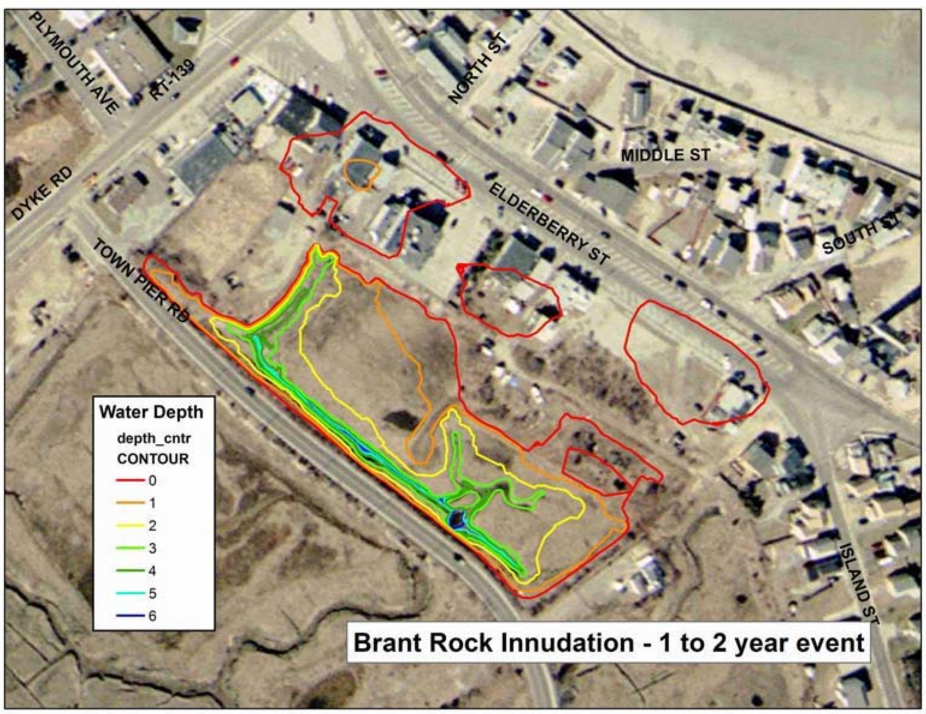


Figure 15. Brant Rock for 1 to 2 year storm - existing conditions

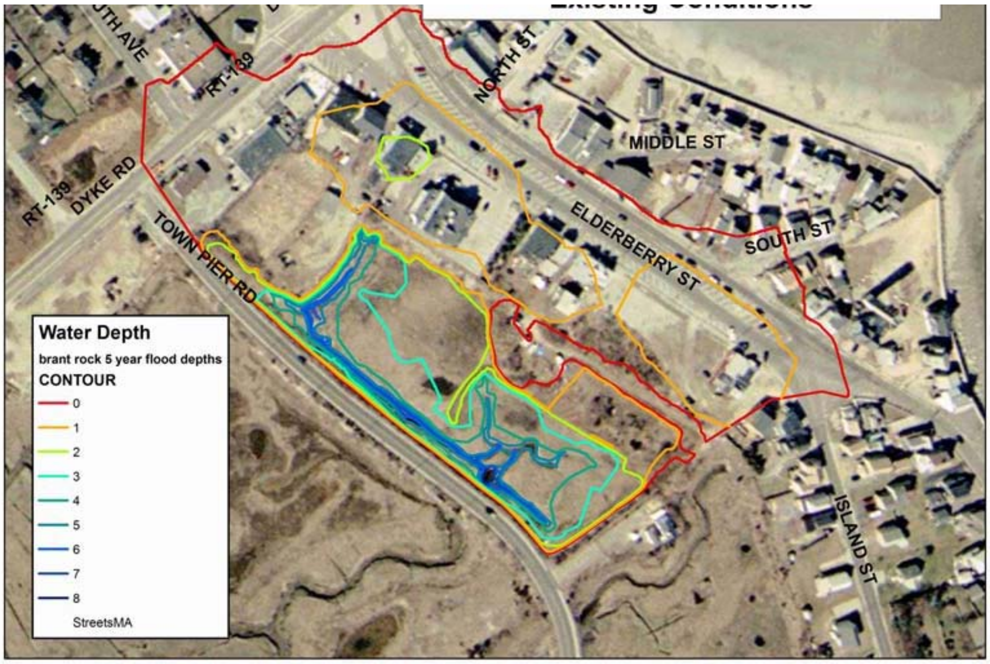


Figure 16. Brant Rock for 10+ year storm - existing conditions

4.2.2 Previous Studies and Observational Information

Without actual overtopping and flood depth data to verify the calculations, past studies and personal observations from the Town staff and residents were checked to see if the calculated values were reasonable. Comparison to previous studies was difficult since they did not look at the specific issue of wave overtopping and subsequent flooding. The previous studies by the Corps and consultants for the Town analyzed flooding due to Green Harbor, tide gate control, fresh water run off/drainage, and a combination of all three. This investigation's focus was to investigate the impact of wave/ocean overtopping the seawall.

The FEMA map for the area, identifies two areas of interest do have AO, AH, and AE type flooding (Figure 18). As shown in flood zone legend in Figure 18 this is sheet flow type flooding, and so for this area, overtopping of the seawall and the subsequent flow down to the lower elevations of each area.

At Brant Rock significant overtopping was reported by town officials fairly frequently (1 to 5 year events). The overtopping and subsequent low elevation flooding has resulted in frequent residential and commercial property losses. At the Brant Rock area it has been noted that the flooding is caused almost entirely by wave overtopping of the seawall. This is logical when examining the surrounding topography and noting the relatively small area that drains into Brant Rock. Due to installation of the raised seawall for the Fieldston area, low lying area flooding is generally caused by fresh water draining.

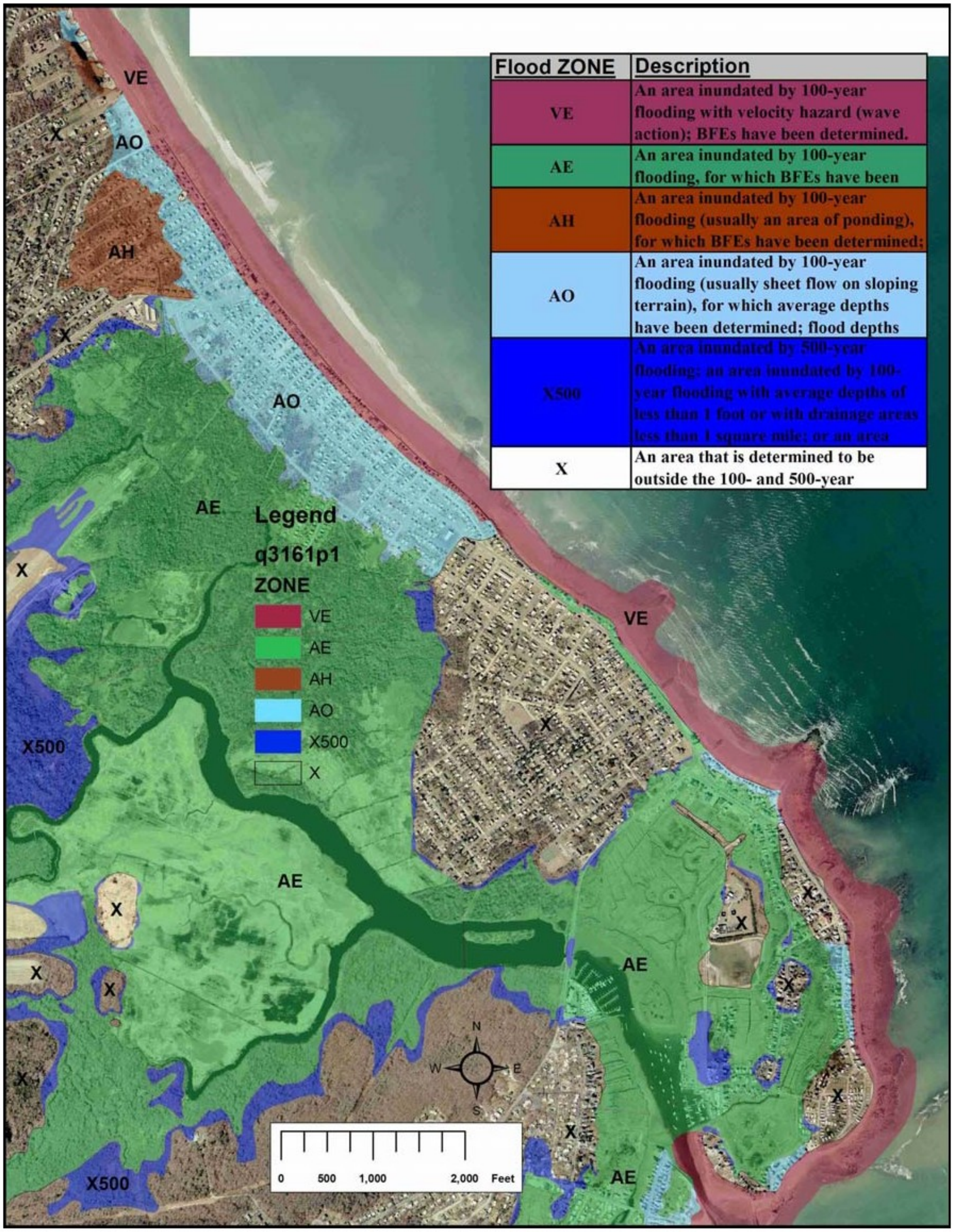


Figure 17. FEMA flood zone mapping

4.2.3 With-Project Condition

To determine if a cost effective alternative was available to help reduce the wave overtopping flooding problems, increasing the height of the seawall by two feet at Brant Rock was investigated, as well as elevating homes/commercial structures.

To analyze the risk reduction effects of increasing the height of the wall at Brant Rock the same procedure using the same storm water levels, wave heights, and overtopping analysis was used to determine overtopping rates for a with-project condition. The same method for determining the flood levels for each area were also used. The updated overtopping rates for the various return period storms for Brant Rock was provided as Figures 24 (same as Figures 10 and for the existing conditions). Once again, for the more extreme interior flood depths, FEMA BFE's were used.

