Duxbury Seawalls
Condition Survey and Study
Duxbury, MA

Project No. P10-2606-G2, (3779-G)

July 2012

Prepared For:
Town of Duxbury
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1 INTRODUCTION

The existing seawalls on Duxbury Beach have been the subject of a number of studies and were identified in the recent Coastal Hazard Infrastructure report as High Priority structures with condition ranging from fair to good. The seawalls have been repaired a number of times and provide limited flood protection to the many homes behind the walls. The Town of Duxbury, Massachusetts contracted Bourne Consulting Engineering (***BCE***) to perform a study of the Seawalls in Duxbury, Massachusetts under Project No. P10-2606-G2, (3779-G) with the purpose of developing recommendations for repairs and upgrades to address identified concerns with these important coastal protection structures.

The extent of the study area is shown on the locus map below and includes areas described as follows:

- Area 1 – from 200 feet north of Duxbury/Marshfield Town line to Gurnet Light
- Area 2 – Public access at or over existing wall at:
  - Pedestrian access Ocean Road North and Ocean Road South
  - Restricted vehicle access at Ocean Road North
- Area 3 – Existing low seawall from southern terminus at Ocean Road South to high wall
- Area 4 – Existing high seawall from Area 3 to vicinity of Plymouth Avenue and along Bay Avenue to 200 feet north of Duxbury/Marshfield Town line.
- Area 5 – Area with no seawall or revetment in vicinity of Plymouth Avenue

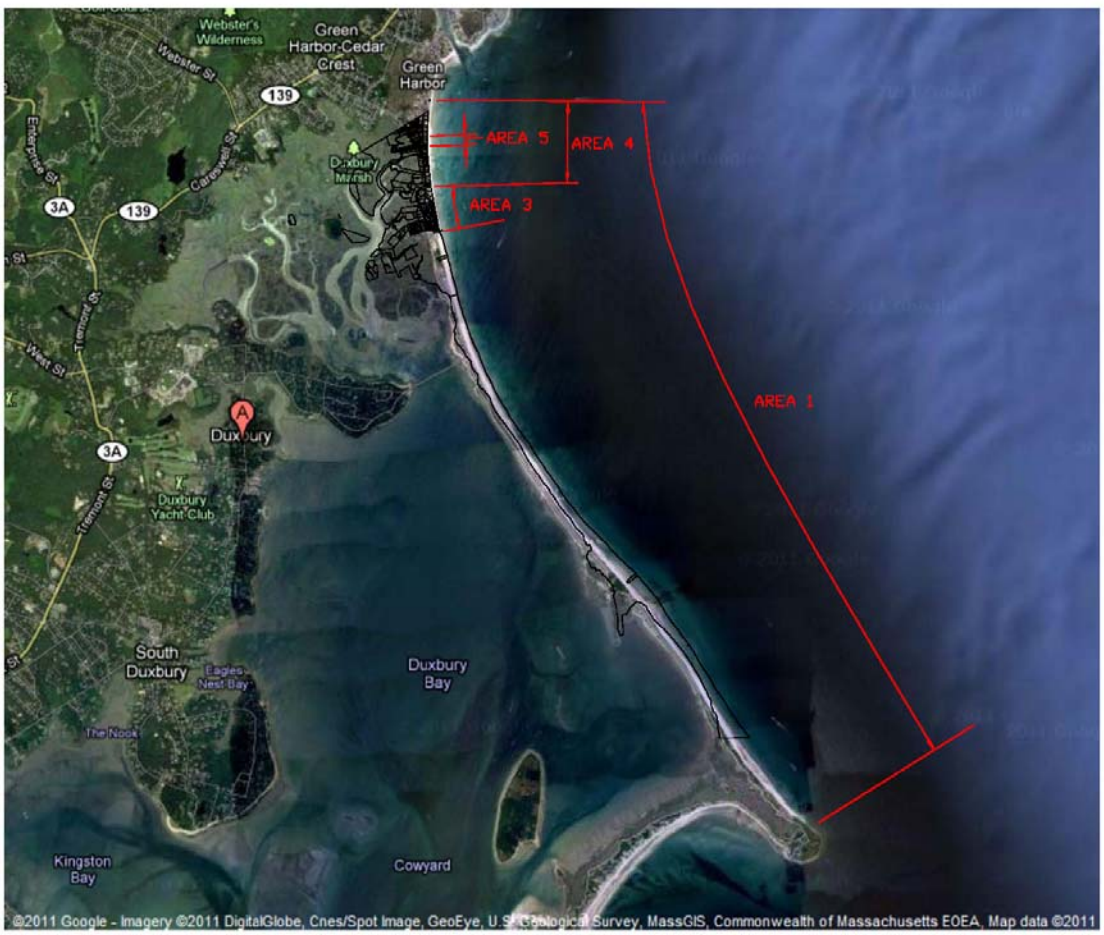


Figure 1-1 – Project Locus and Key Plan

2 PURPOSE

The purpose of this project is to perform a study of the existing shoreline conditions along Duxbury Beach in order to develop recommendations for repairs and improvements to the existing seawalls and to develop a beach maintenance plan for Duxbury Beach overall. The main emphasis of the study is on the seawalls and the open area between the walls (through Areas 3, 4 and 5) but the adjacent areas are included in order to be able to assess any impacts of proposed works.

The study includes review of historical information, topographic and hydrographic surveys, condition surveys and an alternative analysis for seawall modifications. The goal is to identify areas of concern and develop a comprehensive review of potential options to address these concerns. The overall intent is to develop a preferred plan for the entire length of the beach with particular emphasis on the existing seawalls.

3 REVIEW OF EXISTING INFORMATION

Historical documents relating to the site were provided by the Town of Duxbury and the Massachusetts Department of Conservation and Recreation. These documents and drawings were reviewed in order to develop a chronological history for each area. Documents reviewed also included historical reports from earlier studies. Relevant portions of these reports are also summarized below. Lists of all documents reviewed are included in Appendix D.

A summary of information applicable to both sections of seawall is as follows:

- The wall has been maintained in the past by both the Town and the Commonwealth of Massachusetts (Department of Environmental Management).
- Commonwealth of Massachusetts is the owner of the wall.
- There is no documentation of a wall ever being present between the Southern and Northern Seawalls.
- Houses are shown as existing throughout the length of the walls prior to 1968.

3.1 <u>WALL HISTORY</u>

3.1.1 <u>South Seawall – Low Wall and High Wall (STA 100+00 to 130+00)</u>

The following is a summary of the history of the beach area of the Southern Seawall presented in chronological sequence of events:

Pre-1946 Shoreline protection consisted of dumped stone revetment, stone seawalls or beach had no protection at all.

1946 Riprap placement by the Department of Public Works under DPW Contract No. 948 from approximately STA 128+00 to 129+00.

1946 Concrete seawall was constructed by the Department of Public Works under DPW Contract No. 960 from approximately STA 116+00 to 128+00.

1953 Concrete seawall was constructed by the Department of Public Works under DPW Contract No. 1339 from approximately STA 100+00 to 116+00.

1954 Concrete Steps constructed by the Department of Public Works under DPW Contract No. 1339. Field observations found stairs at one location STA 106+00.

1962 Concrete seawall was constructed by the Department of Public Works under DPW Contract No. 2357 from approximately STA 128+00 to 130+00.

1993 The Town performed emergency repairs which included placement of approximately 280 cubic yards of stone as a revetment adjacent to the wall from approximately STA 116+50 to 119+50.