The storage volume vs. elevation and total storm overtopping volumes has been provided in Tables 8 and 9. The revised flooding depths for the Brant Rock, with-project conditions, are provided in Figures 18 and 19. It can be seen that, when comparing these figures to Figures 15 and 16, the flooding due to frequent flood events is reduced. However, it is calculated that the 15 year storm event would still fully inundate the Brant Rock low elevation area. Significant reduction in flooding would not be achieved given the with-project condition of a raised seawall.

Elevating backshore structures was also analyzed for the with-project condition for both the Fieldston and Brandt Rock areas. To allow for the greatest benefit for the affected property owners, it is assumed structures would be elevated over the 100 year flood level as determined by FEMA, elevation 10' NAVD88. No additional overtopping analysis was required for the analysis of this alternative.

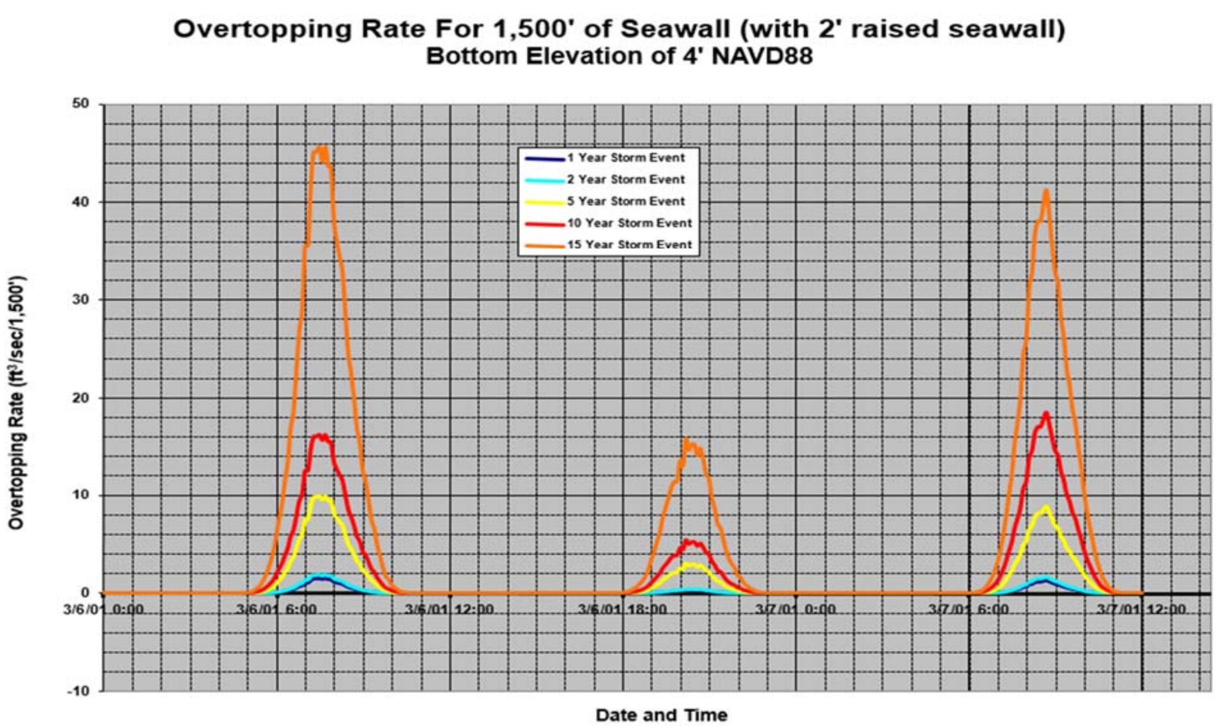


Figure 18. Overtopping rate for the Brant Rock area seawall (with 2' seawall raise).

Table 8 and 9. Brant Rock storage volume vs. elevation and storm overtopping volume (with 2' seawall raise)

<u>Brant Rock Area Storage Capacity and Storm Overtopping Volumes (with 2' seawall raise)</u>

Volume vs Elevation

Elevation ft-NAVD88	Volume ft^3
4	27,850
4.5	49,178
5	80,069
5.5	126,720
6	180,489
6.5	269,970
7	382,133
7.5	535,913
8	710,897

Overtopping Volume vs. Storm Event with 2 foot wall increase

Storm Return Period Year	Volume of Overtopping ft^3	Elevation (ft)
1	17,270	3
2	22,100	3.9
5	194,666	6
10	369,590	7
15	713,407	8+

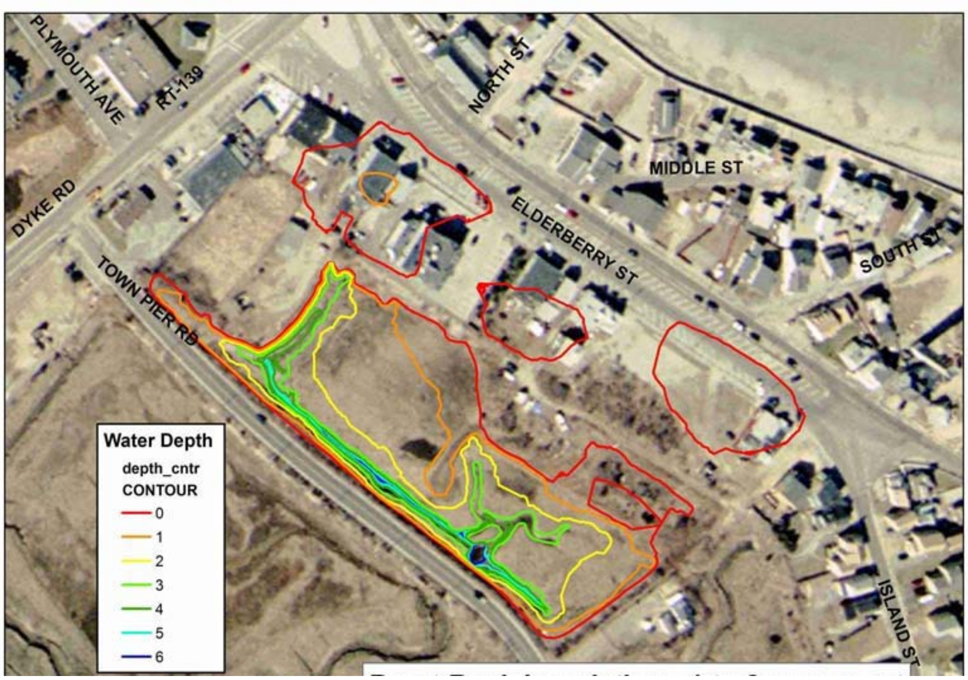


Figure 19. Brant Rock for 5 year storm – With project conditions

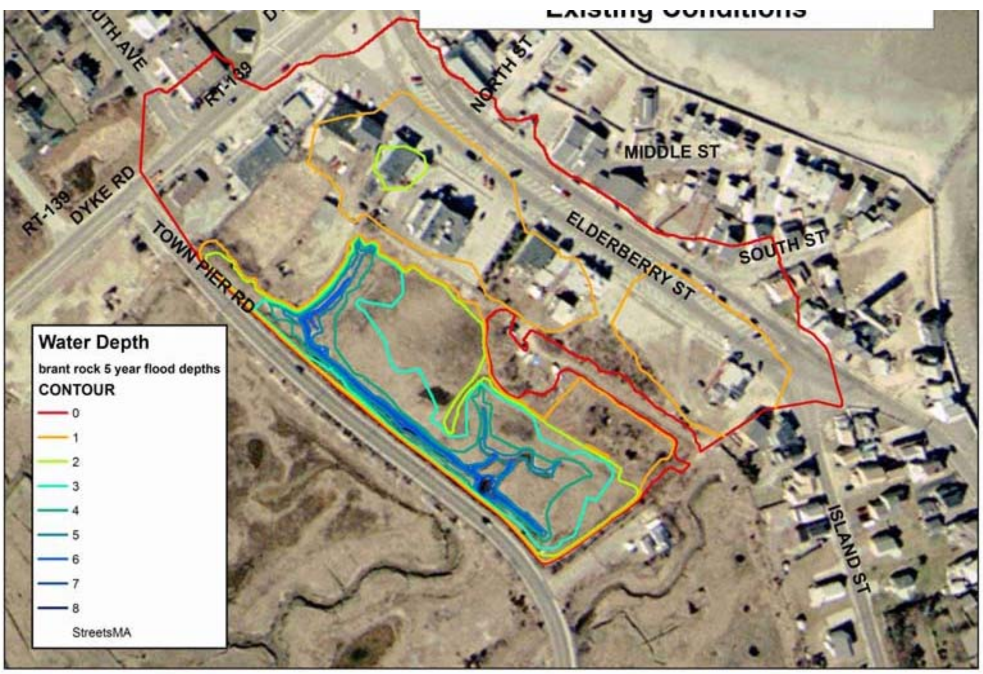


Figure 20. Brant Rock for 20+ year storm – With project conditions

4.2.4 Sea Level Rise Considerations

As ocean level rises, overtopping volumes will increase for both the with and without project conditions due to less freeboard. Larger waves will be able to make it to the seawall due to increased water depth over the existing beach. Water levels used in the base overtopping analysis summarized above are adjusted to account for historic sea level rise by adding the historic sea level rise rate provided by NOAA for Boston Harbor. This value was assumed constant for the project life in this initial analysis.

Updated SLC guidance in the form of EC 1165-2-211, however, requires a multiple scenario approach for three sea level rise scenarios. These curves are; the historic rate of SLC at the project area, an intermediate SLC curve (modified NRC Curve I), and a high SLC curve (modified NRC Curve III). Each scenario is considered equally plausible. Curves for the Boston gage can be found using the Corps' Institute of Water Resources (IWR) online worksheet and graph plotting website. The address of this web tool is http://www.corpsclimate.us/ccaceslcurves.cfm and the SLC results for the project area have been shown in Figure 21. A 50 year project economic life is shown with a construction completion in 2015. For example, the low curve estimates a rate of 0.17 feet/year in 2010 and 0.61 ft/ year at the end of the 50 year project life.

For this study, however, it was determined that the scenarios did not need to be analyzed. The sea level curves represent a more extreme flood scenario than the initial scenario analyzed. For the Brandt Rock area there was not a significant reduction in damage provided by raising the seawall, from the initial analysis above. The inclusion of more extreme/rare conditions would result in even less flood reduction impact of raising the seawall.
Additionally, when considering the impacts of sea level rise on the elevated homes alternative, recall that maximum flood elevations for each area were controlled by local site conditions (elevations of 4.5 feet NAVD88 and 8 feet NAVD88, respectively). Once the water elevation reached these elevations, it is assumed the water would overflow the road and enter Bass Creek/Green Harbor, and therefore more extreme overtopping scenarios would not result in greater flood depths in these areas. Thus the analysis of more extreme conditions would not result in increased elevations for the elevated homes alternatives.