Environmental Notification Form (EOEA No. 9850) stated that the beach surface lowered so far that the base of the wall was undermined, due to a combination of high tides and extreme waves by the offshore storm of December 9 through 16, 1993, over a 300 linear foot section of seawall located off Gurnet Road. Wall moved out shore resulting in cracking in the concrete wall, bowing, leaning and settlement of the backfill in tension cracks.

1994 MA DEP Waterways Ch. 91 License Plan No. 4235 shows seawall repairs from approximately STA 116+50 to 119+50. Repairs consisted of placement of revetment out shore of seawall up to elevation +16.0 and the installation of weep holes and repairing deteriorated concrete. Presumed to be license application for emergency repairs with additional concrete repairs.

1994 Order of conditions for site located off Gurnet Rd. No drawings or description but presumed to be repair described above.

1995 Order of conditions for site located off Gurnet Rd. Extension, lot 220-400-000 registered portion only (Handicap Access). No drawings available.

1997 Seawall repairs from approximately STA (115+85 to 116+80). MA DEP Waterways Ch.91 drawings show repairs consisted of placement of revetment out shore of seawall up to elevation +15.0 and the installation of weep holes. There is also a letter to MA DEP (License No. 6664) confirming start of construction of this project.

2007 Seawall repairs from approximately STA (100+00 to 100+32). Repairs consisted of the removal and replacement of the top 8 ft of the existing seawall.

2010 Emergency Certification Form, in order to “deposit sand in front of seawall prior to the next 12-foot high tide to fortify wall”. Site location is off Gurnet Rd. and Ocean Road North. Work was in progress at time of first site inspection by ***BCE*** and, based on field observations, sand was deposited from approximately STA 121+00 to 124+00.

3.1.2 North Seawall – High Wall (STA 199+43 to 211+80)

The following is a summary of the history of the beach area of the Northern Seawall presented in chronological sequence of events:

Pre-1946 Shoreline protection consisted of dumped stone revetment, stone seawalls or beach had no protection at all.

1946 Concrete seawall was constructed by the Department of Public Works under DPW Contract No. 960 from approximately STA 205+00 to 209+00 & 209+00 to 211+80.

1953 Concrete seawall was constructed by the Department of Public Works under DPW Contract No. 1339 from approximately STA 199+43 to 205+00.

1997 Seawall repairs from approximately STA 203+50 to 205+00 & 207+00 to 208+50. Repairs consisted of placement of revetment out shore of seawall up to elevation +15.0 and the installation of weep holes. There is also a letter to DEP (License No. 6664) confirming start of construction of this project.

2007 Seawall repairs from approximately STA 203+50 to 208+50. Repairs consisted of installing a new concrete footing overlay (underpinning at toe down to El +5.0) over this entire length and reconstructing existing stone toe revetment up to elevation +15.0 from STA 205+74 to 207+39.

3.2 PREVIOUS INVESTIGATIONS AND REPORTS

3.2.1 Report by Nucci Vine Associates, Inc. titled "Duxbury Beach Seawall Investigations"

This report was prepared in December 1994 and a summary of key items from the report are as follows:

Condition of wall:
Overall, with the exception of the 300 foot length of seawall (STA 116+50 to 119+50) which was stabilized in December of 1993, the seawall was observed to be in good condition with the following exceptions:

- Existing expansion joints from the south end of the southern wall northward five hundred seventy feet (570 ft) had rubber backing rod and epoxy sealer but the remaining expansion joints were unsealed. No structural problems noted.
- Vertical cracks were observed along almost the entire length of seawall. There were two types of cracks observed, major and minor. Major cracks had widths ranging from ¼" to ¾" while minor cracks had widths ranging from hairline (less than 0.006 inch) to ¼". Typically for every 40 to 50 foot length of wall (i.e. between expansion joints) there were 1 major crack and 2 minor cracks.
- Horizontal cold joints were observed with the majority being in the northern portion of the site.
- Concrete block seawall at the southern end of the North Seawall was in fair to poor condition with concrete spalling and deterioration observed.
- Undermining was observed over a 40 ft length of the North Seawall with the concrete footing visible.
- At the time of this inspection, the 300 ft length of seawall (STA 116+50 to 119+50) described above was scheduled to be repaired during the fall/winter of 1994-1995.
- Report states that the seawall is unreinforced concrete wall, and the frequent vertical cracks observed are probably due to shrinkage resulting from uneven heat of hydration and internal stresses and improper curing methods when the wall was initially poured.
- Recommendations included repair of selected cracks only (for cost saving purposes) using epoxy injection where the gap is isolated and epoxy material is injected into the void under pressure.
- Concrete appeared to be deteriorated due to wave driven sand and gravel but no major problem. Wall is not reinforced and loss of cover material not anticipated to be an issue.
- Report did not recommend taking any measures to restore the abraded surface concrete.

Flood Protection Performance (Existing Conditions):

- Report uses Ahrens and McCartney (1975) and Ahrens and Titus (1985) to determine Run-up conditions. Overtopping calculations were based on empirical equations by Weggel (1976).
- Assumes the beach/toe of the seawall to be at EL +12.0 (MLW).
- Chose a wave period of 6 seconds, assuming longer period waves broke before reaching the structure.
- Analysis does not incorporate the wave-return lip as is typical.
- Analysis assumes top of wall elevation to be +22.5 (MLW) and FEMA flood elevation (water level + wave height) to be +22.0.
- Existing overtopping rates estimated to be 2.63 ft3/s/ft based on wall height as above with a water depth of 7ft, no wind and significant wave height of 4 ft. (Based on the water depth and toe given above, the Stillwater elevation used was EL +19.0 MLW).
- Report does not state any acceptable magnitude of overtopping.

Recommendations & Findings:

- Repair recommendation was to place revetment outshore of the seawall to EL. +16.0 (MLW). The berm width shown is 3 ft, with the rip rap slope changing to 1:1.5 down to elevation -4.0. Repairs protrude approximately 21 ft outshore of the wall.
- Estimated overtopping rate for proposed repair was 0.16 ft3/s/ft based on a water depth of 7 ft, no wind and a wave height of 4 ft.
- Report concluded:
    - proposed repairs would provide an immediate improvement to the stability of the wall
    - Predicted run-up and overtopping is slightly lower than pre-existing conditions but, because the analysis model is an approximation, post repair conditions will most likely be comparable to pre-existing conditions.
- The estimated cost (in 1994) for performing the above stated repair for the entire length of seawall was $1,225,000 (approximately $350/LF @ 3,500 LF).

3.2.2 Report by Nucci Vine Associates, Inc. titled "Shore Protection Inventory". March 2005

This report was prepared in March of 2005 to document existing shore protection and a summary of key items relating to Duxbury Beach seawalls are as follows:

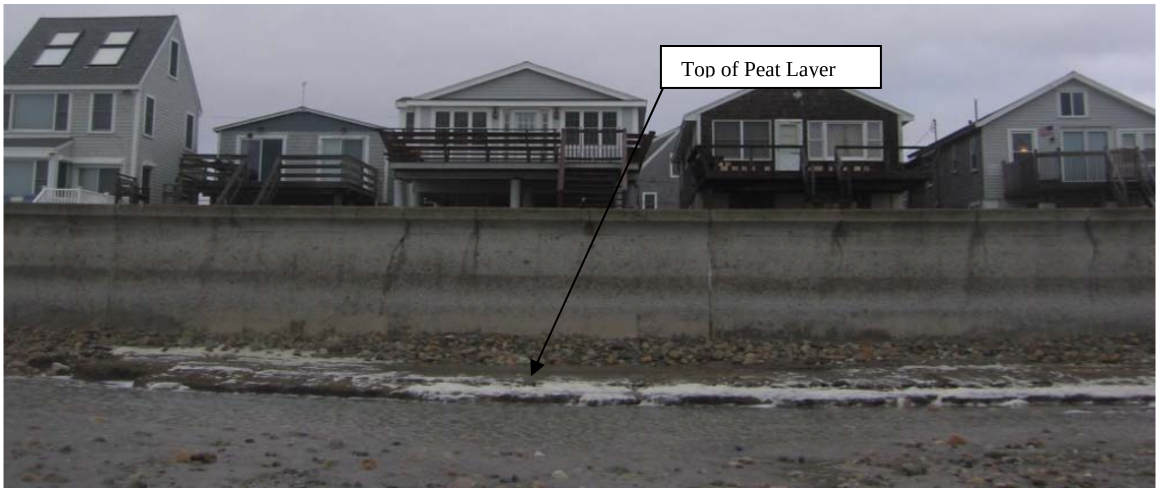
- Visual inspection determined many of the same defects in the seawall as in the 1994 report but report also documented movement of wall at the following locations:
    - Rotation or leaning outshore from STA 115+70 to 119+43 & 199+43 to 208+50 (BCE stationing)
    - Minor vertical shifting from STA 110+63 to 115+70 (BCE stationing)

3.3 EXISTING GEOTECHNICAL INFORMATION

DPW Contract No 2357 Drawing shows two soil borings to a depth of 15 and 16 feet. Both borings show Medium dense and Dense sands and gravels. Borings are located at northern limit of South High Wall – Area 4A – approx. STA 128+00. Copy of the drawing is attached in Appendix E.

A geotechnical investigation was performed in 1994 of the area between STA 116+00 and 120+00. Report and soil borings are attached in Appendix E. Soil borings typically show Medium dense to Dense sands and gravels at the wall foundation elevation but a layer of dense peat is also present in all borings. The top of peat layer appears to become shallower moving in southerly direction along the wall. Estimated top of peat elevation varies between elevations 0.0 feet MLW and +7 feet MLW.

Peat layer was visible on the beach while it was in an eroded condition in November 2010 between STA 107+00 and 109+00 along the South Low Wall. Typical photograph is shown below.



4 NATURAL RESOURCES

4.1 SITE DESCRIPTION

The entire length of Duxbury Beach is mapped as a Barrier Beach. It is exposed to open ocean and is a dynamic environment. No eelgrass is mapped on the ocean side of the beach.

The beach is mapped as Area Suitable for Shellfish and is designated as suitable for Surf Clams. No survey has been performed to verify their presence or density.

The areas outshore of the beach are within a Designated Shell Fish Growing area.

Almost the full length of the beach is shown as Estimated and Priority Habitat by the Massachusetts Natural Heritage & Endangered Species Program. A MESA Information Request was made and the following species were identified as having been found in the vicinity of the site:

- Piping Plover
- Roseate Tern
- Common Tern
- Arctic Tern
- Least Tern

Extracts from MA GIS data showing the extents of the above identified areas are included in Appendix F.

4.2 ***BEACH MATERIAL SAMPLES***

Ten grab samples were taken from the beach between December 12 and December 16, 2010. Gradation analysis was performed on these samples and the full results can be seen in Appendix G.

A summary of the gradation analysis is as follows:

Table 4.1 – Beach Material Gradation				
Sample Ref	% Cobble	% Gravel	% Sand	% Silt/Clay
South Wall				
1	-	5.8	94.0	0.2
3	-	-	99.9	0.1
4	-	1.1	98.8	0.1
6	-	6.8	92.8	0.4
7	-	36.4	63.5	0.1
North Wall				
9	-	16.7	83.2	0.1
11	-	10.7	89.2	0.1
Beach South of Seawalls				
12	-	0.4	99.3	0.3
13	-	13.9	85.6	0.5
14	-	32.2	67.3	0.5

As would be expected by visual examination, the beach material is classified as sand and gravel with a significant proportion of gravel in some samples.

5 TOPOGRAPHIC AND HYDROGRAPHIC SURVEY

5.1 ***TOPOGRAPHIC SURVEY***

Topographic survey was performed by Alpha Survey and Engineering, Inc. between November 22, 2010 and December 3, 2010. The survey included the beach area from Gurnet Pt. Light to two hundred feet north of the Duxbury/ Marshfield Town line as well as the two sea walls and existing inshore grades to a maximum of two hundred feet. The topographic survey also established survey control for the hydrographic survey. Topographic survey drawings are attached at Appendix A.

5.2 ***HYDROGRAPHIC SURVEY***

The hydrographic survey of the waters out shore of MLW to an extent of one thousand feet offshore was done on multiple days due to weather limitations. The survey was completed using an 18 ft motorboat with onboard equipment including Trimble GeoXH GPS and an Odom Hydrotrack single beam echo sounder with an 8º transducer. Data was collected through an on-board laptop computer using Hypack Hydrographic Survey Software. The survey was performed along the length of the sea walls on January 6th 2011. The remaining survey along the length of the Barrier Beach was performed between January 2011 and June 2011. Hydrographic survey data was merged with the topographic survey and the combined survey plans are attached at Appendix A.

All recorded benchmarks for this project are given relative to MLW (Mean Low Water) based on a correction between MLW and NAVD 88. The tidal datum correction was determined based on the NOAA Tidal Datum station #8446166 - Duxbury Harbor. The correction used for this site was NAVD 88 datum is + 5.58 ft above MLW. Relationships used for this report are shown in Table 5.1 below.

Table 5.1 – Tidal Datums & Water Elevations			
	NAVD 88	**NGVD 29**	**MLW**
FEMA 100YR -STILL	12.49	13.3	18.07
FEMA 50YR - STILL	9.09	9.9	14.67
MHW	4.31	5.12	9.89
NAVD 88	0.00	0.81	5.58
NGVD 29	-0.81	0.00	4.77
MLW	-5.58	-4.77	0.00

6 CONDITION INSPECTION

On November 11th, November 19th, and December 12th ***BCE*** performed a condition survey of the Duxbury Beach seawalls. The condition survey consisted of a visual inspection with detailed photo documentation of existing conditions. The inspection was performed commencing at low water to enable an inspection of the lower parts of the wall and surrounding beach. Wave conditions varied based on the day of inspection. Wave heights ranged widely between 1 ft and 10 ft breaking on the beach. Weather conditions also varied with fair to moderate weather and generally low ambient temperatures.

6.1 *SOUTH WALL – LOW WALL* – AREA 3 (STA 100+00 TO STA 116+00)

The seawall in this area was concrete with a re-curve shape. Top of wall width typically was 30" wide and below recurve, the wall face sloped at a 2 vertical to 1 horizontal slope continuing to below the existing beach grade. The top of wall elevation varied between 19.5 ft and 19.9 ft MLW. Exhibit 1 shows a typical cross section through the wall in this area. Condition Survey Sheet 1 of 3 in Appendix B shows typical conditions along this length of seawall.

Inspection was performed on two separate dates (11/11/10 and 12/14/10) and significant changes in beach elevation and exposed height of wall were noted – the differences ranged from 0.5 ft to 6.9 ft. Table 6.1 shows the variation along seawall. The foundation was exposed from STA 107+00 to 111+00.

From STA 100+00 to 110+50 the grade behind the wall was typically level and ranged between even with top of wall and 2 ft below the top of wall. Further from the wall the grades typically slope down away from the wall. Many of the homes behind the wall are on foundations raised above grade and the buildings are close to the wall. Homes in this length are at higher risk of damage due to flood water overtopping the seawall.

From STA 110+50 to the end of the low wall the grade behind the wall sloped up away from the wall and the houses are typically further from the wall. The risk of flood damage to homes in this area would be expected to be lower.