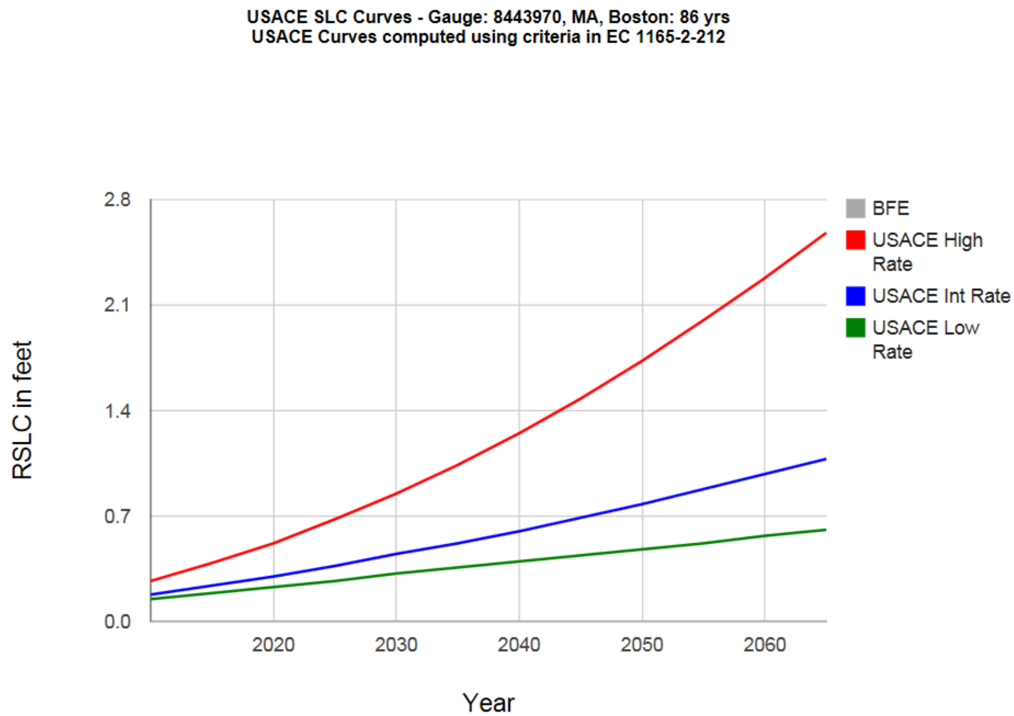


Figure 21. Sea Level Change curves, Boston, MA

5.0 Conclusions and Summary

As part of an appraisal for this Continuing Authority Program (CAP) Section 103 – Storm Damage Reduction Project, a wave overtopping/flooding depth analysis was conducted at two locations within Marshfield, MA. The locations were the Fieldston/Rexhame area and the Brant Rock area. Both locations were relatively low in elevation and suffer from poor drainage, which allowed storm wave overtopping to be trapped in these areas. The Brant Rock location was found to be impacted by lower level coastal storm events (1 to 10 year events) and that the wave overtopping volumes over the existing seawalls were significant enough to cause flooding. Increasing the height of the Brant Rock' seawall was investigated. An overtopping/flooding analysis was done for both the with and without project condition. It was found that, while increasing the wall height by 2 feet reduced flood depths for a low level/frequent storm event, significant flooding is still expected for higher level/lower frequency storms, such that there would not be a significant reduction in flooding. Although elevating the first floors of structures in both Fieldston and Brandt Rock above the BFE will reduce flood damages, these areas were found to lack economic justification.

References

North Atlantic Coast Comprehensive Study. Phase I: Statistical Analysis of Historical Extreme Water Levels with Sea Level Change; Coastal and Hydraulics Laboratory
Norberto C. Nadal-Caraballo and Jeffrey A. Melby October 2013

New England Tide report
Updated Tidal Profiles for the New England Coastline DRAFT December 23, 2011

Marshfield, MA
Section 103 Feasibility Study (revised)
Section 14

Engineering Design Analysis
and MCACES Cost Estimate

Appendix B

Due to the uncertainty of the depth of the seawall at Brant Rock, test pits were dug by the town of Marshfield and Corps personnel on 20 June 2014. At the Test No. 1 location, the seawall's height was 13 feet with the toe of the wall buried 4 feet. At Test Pit No. 2, the seawall's height was 11.4 feet with the toe of the wall buried 5 feet (See Test Pit Locations photo below). It was noted by Marshfield DPW staff that the gravel/sand transport of beach material usually builds up along the seawall at this location during the summer months. During the winter months, the sand and gravel are taken by the tides off-shore exposing the seawall's toe at some locations. If the erosion persists, there is a potential for undermining portions of existing seawall causing overturning or sliding of the wall. The overturning and sliding failure modes were evaluated (see Figure 2) assuming a worst case scenario: seawall with a height of 14 feet, no sand protecting the toe of the seawall and the depth land on the protected side of the seawall is also 14 feet.

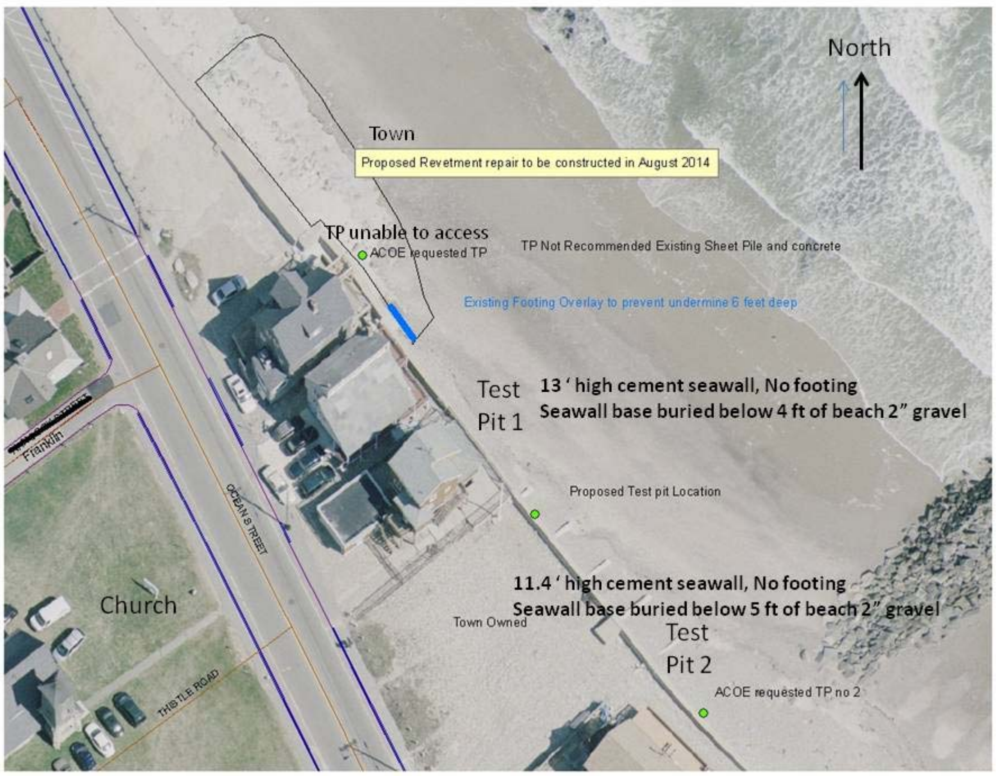


Figure 1: Test Pit Locations

For the sliding failure mode, the wall was analyzed with no sand protecting the toe of the wall. This worst case scenario shows that a minimum of 3.5 feet of compacted sand should be maintained in front of the seawall to prevent the wall from sliding.

Using the worst case scenario, the wall will not overturn. However, if the sand in front of the toe continues to erode the wall could be undermined leading to the potential for the wall to overturn. It is recommended that toe protection be placed in front of the wall to protect the wall from undermining.

Two methods of toe protection were proposed to address these possible failure modes starting at Franklin Street and extending 300 feet southeast, the area of concern. A toe protection revetment and a cobble berm (coarse sand to cobble fill) both built to elevations sufficient to meet sliding and overturning criteria.

The toe protection revetment will consist of armor stone, filter stone, and bedding layers extending out from the seawall 56 feet, with a cobble beach placed at a 5H: 1V slope on top of the toe protection (See. Diagram1: Rip Rap Toe Protection).

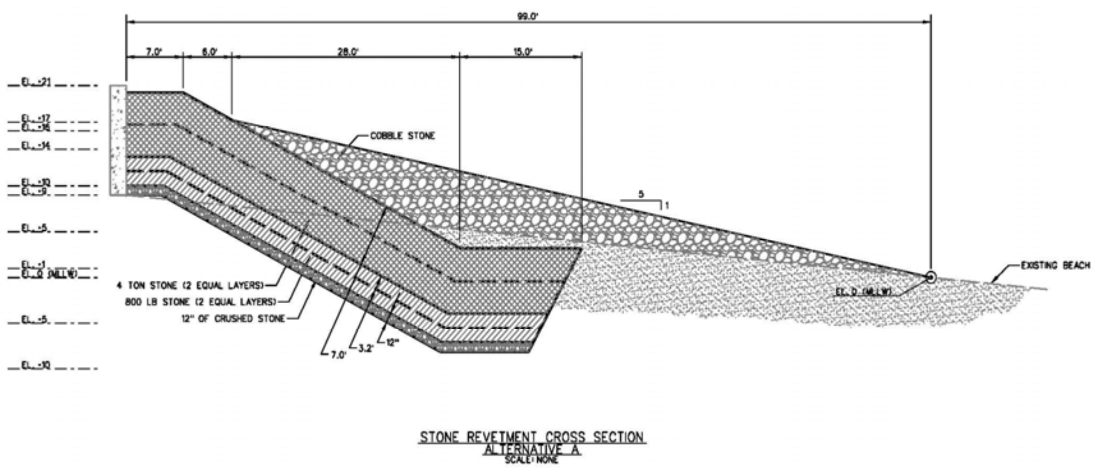


Diagram 1: Rip Rap Toe Protection

The cobble berm alternative (shown below, Diagram 2: Cobble Berm) would consist of a 5 foot think coarse sand to rounded cobble fill extending towards the water about 5 feet and then beginning a shallow slope towards the water until it is met with the existing beach. Maintenance must be carried out every 5 years with 20% of initial fill replaced, to be confident that the berm provides the required toe protection.