Table 6.1 - South Wall Exposed Wall Heights

STA	Est. Top of Wall El.	11/11/2010 Exposed Height	11/11/2010 Beach El.	12/14/2010 Exposed Height	12/14/2010 Beach El.	Difference
100+00	19.7	6.7	13.0	5.0	14.7	1.7
101+00	19.7	4.5	15.2	4.0	15.7	0.5
102+00	19.7	6.7	13.0	4.2	15.5	2.5
103+00	19.7	7.0	12.7	4.9	14.8	2.1
104+00	19.7	8.5	11.2	4.0	15.7	4.5
105+00	19.7	8.2	11.5	4.7	15.0	3.5
106+00	19.7	stairs				
107+00	19.7	10.3	9.4	5.2	14.5	5.1
108+00	19.7	10.5	9.2	5.0	14.7	5.5
109+00	19.7	10.3	9.4	5.0	14.7	5.3
110+00	19.7	10.8	8.9	6.7	13.0	4.1
111+00	19.7	10.5	9.2	3.6	16.1	6.9
112+00	19.7	9.0	10.7	6.0	13.7	3.0
113+00	19.7	7.3	12.4	3.7	16.0	3.6
114+00	19.7	6.0	13.7	3.9	15.8	2.1
115+00	19.7	5.3	14.4	3.2	16.5	2.1
116+00	21.7	7.3	14.4	5.6	16.1	1.7
117+00	21.7	8.5	13.2	5.7	16.0	2.8
118+00	21.7	5.5	16.2	4.7	17.0	0.8
119+00	21.7	7.5	14.2	5.3	16.4	2.2
120+00	21.7	10.3	11.4	5.8	15.9	4.5
121+00	21.7	11.2	10.5	6.3	15.4	4.9
122+00	21.7	11.7	10.0	6.7	15.0	5.0
123+00	21.7	11.7	10.0	6.3	15.4	5.4
124+00	21.7	10.1	11.6	6.5	15.2	3.6
125+00	21.7	11.2	10.5	6.4	15.3	4.8
126+00	21.7	10.0	11.7	6.8	14.9	3.2
127+00	21.7	10.5	11.2	6.8	14.9	3.7
128+00	21.7	11.2	10.5	6.2	15.5	5.0
129+00	21.7	10.6	11.1	5.7	16.0	4.9
130+00	21.7	9.7	12.0	7.0	14.7	2.7

Table 6.2 - Exposed Wall Heights

STA	Est. Top of Wall El.	11/11/2010 Exposed Height	11/11/2010 Beach El.	12/14/2010 Exposed Height	12/14/2010 Beach El.	Difference
200+00	21.7	9.0	12.7	5.6	16.1	3.4
201+00	21.7	12.0	9.7	7.1	14.6	4.9
202+00	21.7	10.5	11.2	6.9	14.8	3.6
203+00	21.7	9.0	12.7	7.5	14.2	1.5
204+00	21.7	9.3	12.4	8.2	13.5	1.1
205+00	21.7	7.0	14.7	7.7	14.0	-0.7
206+00	21.7	8.0	13.7	7.0	14.7	1.0
207+00	21.7	8.6	13.1	7.0	14.7	1.6
208+00	21.7	8.5	13.2	7.4	14.3	1.1
209+00	21.7	8.3	13.4			
210+00	21.7	6.7	15.0			
211+00	21.7	6.2	15.5			
211+80	21.7	6.6	15.1			

Overall the condition of the concrete seawall through this area was fair to good but many joints showed differential movement in the range ¼ “ to ½ “ and wide shrinkage cracks were present. Typical wall conditions included:

- Minor vertical and horizontal cracking <1/16” wide was typical throughout wall
- Efflorescence was present along cracks in concrete
- Joints were spaced approximately 45 ft o.c. At the time of inspection the ambient temperature was close to freezing and the joints were wide open.
- Joint sealant was typically weathered and cracking.
- Major vertical cracks ranging between 1/8” to 2” in width approximately 15 ft to 20 ft o.c.
- More significant movement was noted at STA 101+75 - shift 2” vertically & ½” out shore on north side of joint
- Exposed concrete surface was abraded by wave action on beach sand and gravel up to 4 ft below top of wall
- Beach cobbles and gravel were present in areas behind wall
- Stairs at STA 106+00
    - Had scaling and damage due to debris and stones abrading the concrete
    - Concrete had been patched previously but patch was failing
- Adjacent to wall, beach material grading was 6” stones and down to sand.
- Out shore of wall, beach was sand and gravel with an approximate slope of 1:20

6.2 SOUTH WALL – HIGH WALL – AREA 4A

The seawall in this area was concrete with a re-curve shape. Typically, top of wall was 30” wide. Below the recurve, the wall face sloped down at a 2 vertical to 1 horizontal slope to below the existing beach grades. Top of wall elevation varies between +21.0 feet MLW and +21.7 feet MLW. The beach elevations and exposed height of wall varied significantly on the two separate inspection dates and a summary of the differences is shown in Table 6.1. The grade behind the wall was typically level and ranged between even with and 2 ft below the top of wall. A typical wall cross section is shown in Exhibit 2. At the northern end the wall transitioned into a smooth placed riprap revetment and then into the open beach area (Area 5). Condition Survey Sheet 2 of 3 in Appendix B shows typical conditions along this length of seawall.

Inspection was performed on two separate dates (11/11/10 and 12/14/10) and significant changes in beach elevation and exposed height of wall were noted – the differences ranged from 0.8 ft to 5.4 ft. Table 6.1 shows the variation along seawall. The foundation was exposed and undermined from STA 121+00 to 124+00. At the time of the first inspection, the Town was filling this area with sand to stabilize the wall.

Overall the condition of the seawall concrete in this Area was fair but most joints showed some differential movement. The wall also has a significant outward bow in the alignment when viewed along its length. Typical wall conditions included:

- Joints approximately spaced 45 ft o.c.
- Joint sealant was weathered and cracking. At the time of inspection, the ambient temperature was close to freezing and the joints were wide open.
- Minor vertical and horizontal cracking < 1/16” wide was typical throughout the wall concrete
- Efflorescence was present along many of the cracks
- Major vertical cracks ranged between 1/8” to 1” in width approximately 15 ft± O.C. between joints.

- Major horizontal cracking < 1/8" wide and approximately 15 ft long between STA- 120+00 to STA 130+00
- More significant movement was observed at the following joints:
  - STA 116+25 ½" shift out shore and ½" drop on north side of joint
  - STA 116+45 ¾" shift out shore on north side of joint
  - STA 116+90 2.5" shift out shore at base and 5.5" shift out shore at top of wall, on north side of joint
  - STA 117+80 1.5" shift out shore on north side of joint
  - STA 119+75 10" shift outshore on south side of joint
- STA 120+50 to 124+00 wall movement and undermined foundations were present:
  - Bottom of wall was visible and undermined prior to town filling in beach material
  - ½ "-2"Cracking in ground approximately 10 ft inshore of wall
  - 1.5" gap between back of wall and soil
  - 3" of settlement found along back of wall
- Rust staining at spots from form ties, some steel visible
- Scaling and damage along top of wall from debris
- Beach sand and gravel present behind wall on grass
- Evidence of previous overtopping present including debris (drift wood, gravel, etc.) found behind wall as well as dead grass observed in adjacent yards.
- Riprap was visible from STA 116+00 to STA 120+00
  - Rip Rap varies between smooth placed slope and dumped rip rap
  - Riprap elevation at wall was approx. +12.5 feet MLW
  - Stone sizes vary 1.5'x2'x2' to 3'x3'x6' (approx. ½ ton to 4 ton)
- Adjacent to riprap, beach material grading was 6" stone and down.
- Out shore of wall, beach was sand and gravel with an approximate slope of 1:15

6.3 <u>AREA WITH NO WALL BETWEEN SOUTH AND NORTH WALLS (AREA 5)</u>

There was no seawall in this area. A sand dune with vegetation forms the upper limit of the beach approximately 60 ft offset from the line of the seawalls. The vegetation does not extend down the face of the dunes to the beach elevation. Observations were as follows:

- High tide mark is up on face of dune, evident by rack line
- Erosion was evident due to the loss of material in the middle of gap
- Erosion was evident in dune adjacent to rip rap at south wall
  - Stair piles were exposed indicating erosion of beach material
  - Vegetation mat was overhanging at top of slope, also indicating loss of material
- Inspection took place on two separate dates 11/11/10 and 12/14/10 and beach material grading appeared to vary. During the first inspection the surface material was noted to be finer and more sandy. On the second inspection, more coarse material was visible with cobbles to 6", sand and gravel.