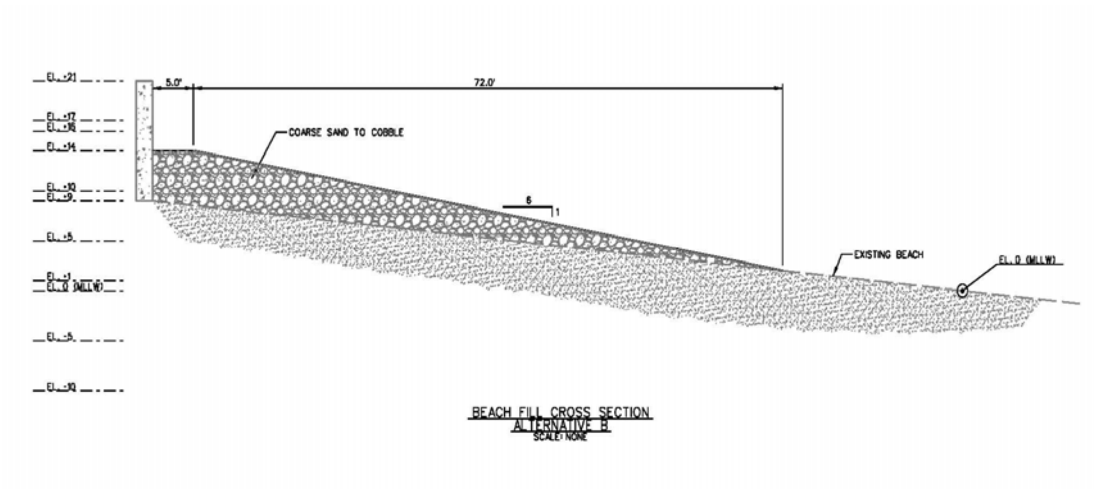


Diagram 2: Cobble Berm

The calculations below show that the worst case scenario would be a wall 14 feet high, no sand protecting the toe, and having the ground depth on the protected side of the wall also being 14 feet deep. At this site, the water surface was assumed to be below the base of the wall. Furthermore, it was assumed that the material on either side would allow water to equilibrate between the land and the ocean sides and the effects are negligible. With all of these assumptions, for wall to be within an approved factor of safety, it was concluded that there needs to be at least 3.5 feet of compacted sand in front of the toe of the seawall to prevent the wall from potential failure.

Overturning and Sliding Calculations

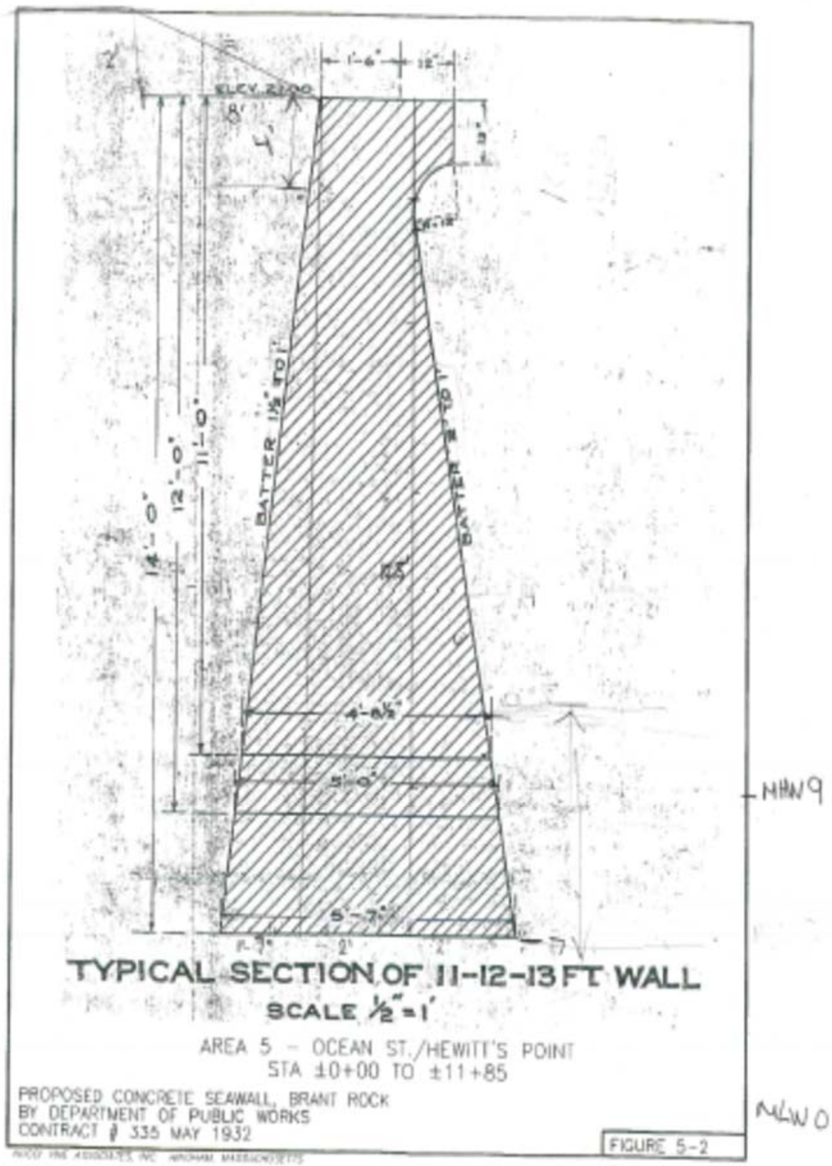
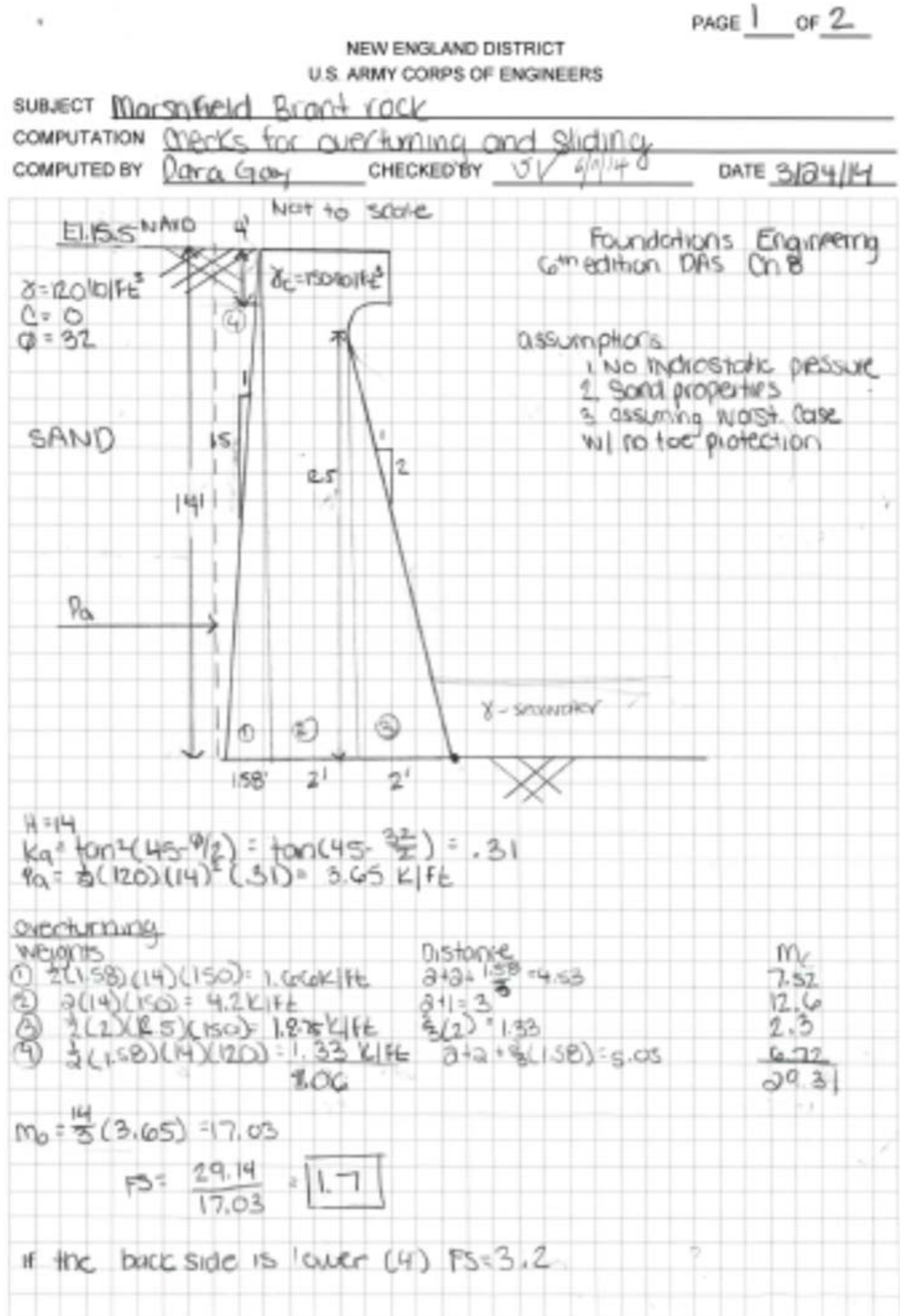


Figure 2: Typical As-Built Section of the Wall



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NEW ENGLAND DISTRICT
U.S. ARMY CORPS OF ENGINEERS

SUBJECT Marshfield Brant rock
COMPUTATION Checks for overturning and Sliding
COMPUTED BY Dara Gay CHECKED BY JV 6/10/14 DATE 3/24/14

H=14
Ka= tan²(45-φ/2) = tan(45-32/2) = .31
Pa= ½(120)(14)²(.31)= 3.65 K/ft

Overturning

Weights	Distance	Mr
① ½(1.58)(14)(150)= 1.66K/ft	2+2+1.58/3 =4.53	7.52
② 2(14)(150)= 4.2K/ft	2+1=3	12.6
③ ½(2)(12.5)(150)= 1.875K/ft	⅔(2) = 1.33	2.5
④ ½(1.58)(14)(120)= 1.33 K/ft	2+2+⅔(1.58)=5.05	6.72
8.06		29.31

Mo = 14/3 (3.65) = 17.03

FS = 29.14 / 17.03 = **1.7**

If the back side is lower (4) FS=3.2

Figure 3: Overturning and Sliding Calculations

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NEW ENGLAND DISTRICT
U.S. ARMY CORPS OF ENGINEERS

SUBJECT Marshfield Brant rock.
COMPUTATION Checks for overturning and sliding
COMPUTED BY Dana Gay CHECKED BY JV 6/11/14 DATE 6/11/14

Sliding

$k_1 = k_2 = 2/3$ assuming $P_p = 0$

$$FS_{sliding} = \frac{\Sigma V \tan(2/3\,\phi) + B(2/3)C}{P_a}$$

$$\frac{8.92\tan(2/3 \times 32)}{3.65} = \frac{3.48}{3.65} = \boxed{.95}$$ Not sufficient ✓

Assuming 2' of sand in front of the toe

$$FS = \Sigma V \tan(k\phi) + Bk_2C_2' + P_p$$

$$P_p = \tfrac{1}{2}\gamma H^2 k_p + 2C' H\sqrt{k_p}$$

$$k_p = \tan^2(45 + \tfrac{\phi}{2}) = \tan^2(45 + \tfrac{32}{2}) = 3.3$$

$$P_p = \tfrac{1}{2}(120)(2)^2(3.3) = .792\ k/ft$$

$$FS = \frac{8.92\tan(2/3 \times 32) + .792}{3.65} = \boxed{1.2}$$ Not sufficient ✓

assume 3'

$k_p = 3.3$

$$P_p = \tfrac{1}{2}(120)(3)^2(3.3) = 1.782\ k/ft$$

$$F_s = \frac{8.92\tan(2/3 \times 32) + 1.782}{3.65} = \boxed{1.44}$$ ✓

assume 3.5'

$k_p = 3.3$

$$P_p = \tfrac{1}{2}(120)(3.5)^2(3.3) = 2.43$$

$$FS = \frac{3.48 + 2.43}{3.65} = \boxed{1.6}$$ sufficient ✓

→ EM 1110-2-2502 Table 4-1

Figure 4: Overturning and Sliding Calculations Continued

HURRICANE AND COASTAL STORM DAMAGE REDUCTION @ BRANT ROCK AND FIELDSTON AREAS, MARSHFIELD, MA – SECTION 14

COST ESTIMATE, RISK ANALYSIS, TPCS DEVELOPMENT SUMMARY

COST ESTIMATE

The cost estimate is based on a detail drawing of the revetment cross section from the civil engineering section. The estimate is based on this plan and the assumption that the construction effort will be land based. It is worth noting that the original alternatives included both a cobble/sand mix revetment option (Alternative 1) and a stone revetment option (Alternative 2); with the PDT ultimately selecting the cobble/sand mix revetment option going forward.

Quantities for the cost estimate were developed by the cost engineer using the revetment cross sectional area (approximately 222.5 sf) multiplied by the length of the project (300 lf) to calculate the total volume of cobble/sand mix to be approximately 2,475 cy. It should be noted that the quantities developed assumed no porosity or void ratios and assumed a solid volume of cobble/sand mix throughout the revetment.
Actual quantities developed in the PED phase will likely include a small amount of void space and porosity and may result in a lower total cubic yardage.

Assumptions

- Estimate assumes stone will be imported from Bridgewater/Raynham, MA area, transported by truck and stockpiled at the site.
- Construction methodology: Estimate assumes supplier will deliver cobble/sand mix to site and stockpile it at designated area on the beach. Rock trucks will be loaded at the stockpile site and will deliver material to the construction area. An excavator and dozer will place the material and slightly compact it to ensure it stays in place during high tide.
- Estimate assumes no dewatering will be needed for mix placement at the toe of the revetment.
- Estimate assumes construction operation only during low tides.
- Estimate assumes competitive SBA acquisition.
- Estimate assumes a Prime Contractor will manage the project and will employ a Heavy Earthwork subcontractor to perform the cobble/sand mix installation.
- Estimate assumes both the prime and subcontractor will be local to site and that employees will travel to the site daily.

RISK ANALYSIS

Risk Mitigation was conducted through an Abbreviated Risk Analysis of the project as it is currently presented in addition to the acknowledgement of risk in the scope and estimated quantities of material. The District has taken an approach to mitigate this risk through a conservative approach to the size of revetment in addition to the stone cost and more importantly the method of placement. The amounts included in the project cost provide an amount that the PDT is confident will provide substantive costs to mitigate issues. The District will continue to monitor and include all risks in continuing assessment of contingency and amend as necessary as an essential element to the continued development of the project. The key cost risk drivers identified through formal risk and sensitivity analysis were; General Conditions (Mob & Demob), Site Preparation/Restoration, Cobble Purchase & Delivery, and Cobble Placement.

The Abbreviated Risk Analysis (ARA) was developed relying on local District staff to provide expertise and information gathering. The cost engineer facilitated a risk identification meeting on site with the PDT in addition to a qualitative analysis to produce a risk register that served as the framework for the risk analysis.

The ARA assumes the Project Development Stage/Alternative is “Feasibility (Recommended Plan)” with a “Low Risk” risk category based on the experience of the cost engineer and vetted with the PDT. The resultant contingencies are 18.14% for the Total Construction Estimate, 5.00% for Total Planning, Engineering & Design, and 6.97% for Total Construction Management. These contingency percentages were then utilized in the Total Project Cost Summary. It should be noted that no Lands and Damages are anticipated for this project.

TOTAL PROJECT COST SUMMARY (TPCS)

The Total Project Cost Summary (TPCS) was then computed to summarize the construction cost, project first cost, and the Total Project Cost or the Fully Funded Cost. The TPCS was utilized to calculate the construction cost estimate applied contingency and escalated to the midpoints of the features of work and the remaining work breakdown structure to include Planning, Engineering & Design (PED) and Construction Management. The inputs of the TPCS, to include percentages for the PED phase and Construction Management were obtained from the project manager.

The resultant TPCS from the cost estimate, risk analysis, and escalation is $794,000 with an estimated federal cost of $516,000 and non-federal cost of $278,000 utilizing a 65%/35% federal/non-federal cost of project split.

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **Hurricane and CSD Reduction @ Brant Rock and Fieldston Areas, Marshfield, Massachusetts**
PROJECT NO: **P2 172233**
LOCATION: **Marshfield, MA**

DISTRICT: **NAE New England**
PREPARED: **10/9/2015**
POC: **CHIEF, COST ENGINEERING, Patricia Bolton**

This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - Marshfield

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
							Program Year (Budget EC):			2016					
							Effective Price Level Date:			1-Oct- 15					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	REMAINING COST ($K)	Spent Thru: 10/1/2015 ($K)	TOTAL FIRST COST ($K)	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
10	BREAKWATER & SEAWALLS	$509	$92	18%	$602		$509	$92	$602		$602	1.8%	$518	$94	$612
	#N/A		-			-						-			
	CONSTRUCTION ESTIMATE TOTALS:	$509	$92		$602		$509	$92	$602		$602	1.8%	$518	$94	$612
01	LANDS AND DAMAGES		-			-						-			
30	PLANNING, ENGINEERING & DESIGN	$123	$6	5%	$129		$123	$6	$129		$129	1.9%	$125	$6	$132
31	CONSTRUCTION MANAGEMENT	$46	$3	7%	$49	0.0%	$46	$3	$49		$49	1.8%	$47	$3	$50
	PROJECT COST TOTALS:	$678	$102	15%	$780		$678	$102	$780		**$780**	1.8%	$690	$104	$794

ESTIMATED TOTAL PROJECT COST:		**$794**
ESTIMATED FEDERAL COST:	65%	$516
ESTIMATED NON-FEDERAL COST:	35%	$278
22 - FEASIBILITY STUDY (CAP studies):		**$200**
ESTIMATED FEDERAL COST:		$165
ESTIMATED NON-FEDERAL COST:		$35
ESTIMATED FEDERAL COST OF PROJECT		**$681**

______________________ CHIEF, COST ENGINEERING, Patricia Bolton

______________________ PROJECT MANAGER, xxx

______________________ CHIEF, REAL ESTATE, Joseph Redlinger

______________________ CHIEF, PLANNING, John Kennelly

______________________ CHIEF, ENGINEERING, Scott Acone

______________________ CHIEF, OPERATIONS, Francis Fedele

______________________ CHIEF, CONSTRUCTION, Sean Dolan

______________________ CHIEF, CONTRACTING, Sheila Winton

______________________ CHIEF, PM-PB, xxxx

______________________ CHIEF, DPM, William Scully

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Hurricane and CSD Reduction @ Brant Rock and Fieldston Areas, Marshfield, Massachusetts
LOCATION: Marshfield, MA
This Estimate reflects the scope and schedule in report; CAP Feasibility STUDY - Marshfield