6.4 <u>NORTH WALL – HIGH WALL - AREA 4B</u>

<u>STA- 199+43 to STA 200+00</u>

The sea wall in this area consisted of placed concrete blocks 3 ft tall x 2 ft wide with varying lengths. The blocks were stacked with two rows exposed. The area behind the blocks had extensive erosion and blocks showed significant movement outshore and settlement. The blocks were in poor condition with moderate spalling. This section is considered ineffective for shore protection.

STA- 200+00 to STA 209+00 (Area 4B)

The seawall in this area was concrete with a re-curve shape. The top of wall was approximately 30" wide with a 12" vertical face above the recurve. Below the recurve the wall face extended down below beach grades at a 2 vertical to 1 horizontal slope. Top of wall elevation varied between +21.5 feet MLW and +21.9 feet MLW. The wall inspection took place on three separate dates (11/11/10, 11/19/10 and 12/14/10) and significant change in beach elevations were noted ranging between -0.7 ft and 5 ft as shown in Table 6.2. The grade behind the wall was typically level and approximately 1 ft below the top of wall. Some of the homes behind the wall were on foundations raised off the ground and most of the buildings are relatively close to the wall placing them at higher risk of flood damage due to overtopping. Town line is at approx. STA 208+45. Condition Survey Sheet 3 of 3 in Appendix B shows typical conditions along this length of seawall.

Wall Condition
Overall the condition of the seawall concrete in this Area was fair to poor with many of the joints showing differential movement. Typical wall conditions were as follows:

- Vertical joints were spaced approximately 45 ft o.c.
- Minor vertical and horizontal cracking < 1/16" wide was typical
- More closely spaced vertical and horizontal cracking <1/16" wide between STA 202+00 and STA 203+00
- Major vertical cracking approx. 1/8" between STA 202+00 and STA 203+00
- Between STA 203+00 and 209+00:
    - Major vertical cracking up to 2" wide approximately 15 ft o.c. between vertical joints
    - Major horizontal cracking up to 1" wide at some locations
- More significant wall movement was present as follows:
    - STA 203+50 shift 3" out shore on north side of joint
    - STA 204+01 shift 3" out shore on north side of joint
    - STA 205+02 shift 6" inshore on north side of joint
    - STA 206+75 shift <1" vertical and horizontal
- Joint sealant was typically weathered and cracking
- Repairs present along wall on some cracks
- Efflorescence along cracks
- Spalling / rock damage on top of wall
- Abrasion of exposed concrete surface up to 4 ft below top of wall
- Between STA 203+00 and 209+00, rip rap was visible outshore of the wall
    - Stone sizes varied between 1.5'x2'x3' to 3'x3'x10' (estimated 1 ton to 7 ton)
    - Between STA 203+00 and STA 204+00, riprap was placed with flat sides up
    - Between STA 204+00 and STA 205+00 riprap was dumped
- Evidence of previous overtopping was present including rocks and debris found behind the wall
- Outshore of wall, the beach was 6" stones and down with an approximate slope of 1:15

6.5 RAMP OPENING AT APPROX. STA 208+60

The area consists of a concrete ramp and concrete side walls. The inshore limit of this area is a sand parking lot separated from the ocean by a steel beam and timber wall approximately 4 ft in height. The concrete ramp consists of multiple concrete pours placed on top of rip rap stones and at the outshore limit only exposed riprap is present. At the south side of ramp retaining wall, there was a 1” joint between side retaining wall and sea wall without grout infill and the north side retaining wall had extensive random cracking. Overall the ramp is in poor condition for use as a beach access.

6.6 WALL NORTH OF TOWN LINE - AREA 4B (STA 208+77 TO STA 211+15)

Description

From the ramp up to STA 210+65, the seawall was concrete with a re-curve shape. Top of wall width typically was 30” with a recurve profile below merging into the outshore face extending down on a 2 vertical to 1 horizontal slope with a concrete footing approximately 2 ft wide. The concrete footing stepped down to below the rip rap. Out shore of the wall rip rap was exposed with average approximate size of 3-4 ton stones

Beyond STA 210+65 to the end of the project, the concrete seawall profile changed to an angled face. The top 2 ft of the wall consisted of a cap with the out shore face angling outshore to direct runup water away. Below the angled face, the wall had an approximate 2.5:1 slope down to a concrete footing or toe protection approximately 2 ft wide. The footing extended down to below the rip rap.

The grade behind the wall was typically level approximately 1 ft below the top of wall. Some of the homes behind the wall were on raised foundations above grade.

Wall Condition

- Exposed height above footing was constant at approx. 6 feet along length
- Top of wall elevation varied between 21.4 ft and 21.6 ft MLW
- Minor vertical and horizontal cracking up to 1/16” wide was typical
- Joints approximately spaced 45 ft O.C.
- Before STA 210+65:
    - Major vertical cracking up to 1” wide approximately 15 ft O.C. between joints
    - Major horizontal cracking 1/4” to 1/2” wide
- After STA 210+6, Major vertical and horizontal cracking < 3” wide approximately 25 ft O.C.
- Abrasion of exposed concrete surface found up to 4 ft below top of wall
- Efflorescence along cracks
- Concrete looked weathered in comparison to rest of walls
- Previous repairs present
- Deterioration (spalling, cracking) between cold joint of toe protection and face of sea wall
- Aggregate (> 3”) exposed in face of sea wall
- Rust staining spots from form ties, some steel visible
- Concrete placed between rip rap stones
- Beach was smooth packed sand approximate slope 1:13 out shore of rip rap

7 SHORELINE CHANGES

Inspection of the shoreline through the area of the seawalls showed that it can experience rapid short term changes. A very rapid change in beach elevation was noted during the period when site inspections were being performed between November 11 and December 14, 2010. During this short time period, beach elevations changed by between +0.5 feet and +6.9 feet in areas not covered by riprap. The magnitude of this change was primarily because the beach was in an eroded condition at the start of this period and sections of the wall were undermined. The Town was performing emergency filling to sections of the South High Seawall close to STA 122+00 in Area 4A. Between the two inspection dates, accretion took place and the beach elevations typically increased by approximately 5 feet.

Given these rapid changes, it should be noted that the topographic survey for this project was performed between November 22, 2010 and December 3, 2010 and the survey plans only indicate the beach condition during this brief period.

All five areas in the study are located within one littoral cell that comprises approximately 6.5 miles of shoreline extending from Brant Rock in Marshfield to Gurnet Point in Plymouth (Applied Coastal Engineering, Inc., 2005). A littoral cell is a coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks (Inman, D. L., 2003). Excluding approximately 900 linear feet in Brant Rock, 650 feet south of Green Harbor and 340 feet (Area 5) in the northern one-third (nearly 2 miles) of the cell, the shoreline is protected by coastal engineering structures. As such, only 18% of the shoreline in this part of the littoral cell provides a source of sediment from the upland. The remaining 4.5 miles of shoreline from Ocean Road South to the Gurnet is a natural barrier beach and a dominant sediment source. Sediment sinks in the cell include Green Harbor, overwash and any offshore shoals or bars.