DISTRICT: NAE New England
POC: CHIEF, COST ENGINEERING, Patricia Bolton

PREPARED: 10/9/2015

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: / Estimate Price Level:			10/9/2015 / 42278	Program Year (Budget EC): / Effective Price Level Date:			2016 / 1 -Oct-15					
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	RISK BASED CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	TOTAL ($K) *J*	Mid-Point Date *P*	ESC (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
	PHASE 1 or CONTRACT 1													
10	BREAKWATER & SEAWALLS	$509	$92	18.1%	$602		$509	$92	$602	2017Q1	1.8%	$518	$94	$612
	#N/A													
	CONSTRUCTION ESTIMATE TOTALS:	$509	$92	18.1%	$602		$509	$92	$602			$518	$94	$612
01	LANDS AND DAMAGES													
30	PLANNING, ENGINEERING & DESIGN													
0.01675	Project Management	$9	$0	5.0%	$9		$9	$0	$9	2016Q3	1.6%	$9	$0	$10
0.0067	Planning & Environmental Compliance	$3	$0	5.0%	$3		$3	$0	$3	2016Q3	1.6%	$3	$0	$3
0.14	Engineering & Design	$71	$4	5.0%	$75		$71	$4	$75	2016Q3	1.6%	$72	$4	$76
0.03	Engineering Tech Review ITR & VE	$15	$1	5.0%	$16		$15	$1	$16	2016Q3	1.6%	$15	$1	$16
0.015	Contracting & Reprographics	$8	$0	5.0%	$8		$8	$0	$8	2016Q3	1.6%	$8	$0	$9
0.0201	Engineering During Construction	$10	$1	5.0%	$11		$10	$1	$11	2017Q1	3.6%	$10	$1	$11
0.0134	Planning During Construction	$7	$0	5.0%	$7		$7	$0	$7	2017Q1	3.6%	$7	$0	$8
	Project Operations			5.0%										
31	CONSTRUCTION MANAGEMENT													
0.07	Construction Management	$36	$3	7.0%	$39		$36	$3	$39	2017Q1	1.8%	$37	$3	$39
	Project Operation:			7.0%										
0.02	Project Management	$10	$1	7.0%	$11		$10	$1	$11	2017Q1	1.8%	$10	$1	$11
	CONTRACT COST TOTALS:	$678	$102		$780		$678	$102	$780			$690	$104	**$794**

Abbreviated Risk Analysis

Project (less than $40M): **Hurricane and CSD Reduction @ Brant Rock and Fieldston A** — Alternative: **Cobble/Sand Revetment Option**

Project Development Stage/Alternative: **Feasibility (Recommended Plan)**

Risk Category: **Low Risk: Typical Construction, Simple** — Meeting Date: **10/7/2015**

Total Estimated Construction Contract Cost = $ 509,296

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	**Real Estate**	$ -		0.00%	$ -	$ -
1	10 BREAKWATERS AND SEAWALLS	**General Conditions (Mob & Demob)**	$ 172,869		16.99%	$ 29,366	$ 202,235
2	10 BREAKWATERS AND SEAWALLS	**Site Preparation/Restoration**	$ 20,431		24.13%	$ 4,929	$ 25,360
3	10 BREAKWATERS AND SEAWALLS	**Cobble Purchase & Delivery**	$ 152,546		18.39%	$ 28,048	$ 180,594
4	10 BREAKWATERS AND SEAWALLS	**Cobble Placement**	$ 163,450		18.39%	$ 30,053	$ 193,503
5			$ -		0.00%	$ -	$ -
6			$ -		0.00%	$ -	$ -
7					0.00%	$ -	$ -
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
10			$ -		0.00%	$ -	$ -
11			$ -		0.00%	$ -	$ -
12	All Other	**Remaining Construction Items**	$ -	0.0%	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 89,025		5.00%	$ 4,451	$ 93,476
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 50,013		6.97%	$ 3,488	$ 53,501
XX	FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals	Contract Cost	% Contingency	$ Contingency	Total
Real Estate	$ -	0.00%	$ -	$ -
Total Construction Estimate	$ 509,296	18.14%	$ 92,396	$ 601,692
Total Planning, Engineering & Design	$ 89,025	5.00%	$ 4,451	$ 93,476
Total Construction Management	$ 50,013	6.97%	$ 3,488	$ 53,501
Total	**$ 648,334**	**15%**	**$ 100,335**	**$ 748,669**

	Base	50%	80%
Range Estimate ($000's)	$648k	$709k	$749k

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.	

Hurricane and CSD Reduction @ Brant Rock and Fieldston A ... **tion**

Feasibility (Recommended Plan)
Abbreviated Risk Analysis
Meeting Date: 7-Oct-15

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Register

Risk Element	Feature of Work	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Scope Growth				Maximum Project Growth		**40%**
PS-1	General Conditions (Mob & Demob)	Are the standard project assumptions okay for this project?	The PDT is satisfied with the development of the cost estimate. Scope growth will increase this line item incrimentally with the project cost, however the scope is very well defined even at the feasibility phase.	Marginal	Unlikely	0
PS-2	Site Preparation/Restoration	Amount of site prep/restoration is too little.	The PDT has determined that the site layout is very clear and the historical information is sufficient to determine the amount of prep and restoration. Storm activity and erosion/accreation will like have some effect positively or negatively on this line item.	Marginal	Likely	2
PS-3	Cobble Purchase & Delivery	Is the current design sufficient to accomplish the project goals?	The project limits are defined by the adjacent revetments to the north and south of the project. The actual project limits could not increase, however the type of revetment required could change and have a significant impact but this is unlikely.	Significant	Unlikely	2
PS-4	Cobble Placement	Is the current design sufficient to accomplish the project goals?	The project limits are defined by the adjacent revetments to the north and south of the project. The actual project limits could not increase, however the type of revetment required could change and have a significant impact but this is unlikely.	Significant	Unlikely	2
PS-13	Planning, Engineering, & Design	No concerns.	PED costs are considered high given the simple design and the fact that NAE has designed and constructed numerous breakwater, revetment, and seawall projects in recent years and has applied, and will continue to apply, lessons learned to both design and constructon management (QC) activities.	Negligible	Unlikely	0
PS-14	Construction Management	No concerns.	NAE has designed and constructed numerous breakwater, revetment, and seawall projects in recent years and has applied, and will continue to apply, lessons learned to both design and constructon management (QC) activities.	Negligible	Unlikely	0
Acquisition Strategy				Maximum Project Growth		**30%**
AS-1	General Conditions (Mob & Demob)	Anticipated low dollar value project leans toward 8a/small business/hub zone contracting method. KTR requires capability to economically mobilize to the site.	Risk mitigated in cost estimate through additional equipment mobilizations by the heavy earthwork KTR. Additional GCs (to include per diem and travel) are not included in the cost estimate by are possible depending on the KTR.	Marginal	Likely	2

AS-2	Site Preparation/Restoration	KTR requires marine stone work experience and capability to avoid large mods due to poor bid/estimate on KTR part; KTR planning and methodology is important. Additional concerns over acquisition strategy, KTR availability, and bid schedule (resulting in unbalanced bids).	Small business acquisition likely. Risk mitigated in cost estimate by assuming a small business prime subcontracting a majority of the work to a heavy earthwork KTR. No concerns remain.	Negligible	Unlikely	0
AS-3	Cobble Purchase & Delivery	KTR requires marine stone work experience and capability to avoid large mods due to poor bid/estimate on KTR part; KTR planning and methodology is important. Additional concerns over acquisition strategy, KTR availability, and bid schedule (resulting in unbalanced bids).	NAE has done extensive stone work over the last several years and has not had significant issues with KTRs of any size bidding and performing on these projects. PDT can mitigate bid schedule concerns by reviewing and commenting prior to solicitation. It is unlikely whichever type of acquisition strategy is used will effect the project, but the impacts could be moderate.	Moderate	Unlikely	1
AS-4	Cobble Placement	KTR requires marine stone work experience and capability to avoid large mods due to poor bid/estimate on KTR part; KTR planning and methodology is important. Additional concerns over acquisition strategy, KTR availability, and bid schedule (resulting in unbalanced bids).	NAE has done extensive stone work over the last several years and has not had significant issues with KTRs of any size bidding and performing on these projects. PDT can mitigate bid schedule concerns by reviewing and commenting prior to solicitation. It is unlikely whichever type of acquisition strategy is used will effect the project, but the impacts could be moderate.	Moderate	Unlikely	1
AS-13	Planning, Engineering, & Design	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
AS-14	Construction Management	KTR requires marine stone work experience and capability to avoid large mods due to poor bid/estimate on KTR part; KTR planning and methodology is important.	If an inexperienced KTR successfully bids and wins the project, there exists the potential of the KTR working on a learning curve. This is unlikely but could have a moderate impact.	Moderate	Unlikely	1
Construction Elements				**Maximum Project Growth**		**15%**
CE-1	General Conditions (Mob & Demob)	Staging areas not being large enough.	An area adjacent to project site has been allocated as a laydown area for the KTR(s) and a beach area also adjacent to the site has been identified as a material stockpile area. No concerns remain.	Marginal	Likely	2
CE-2	Site Preparation/Restoration	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
CE-3	Cobble Purchase & Delivery	Material cost increasing is a concern. Concerns over material storage/stockpiling is also an issue.	The quote provided by a reputable quarry location was increased an additional 10% to account for any unforeseen increases. A beach area adjacent to the project site has been allocated as a stockpile location. This will require the KTR to double handle the material; this risk has been mitigated by accounting for sufficient equipment/labor to handle the material twice.	Negligible	Unlikely	0
CE-4	Cobble Placement	Standby time due to weather/storm surge delays and site contraints. Rehandling stone more than anticipated. Working in high tide.	The cost estimate assumes a 2 month construction duration, which is sufficient to finish constructing the project even with delays. The estimate also assumes the KTR will be limited in working times due to the high tide. The double-handling risk has also been mitigated in the estimate.	Negligible	Unlikely	0
CE-13	Planning, Engineering, & Design	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
CE-14	Construction Management	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0

Quantities for Current Scope				Maximum Project Growth		20%
Q-1	General Conditions (Mob & Demob)	No concerns.	Negligible Impact - Unlikely Probability	Marginal	Likely	2
Q-2	Site Preparation/Restoration	Concern regarding quantity/necessity for additional restoration.	It is likely there will be additional restoration requirements based on the final design and laydown/staging locations determined in PED. The impact could be moderate depending on the extent of restoration required.	Moderate	Likely	3
Q-3	Cobble Purchase & Delivery	Concern regarding increase in cobble/sand quantity.	Possible stone quantity increase risk mitigated by cost estimate assuming cobble/sand mix is solid with no porosity/voids (current quantity was calculated by using cross section area on the plan times the length of the project). The quantity of cobble/sand mix is driven by current beach elevation. Accretion, erosion, and/or local project to repair adjacent sea wall will likely change the quantity during PED. It is very likely the quantity will change, but the impact is negligible since the change may lessen the quantity.	Negligible	Very LIKELY	2
Q-4	Cobble Placement	Concern regarding increase in cobble/sand quantity.	Possible stone quantity increase risk mitigated by cost estimate assuming cobble/sand mix is solid with no porosity/voids (current quantity was calculated by using cross section area on the plan times the length of the project). The quantity of cobble/sand mix is driven by current beach elevation. Accretion, erosion, and/or local project to repair adjacent sea wall will likely change the quantity during PED. It is very likely the quantity will change, but the impact is negligible since the change may lessen the quantity.	Negligible	Very LIKELY	2
Q-13	Planning, Engineering, & Design	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
Q-14	Construction Management	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
Specialty Fabrication or Equipment				Maximum Project Growth		50%
FE-1	General Conditions (Mob & Demob)	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
FE-2	Site Preparation/Restoration	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
FE-3	Cobble Purchase & Delivery	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
FE-4	Cobble Placement	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
FE-13	Planning, Engineering, & Design	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
FE-14	Construction Management	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
Cost Estimate Assumptions				Maximum Project Growth		25%

CT-1	General Conditions (Mob & Demob)	Concerns over KTR markups and expected construction duration.	Risks mitigated by including additional level of markups for assumed 8a/small business acquisition and extending assumed construction duration to 2 months instead of initial assumption of 1 month. No concerns remain.	Negligible	Unlikely	0
CT-2	Site Preparation/Restoration	Concerns over additional prep/restoration necessary in final design.	It is likely there will be additional restoration requirements based on the final design and laydown/staging locations determined in PED. The impact could be moderate depending on the extent of restoration required.	Moderate	Likely	3
CT-3	Cobble Purchase & Delivery	Concerns over cobble/sand mix availability and delivery of material over the public roadways and the need to dou ble handle at the site. Additional concerns regarding necessity for traffic control and truck cleaning area for material delivery.	Traffic control and truck cleaning area not included in the cost estimate. It is likely these items are required but impact will be marginal due to the relatively low cost of these additions. Risk of double handling mitigated in cost estimate by assuming the need for off-highway trucks and front end loader to move material from dump site to placement site.	Marginal	Possible	1
CT-4	Cobble Placement	General assumptions made by the cost estimator relative to the construction revetment.	The estimate was repriced using the latest 2014 Region 1 equipment book. Labor costs were updated to the most recent Wage Determinations and productivity rates were updated using estimator knowledge and experience. Estimator also relied on recent NAE breakwater/revetment work for assumptions made. Where noted, quotes were used. It is possible the costs assumed in the estimate will increase but the impact will be marginal due to the conversative nature of the values currently used.	Marginal	Possible	1
CT-13	Planning, Engineering, & Design	No concerns.	PED costs are generous considering the relatively simple design used in this project.	Negligible	Unlikely	0
CT-14	Construction Management	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
External Project Risks				**Maximum Project Growth**		**20%**
EX-1	General Conditions (Mob & Demob)	Several concerns including sea level rise, increasing fuel prices, and severe weather/tides delaying project construction.	Sea level rise will be a non-issue as it generally a time contingent issue and construction is scheduled for FY16. Fuel prices will possibly increase however the impact will be marginal. KTR should understand tide cycles and have the ability to work around them. Construction delays will also be incorporated into the construction contract.	Marginal	Possible	1
EX-2	Site Preparation/Restoration	Several concerns including sea level rise, increasing fuel prices, and severe weather/tides delaying project construction.	Sea level rise will be a non-issue as it generally a time contingent issue and construction is scheduled for FY16. Fuel prices will possibly increase however the impact will be marginal. KTR should understand tide cycles and have the ability to work around them. Construction delays will also be incorporated into the construction contract.	Marginal	Possible	1

EX-3	Cobble Purchase & Delivery	Several concerns including sea level rise, increasing fuel prices, severe weather/tides delaying project construction and lead time to stockpile enough material to ensure continuous work.	Sea level rise will be a non-issue as it generally a time contingent issue and construction is scheduled for FY16. Fuel prices will possibly increase however the impact will be marginal. KTR should understand tide cycles and have the ability to work around them. Construction delays will also be incorporated into the construction contract. Estimate assumes stone delivery slightly outpaces stone placement which would result in a small stockpile.	Marginal	Possible	1
EX-4	Cobble Placement	Several concerns including sea level rise, increasing fuel prices, severe weather/tides delaying project construction and lead time to stockpile enough material to ensure continuous work.	Sea level rise will be a non-issue as it generally a time contingent issue and construction is scheduled for FY16. Fuel prices will possibly increase however the impact will be marginal. KTR should understand tide cycles and have the ability to work around them. Construction delays will also be incorporated into the construction contract. Estimate assumes stone delivery slightly outpaces stone placement which would result in a small stockpile.	Marginal	Possible	1
EX-13	Planning, Engineering, & Design	No concerns.	Negligible Impact - Unlikely Probability	Negligible	Unlikely	0
EX-14	Construction Management	Potential severe weather/tides could delay project construction.	Weather/tide cycle issus should be known and understood by KTR however large storms and unusually high tide cycles are possible but unlikely which could result in marginal impacts to construction management cost and duration since the contractor will likely have approximately 5-6 months to complete the project. Also, weather standby time is incorporated in construction planning.	Negligible	Unlikely	0

Marshfield, MA
Section 103 Feasibility Study (revised)
Section 14

Economic Appendix C

Marshfield, Plymouth County, MA
Economic Summary
Coastal Storm Damage Reduction
September 2014
(revised May 2016)

Introduction

This report evaluates the economic feasibility of providing coastal storm damage protection for two separate beach communities located in the Town of Marshfield, Massachusetts. The study area includes approximately 300 Feet of shoreline along the Atlantic Ocean in the area known as Brant Rock and approximately 2,500 Feet of shoreline in the Fieldston Area of Marshfield.

The analysis utilizes the U. S. Army Corps of Engineers (USACE) certified Hydraulic Engineering Center-Flood Damage Analysis (HEC-FDA) model and follows guidance for conducting economic analyses of coastal storm damage as contained in ER 1105-2-100, Planning Guidance Notebook, Appendix E, Section IV (2006).

Methodology

Economic analysis considers the difference between the without-project conditions, and the future with-project condition. Benefits are based on damages prevented by the project for different storm exceedance probabilities.

The damage analysis considers wave run-up and flood impacts to structures located a short distance from the Atlantic Ocean. The coastal hydraulic analysis evaluated wave conditions based on storm exceedance probabilities and calculated the volume of water overtopping the existing seawalls. The volume of water was mapped in ArcMap GIS to determine how the water would be distributed based on topography. The maximum water surface elevations were determined using the volume calculator in the ArcMap 3-D Analyst extension. This was done by calculating the volume below each topographical elevation (contour) using digital terrain models developed from the Marshfield contour data. The resulting water surface elevations were used in the Hydraulic Engineering Center-Flood Damage Analysis (HEC-FDA) model to determine project benefits.

The HEC-FDA model also used Depth-Damage relationships for residential structures taken from Economic Guidance Memorandum (EGM) 04-01, 10 October 2003. Depth-Damage relationships for commercial structures were previously developed from FEMA flood insurance rate reviews for depth-damage ratios and used in other New England studies. The benefits and costs were annualized using a Capital Recovery Factor (CRF) of 0.04263 based on the FY 2014 interest rate of 3.50% for a 50 year project life.
For each alternative a benefit-cost ratio is determined by dividing annual benefits by annual costs. An alternative is considered economically feasible if the benefit-cost ratio exceeds or is equal to one.

Study Area

The town of Marshfield, Plymouth County, Massachusetts, is located 30 miles south of Boston on the Atlantic Ocean at the northern extent of Cape Cod Bay (Figure 1). Marshfield has a population of approximately 25,000 year-round residents that increases to approximately 40,000 during the summer rental season.[i] The 2010 Census reports a total of 10,940 Housing Units with an 87% occupancy rate and an average household size of 2.63 persons. The Median household income is $77,243 with a Mean household income of $90,243 (2012 Dollars adjusted for inflation).[ii]

Figure 1Marshfield, Massachusetts

The study area is comprised of two sites within Marshfield located at the Fieldston Beach area in the north and the Brant Rock area to the south (Figure 2). The combined coastline of these areas is approximately 4,000 feet long and reinforced with a number of stabilization structures, including concrete seawalls, stone revetments, groins, and breakwaters.

Figure 2 Two study Areas in Marshfield, MA

The Town of Marshfield is particularly vulnerable to storms with winds coming from the northeast, or nor'easters, because the area is not protected by the sheltering arm of Cape Cod. Nor'easters cover a larger area than hurricanes although the winds are not as high. They also generally last long enough to include at least one high tide, which causes the most severe flooding. Nor'easters can occur at any time of the year but they are most common in winter. Hurricanes are more common in the summer or early fall.

Existing Conditions

Fieldston Beach

The study area for Fieldston consists of 94 single family houses protected by a concrete seawall. There were several openings in the seawalls in the Fieldston beach area that allowed water to pass through the structures and flood backshore neighborhoods during storm events. During the course of this study, the town secured State grant funding, and replaced 1,600 linear feet of concrete seawall along the Fieldston shorefront. The seawall was constructed with a top elevation of 24 Feet NAVD making it 2 feet higher than the original seawall.

The current without-project conditions reflect the new seawall in place and the reduced risk of flooding from failure or splash over during coastal storm events. When the improved conditions with reduced water surface elevations were analyzed using the HEC-FDA tool, results indicated minimal expected annual damages ($1,000) and the Fieldston area was dropped from consideration.

Brant Rock

The Brant Rock study area is fronted by a seawall and bisected by South Street and a stone jetty that runs approximately 475 Feet into the Atlantic Ocean to the geological rock outcropping known as Brant Rock. To the south of the jetty, the beach is cobbled and completely submerged at high tide. A 600 l.f. portion of the seawall is reinforced with a full height rock revetment opposite Knox Street. Several structures, prone to wave damage and flooding, are located in the small area bounded by the seawall, South Street and Ocean Street as shown in Figure 3 below.

To the north of the jetty, the beach is slightly wider. The houses immediately behind the seawall are approximately 20 feet in elevation above the beach, and owners have built stairways to reach the sand below. There is no rock revetment in this area. The elevation decreases to the west toward Ocean Street and Green Harbor Marsh where there is a mix of residential and small seaside town business structures located in an area known as the Esplanade. Flooding at Brant Rock is caused by waves overtopping the seawall and causing water to pool in the low-lying areas of the marsh and Esplanade. According to town officials, the esplanade area floods two to three times a year to a depth of one to two Feet; backing up septic tanks, inundating the Esplanade, and damaging properties in low lying areas. Figure 1 below shows all parcels used in the analysis. Red dots indicate structures surveyed for first floor elevations.