Several different sediment transport directions (i.e., transport paths) have been identified within this littoral cell (Applied Coastal Engineering, Inc., 2005). The predominant sediment transport direction is north to south which is typical for the east-facing shorelines in Massachusetts. However, there are two areas where there is a transport reversal. One is located immediately south of Green Harbor and the other is located in the vicinity of High Pines (see Figures 7-1 and 7-2, respectively). These conditions have the greatest impact on sedimentation, or lack thereof, in Areas 2-5 where the seawalls exist. Because the transport directions diverge in this area, longshore sediment will not accumulate there; but any artificial nourishment of the beaches fronting the walls may have a good residence time.

The dominant coastal processes in the study area also vary within the cell (Applied Coastal Engineering, Inc., 2005). Cross-shore sediment transport (or the component of transport that moves sediment onshore and offshore) is the dominant process for the entire study area and longshore sediment transport is a secondary process (see Figure 7-1). Several secondary processes exist along the barrier beach sections of the study area including barrier beach overwash, longshore sediment transport and aeolian (or wind) transport (see Figure 7-3). To date, the quantification of these transport volumes does not appear to be fully achieved. However, beach profile data have been collected since 2000 at eight stations located south of the seawall areas and some wave modeling has been conducted (FitzGerald and Rosen, 2008). In part, the lack of sediment transport quantification relates to the relative stability of the overall shoreline along Duxbury Beach (pers. comm. Peter Rosen) (Figures 7-4, 7-5 and 7-6).