Figure 3 Parcels analyzed for Brant Rock

Benefit Analysis

Thirty-eight structures in the Brant Rock Area were surveyed for accurate first floor elevations. The structures chosen for survey were in the commercial area around the esplanade and had experienced the worst flooding in past years. Another 227 structures were added to the Structure Inventory when the Study area was further defined by the boundaries of Samoset Avenue to Bryant Street and Webster Avenue to Marshall Avenue. For structures that were not surveyed, ground elevations were obtained from 2007 LIDAR and the first floor elevations were estimated based on GOOGLE street view.

Water Surface Elevations for 8 storm frequencies were provided by the coastal engineer. The frequencies or Annual Exceedance Probabilities (AEP) included: 0.5, 0.2, 0.1, 0.67, 0.04, 0.02, 0.01, and 0.004 (2-, 5-, 10-, 15-, 25-, 50-, 100- and 250- year events). Water Surface Elevations ranged from 4.2 FT for the 0.5 AEP to 11.0 FT for the 0.004 AEP, with the FEMA 0.01 AEP at 10 FT (NAVD88).

Results from the HEC-FDA model are presented in Table 1 below:

Table 1 Expected Annual Damages and Benefits

Plan Name	**Description**	**Expected Annual Damages**	**Annual Benefits compared to WOP**
Without Project	Without Project (WOP)	$115,760	-0-
Raise Wall	Raise Wall to 19.0 FT (NAVD88)	$112,750	$ 3,010
Elevate 100YR+1	Elevate Structures to 11 FT (NAVD88)	$ 16,530	$ 99,230

Raising the Wall

To raise the concrete seawall, to provide additional protection for Brant Rock backshore, would require the complete replacement of the 60 year old seawall. The construction of a new seawall would cost approximately $5.2 million. The new wall could be built two feet higher than existing to provide improved wave splash-over protection. Steel sheeting would need to be driven below grade and a stone toe revetment be constructed to offer footing protection for the seawall. Study analysis indicates that the increasing the elevation of the existing seawall would only provide protection for the Brant Rock area up to the 2-year storm event. The Annual benefits of Raising the Brant Rock Wall amount to $3,010 and would support a project COST of approximately $70,000, based on the 2014 Federal discount rate of 3.5% and no interest during construction. Since the cost of a raised new seawall far outweighs the potential benefits, this alternative was dropped from further consideration.

Elevate Structures 1 Foot above 0.01 Water Surface Elevation

Annual benefits of elevating structures to one foot above the 0.01 Annual Exceedance Probability flood amount to $99,230. Of the structures originally surveyed for Brant Rock, 9 are already above the 0.01 AEP and 29 would need to be elevated. Of the 227 non-surveyed structures, only 9 structures would need to be elevated, for a total of 38 structures eligible for raising the first-floor opening to one-foot above the 100-yr flood level.

This initial list of 38 eligible structures was based strictly on first-floor elevations compared to the 0.01 AEP water surface elevation of 10 FT (NAVD88). An engineering team further evaluated the 38 structures to see if elevating the first floors was feasible. Twenty-seven structures were removed from the eligible list because they were not structurally sound, were located in an area that could not accommodate an elevated structure, or were less than 6 inches below the 10 FT elevation. The HEC-FDA tool was used to analyze the benefits of implementing non-structural measures for the remaining 11 eligible structures. The residual damages by storm frequency for the without project conditions compared to the with-project conditions are presented in Table 2 below.

Table 2
Damages for With- and Without Non-Structural Project
Brant Rock Area, Marshfield, MA

Probability	Recurrence Interval (Years)	Damages Without Project	Damages with Project
0.5	2	$ 27,700	-
0.2	5	$ 42,900	-
0.1	10	$113,800	-
0.04	25	$209,300	-
0.02	50	$230,800	-
0.01	100	$312,100	-
0.004	250	$349,800	-
0.002	500	$435,700	$106,940

Expected Annual Damages in the without-project condition were $60,810 compared to $2,002 with the project in place; yielding $58,800 of estimated annual benefits for implementing non-structural measures.

National Economic Development Plan

A project is considered economically justified if it has positive net benefits and a benefit to cost ratio (BCR) of 1.0 or greater. The alternative which maximizes net annual benefits with a BCR greater than 1.0 is the National Economic Development (NED) plan. A cost benefit analysis of implementing non-structural measures in the Brant Rock area is presented in Table 3 below.

Negative net annual benefits of ($7,182) and a BCR of 0.89 do not support the construction of non-structural measures in the Brant Rock area.

Table 3
Cost Benefit Analysis of Non-Structural Project

Non-Structural Measures in Brant Rock Area	**Cost per structure**	**Number of structures**	**Estimated Cost**
Full foundation with slab footing and full basement	$ 92,900	1	$ 92,900
Pier foundation	$ 107,700	3	$ 323,100
Slab on grade	$ 106,700	3	$ 320,100
Commercial structures eligible for flood proofing	$ 41,500	4	$ 166,000
Supporting Services (brush clean-up, clearing, photo documentation)	$ 8,600	11	$ 94,600
Cost Subtotal			$ 996,700
Professional Services During Construction			$ 219,700
Engineering During Construction			$ 20,000
Plans and Specs			$ 150,000
Supervision and Administration			$ 150,000
Total Construction Cost			$ 1,536,400
Interest During Construction @ FY14 Federal Discount rate of 3.5% for 6 months			$ 11,247
Total Investment Cost			$ 1,547,647
Capital Recovery Factor			0.04263
Annual Cost			$ 65,982
Annual Benefits			$ 58,800
Net Benefits			**$ (7,182)**
Benefit Cost Ratio			**0.89**

Marshfield, MA
Section 103 Feasibility Study (revised)
Section 14
Real Estate Planning Report

Appendix D

U.S. ARMY CORPS OF ENGINEERS
New England District

1. PROJECT DESCRIPTION
2. EXISTING FEDERAL PROJECTS
3. EXISTING FEDERALLY OWNED LANDS
4. LANDS OWNED BY THE NON-FEDERAL SPONSOR
5. NAVIGATIONAL SERVITUDE
6. INDUCED FLOODING
7. BASELINE COST ESTIMATE FOR REAL ESTATE
8. PUBLIC LAW 91-646 RELOCATIONS
9. MINERAL ACTIVITY
10. TIMBER RIGHTS
11. ASSESSMENT OF NON-FEDERAL SPONSOR ACQUISITION CAPABILITY
12. ZONING
13. ACQUISITION SCHEDULE
14. UTILITY AND FACILITY RELOCATIONS
15. ENVIRONMENTAL CONCERNS
16. ATTITUDES OF THE LANDOWNERS
17. NOTIFICATION TO NON-FEDERAL SPONSOR
18. RISK ANALYSIS

1. PROJECT DESCRIPTION: Authorization via Section 14 of the Flood Control Act of 1946, as amended. Emergency Shoreline/Stream-bank Protection, located in Marshfield, Massachusetts.

2. EXISTING FEDERAL PROJECTS: There are no existing Federal projects at this location or modification of an existing Federal project, including navigation.
3. EXISTING FEDERALLY OWNED LANDS, no Federal projects at this location
4. LANDS OWNED BY THE NON-FEDERAL SPONSOR: All projects areas are owned and/or controlled by the Town of Marshfield (local sponsor)
5. NAVIGATIONAL SERVITUDE: does not apply in accordance with project authorities and proposed construction alternative(s).
6. INDUCED FLOODING: feasibility report does not indicate that the constructed project features will induce flooding in new areas or increase flooding in existing flood prone areas.
7. BASELINE COST ESTIMATE FOR REAL ESTATE: Real Estate costs are typically based on the feasibility plan alternatives, project authorities and construction requirements (acquisition requirements). All real property interest are owned by the Local Sponsor the Town of Marshfield. In accordance with USACE regulations, Section 14 projects do not typically qualify for real estate credit, accordingly there are no baseline real estate cost reported. However, there will be administrative costs associated with the local sponsor executing required real estate documentation attesting to property ownership and granting access rights for construction purpose.
8. PUBLIC LAW-646 RELOCATIONS: feasibility report does not indicate there will be any facilities within the project boundaries requiring relocation.
9. MINERAL ACTIVITY The Project Delivery Team (PDT) confirms that there are no present or anticipated mining and drilling activity in the vicinity of the project that may affect project purposes and the operation thereof.
10. TIMBER RIGHTS the Project Delivery Team (PDT) confirms that there are no timber rights required, assumed none. None anticipated.

11. ASSESSMENT OF NON-FEDERAL SPONSOR ACQUISITION CAPABILITY Based on plan review, the Local Sponsor reportedly owns all real property interest required for project construction.

12. ZONING: there will be no zoning considerations associated with this project.

13. Acquisition Schedule: All real property interest are owned by the Town of Marshfield. However, the real estate interest certification (ownership) must be provided by the local sponsor in accordance with project plans (authorization to enter for construction purposes). The project manager indicates that the initial P&S Phase RE Letter is scheduled for (October 2016), followed by meetings with the local sponsor (Novemeber 2016); PM provides RE Division with final plans (March 2017); local sponsor real estate certification provided (May 2017).

14. UTILITY AND FACILITY RELOCATIONS: the project delivery team (PDT) indicates there will not be any facilities within the project boundaries requiring relocation. Confirmation will be conducted during the project's Design and implementation phase.

15. ENVIRONMENTAL CONCERNS The Project Delivery Team (PDT) has NOT confirmed that there are no known or suspected contaminants (HTRW) located in the proposed construction areas. {Environmental Assessment and Finding of No Significant Impact will be issued through a 30-day Public Notice}.

16. ATTITUDES OF THE LANDOWNERS. There have been no comments reported in regards to support and/or acquisition to this project. The proposed project will be offered to the public through the 30-day public notice period to solicit comments and concerns.

17. NOTIFICATION TO NON-FEDERAL SPONSOR: Non-Federal Sponsor executed a feasibility cost share agreement (25 June 2012). If the project is approved, a Project Partnership Agreement will be required scheduled for October 2016.

18. RISK ANALYSIS The real estate acquisition requirements are currently being defined as the study progresses (determination must be made in regards to any significant risks associated with this project). There have been no comments reported in regards to any significant risks associated with this project.

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[i] Town of Marshfield, MA. http://www.townofmarshfield.org/about-marshfield-ma.htm accessed 3/16/14

[ii] Source: U.S. Census Bureau, 2008-2012 American Community Survey