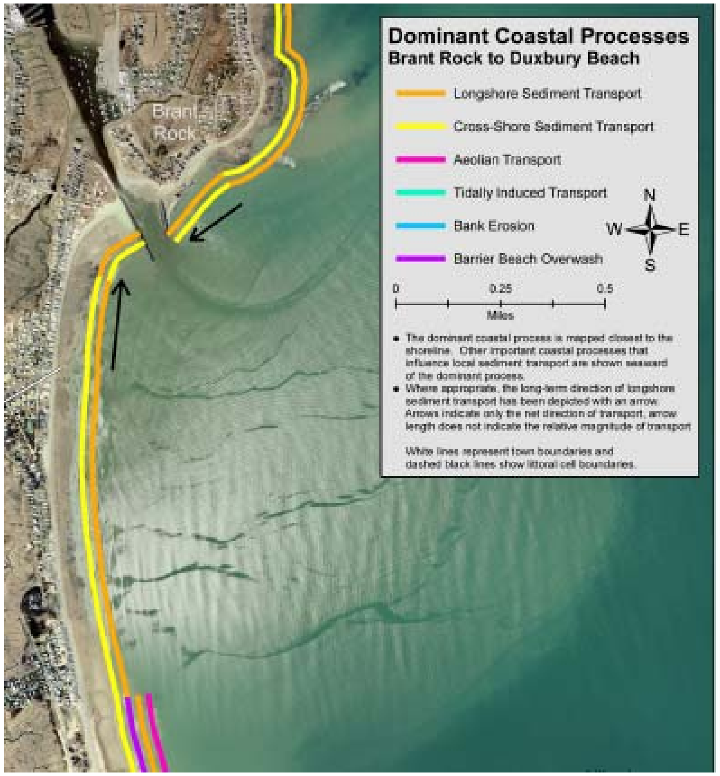


Figure 7-1

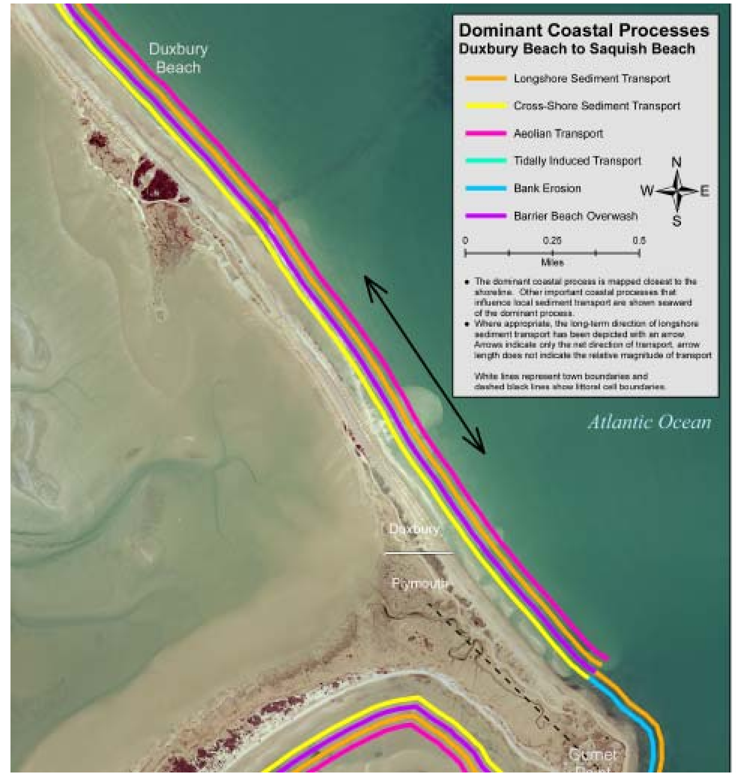


Figure 7-2

Figure 7-3

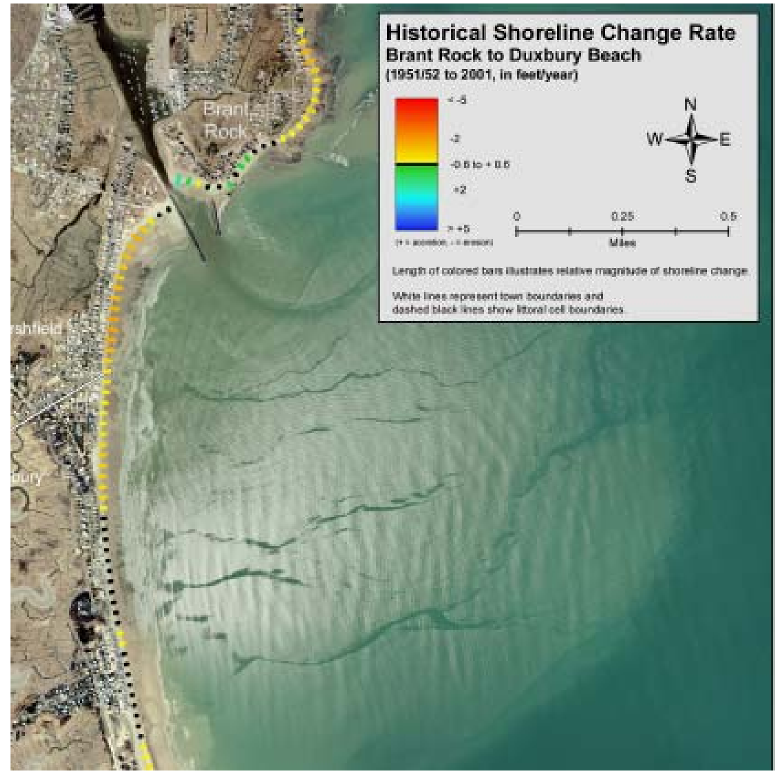


Figure 7-4

Figure 7-5

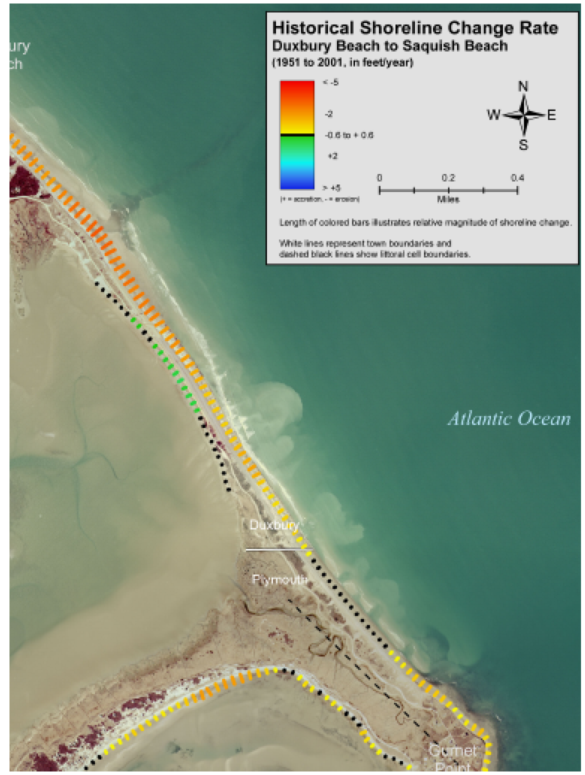


Figure 7-6

With the dominance of cross-shore sediment transport and relative stability of the shoreline, the method of quantifying sediment losses and gains should be approached differently than if longshore sediment transport was dominant and the shoreline was experiencing high levels of erosion and accretion in different areas. All of the beach profile data that have been collected have been plotted and overlaid for each transect, the result of which is a “sweep zone” for each of the eight profile stations (Rosen, 2009). Since these stations are located south of the seawall areas, two other stations were selected to be representative of changes that have occurred there. One station is located at the north end of Area 4 and the other is located at the south end of Area 3. Sweep zones for these two stations were compiled from profile data extracted from surveys done in 1946, 1953, 1996, 2007 and 2010.

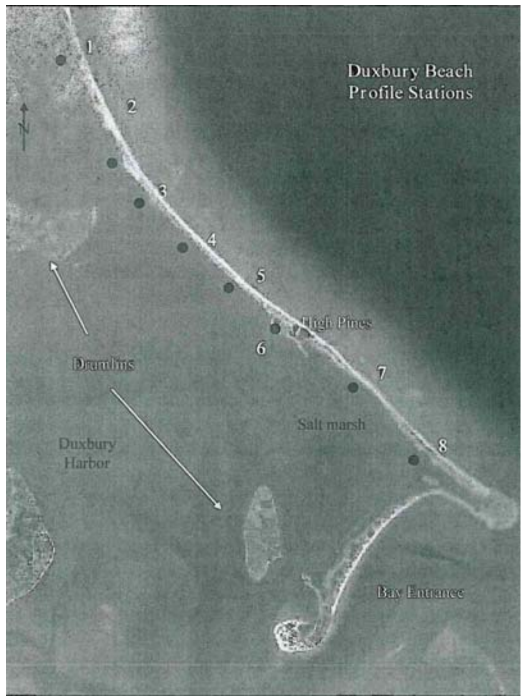


Figure 7-7 – Profile Locations from Duxbury Beach Report 2009

An analysis of the sweep zones was undertaken to quantify the volume of sediment that was actively exchanged in the intertidal zone (between mean high water and mean low water) over a given timeframe. In the case of the Rosen profiles it was a ten year period and for the additional seawall stations it was a 57-64 year period. The area of each sweep zone was computed and multiplied by half the distance to the next station which provided a total volume of sediment for the study area as summarized below:

Station	Area (s.f.)	Distance (l.f.)	Volume (cy)	Vol. per l.f.
Area 4 Wall	493	2200	40,154	18.3
Area 3 Wall	320	2200	26,000	11.8
Profile #1	283	4630	48,529	10.5
Profile #2	406	3370	50,675	15.0
Profile #3	424	2200	34,538	15.7
Profile #4	325	2300	27,685	12.0
Profile #5	271	2530	25,394	10.0
Profile #6	232	3370	28,957	8.6
Profile #7	223	4100	33,863	8.6
Profile #8	122	3950	17,904	4.4

Typically, longshore sediment transport is defined by volumes and rates (c.y./yr.), but as stated above, this area is dominated by cross-shore transport. The difficulty in assigning any rate to these data is that they represent large data sets (10-64 years). We know that northeasterly storms play a dominant role in the generation of cycles of erosion and deposition on beaches in New England; that no stage (i.e., early post-storm, early accretion and late accretion) is unique to any particular season; and, that the cycle is frequently interrupted by recurring storms (Hayes and Boothroyd, 1969).

Since there has not been a seasonal analysis (winter vs. summer beach comparisons) nor has there been an analysis of beach changes vs. storm occurrences, no further analysis of the sweep zone data can be conducted to determine rates of change. However, a maximum range of 5.6 feet along the north seawall and 7.4 feet along the south wall was recorded this past fall (November 11 – December 14) during the recent wall inspections. Given the results of the vertical changes in beach elevations on the seawalls, it would not be unreasonable to expect that the changes in volumes calculated above can occur during one storm or even during a winter/summer season.

Compared to a maximum range of 3.6 – 6.9 feet that occurred within the sweep zones of the beach profile data, the short-term changes along the seawalls are consistent with the longer-term barrier beach fluctuations.

Conclusions of previous studies (Rosen, 2009) indicate that Duxbury Beach has overall been relatively stable since 1999. However, it can experience dramatic erosion within a storm cycle followed by fairly rapid recovery.

8 WAVE CONDITIONS AT SITE

The seawalls are located on the Eastern shoreline of Duxbury and are directly exposed to open ocean waves. Site topography and bathymetry were taken from surveys performed as part of this study. Wave data was obtained from the Wave Information Study (WIS) from the U.S. Army Corp. of Engineers (USACE) for wave hind-cast data and an offshore NOAA data buoy.

Offshore design wave conditions for the Duxbury seawall were determined using the 20-year (1980-1999) wave hind-cast data records from three WIS stations located in Massachusetts Bay. The three stations chosen were numbers 63057, 63058 and 63059. Station 63057 is 20.7 NM Northeast (at 59°) of the site, station 63058 is 17.8 NM Northeast (at 53°) of the site and station 63059 is 14.7 NM Northeast (at 44°) of the site. WIS data can be found at the following link: http://frf.usace.army.mil/wis2010/wis.shtml and clarification and data descriptions can be found at: http://www.frf.usace.army.mil/wis/datadefs.html. The only wave information relevant to this analysis is assumed to be within ±25° of the angle between the WIS station and the site (i.e. waves from the WIS station traveling to the site).

An analysis of wave heights was performed to determine the conditions that are likely to occur for the 25, 50 and 100 year return storm periods at the study site. Annual extreme wave heights (i.e. highest H_{mo}/significant wave heights) were taken from the WIS hind-cast data. These wave height values were then input into the USACE's Automated Coastal Engineering System (ACES) software package to determine the 25, 50 and 100 year return period values of wave height. ACES software provides analysis based on either the FT-1 or Weibull type distributions. For this analysis, the FT-1 and Weibull (K=2.0) distributions were selected based on best fit (higher correlation values and low sum square of residual values). Predicted offshore wave conditions, based on this analysis, are shown in Table 8.1.

A similar analysis of winds was performed in order to estimate wave periods that would correspond to the extreme return period wave heights previously determined. Extreme wind speeds for the Duxbury seawall were determined using 20 years of data (1984-2003) from Massachusetts Bay NOAA buoy 44013 which is located 16.371 NM North of the project site. Wind directions matching WIS wave data were used in the analysis.

After determining the return period wave heights and wind speeds, the ACES "Wind Adjustment and Wave Growth" application was used to estimate the wave periods that correspond to the wave heights. The final offshore wave heights and associated wave periods are as shown above in Table 8.1.

Table 8.1 - Offshore Significant Wave Heights:

	Return Period (years)			
	50		100	
WIS	Height (ft)	Period (sec.)	Height (ft)	Period (sec.)
63057	27.86	12.7	29.89	13.20
63058	29.74	12.8	31.94	13.30
63059	29.15	12.2	31.19	12.60

The Federal Emergency Managements Agency (FEMA) Flood Insurance Study (FIS) for Duxbury, Massachusetts (FEMA, 2005) was used to obtain estimated still water flood elevations for the return periods as shown in Table 8.2. These values are still water and do not include any consideration of wave action. All of the shoreline is within FEMA velocity zones and the published FEMA Flood Insurance Rate Map (FIRM) flood elevations are higher than shown in Table 8.2. Extracts from FEMA FIRM's for the site are attached in Appendix H.

Table 8.2 - Stillwater Flood Elevations (From FIS)

	Return Period (years)					
	50 year Elevation		100 year Elevation		100 year Elevation plus 1 foot	
Transect #	NGVD	MLW	NGVD	MLW	NGVD	MLW
24	9.9	14.67	13.3	18.07	14.30	19.07
25	9.9	14.67	13.3	18.07	14.30	19.07

Nearshore wave conditions were then estimated using a Wave Transformation method by Goda to determine significant wave heights (Hs) & maximum wave heights (H_{max}) at the seawall toe for each stillwater elevation. The project was broken down into three different zones to reflect the changing beach elevations along the length of the seawall, generally described as follows:
Area 3 – Beach Elevation at wall toe is +8.4 feet MLW
Area 4A – Beach Elevation at wall toe is +9.0 feet MLW
Area 4B – Beach Elevation at wall toe is +12.5 feet MLW

Table 8.3 - Significant Wave Heights (H_s) and Maximum Wave Heights (H_{max}) (feet) for Area 3 – South Low Wall Beach El. +8.4' MLW									
	Return Period								
	50 year			100 year			100 year plus 1 foot		
WIS	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)
63057	6.11	9.08	12.7	8.16	11.66	13.20	8.71	12.33	13.20
63058	6.38	9.59	12.8	8.46	12.22	13.30	9.01	12.89	13.30
63059	6.35	9.53	12.2	8.41	12.14	12.60	8.96	12.80	12.60

Table 8.4 - Significant Wave Heights (H_s) and Maximum Wave Heights (H_{max}) (feet) for Area 4A – South High Wall Beach El. +9.0' MLW									
	Return Period (years)								
	50 year			100 year			100 year plus 1 foot		
WIS	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)
63057	5.78	8.68	12.7	7.82	11.26	13.20	8.38	11.93	13.20
63058	6.05	9.19	12.8	8.12	11.82	13.30	8.68	12.49	13.30
63059	6.01	9.13	12.2	8.08	11.74	12.60	8.63	12.40	12.60

Table 8.5 - Significant Wave Heights (H_s) and Maximum Wave Heights (H_{max}) (feet) for Area 4B – North Wall Toe El. +12.6' MLW									
	Return Period (years)								
	50 year			100 year			100 year plus 1 foot		
WIS	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)	H_s	H_{max}	Period (sec.)
63057	3.79	6.29	12.7	5.84	8.87	13.20	6.39	9.53	13.20
63058	4.06	6.8	12.8	6.14	9.43	13.30	6.69	10.09	13.30
63059	4.03	6.73	12.2	6.09	9.34	12.60	6.65	10.01	12.60

Wave heights shown in Table 8.5 should be used for areas of the wall where riprap is present outshore and Tables 8.3 and 8.4 should be used for areas with no riprap.

9 WALL OVERTOPPING ANALYSIS AND REVETMENT DESIGN

9.1 <u>OVERTOPPING METHODS</u>

Two different methods were used to determine seawall overtopping discharge rate (with a third which was primarily used as a check of ACES).

Alternatives consisting of a plain seawall use ACES "Significant Wave Run-up and Overtopping on Impermeable Structures Analysis". ACES uses the empirical equations suggested by Ahrens and McCartney (1975), Ahrens and Titus (1985), and Ahrens and Burke (1987) to predict run-up, and Weggel (1976) to predict overtopping. As a check on this program, the method of determining overtopping defined in US Army Corps of Engineers (USACE) Manual EM1110-2-1614 “Design of Coastal Revetments, Seawalls and Bulkheads” was also used.

Alternatives which include a revetment placed outshore of the seawall use the Bradbury and Allsop method as described in the USACE Manual EM 1110-2-1100 “Coastal Engineering Manual” (CEM).

Alternatives consisting of a full height revetment with no crest wall used the methods by Owen and Van der Meer also as described in the USACE Manual EM 1110-2-1100 “Coastal Engineering Manual” (CEM).

Desirable overtopping limits for each zone along the seawall will vary depending on the typical conditions present. The CEM recommends critical values for average overtopping discharge in Table VI-5-6 of the manual. These critical values are based on safety to vehicles, pedestrians and structures for different types of seawall. Exhibit 9.1 is an extract from the CEM showing the relevant table. The following are the proposed overtopping limits suggested to meet safety criteria:

Table 9.1 – Critical Overtopping Discharges

Safety Criterion	**Metric units**	**Imperial Units**
Damage to paved areas	20 liters/sec/m	0.2 ft^3/sec/ft
Erosion of grassed areas	2 liters/sec/m	0.02 ft^3/sec/ft
Pedestrian safety	0.3 liters/sec/m	0.003 ft^3/sec/ft
Building damage	0.03 liters/sec/m	0.0003 ft^3/sec/ft

Area 3 (Low Wall) - STA 100+00 – 110+50:

- Many houses are on raised foundations above grade.
- Decks are typically elevated on sono-tube foundations and close to back of wall.
- Existing grade behind is below top of wall.
- Minimum house set-back is 18’
- Maximum house set-back is 95’
- Typical house set-back is 30’-40’

Typical condition STA 100+00 – 110+50

- ➢ Raised foundations and grade sloping away behind wall will reduce impact of flood water over wall
- ➢ Close proximity of houses to wall increase potential impacts of structural damage
- ➢ Desirable overtopping limit should be based on minimizing potential for structural damage – Proposed limit 0.0003 ft^3/sec/ft.

South Low Wall (Area 3) - STA 110+50 – 115+50:

- Houses are on grade and grade is raised behind wall.
- Area behind wall is grass.
- Typical house set-back is 95’
- Typical house set-back is 30’-40’

Typical condition STA 110+50 – 115+50

- ➢ Large setback and upward grade will reduce impact of flood water over wall
- ➢ Large setback will reduce potential impacts of structural damage
- ➢ Desirable overtopping limit should be based on minimizing erosion of grassed areas – Proposed limit 0.02 ft^3/sec/ft.

South High Wall (Area 4A) – STA 115+50 – 117+00:

- Many houses are on raised foundation.
- Grade is typically below top of wall and slopes away to Gurnet Road behind.
- Decks are typically elevated on sono-tube foundations
- Minimum house set-back is 26’
- Typical house set-back is 40’-50’

Typical condition STA 115+50 – 117+00

- ➢ Significant setback and sloping grade will reduce impact of flood water over wall
- ➢ Significant setback will reduce potential impacts of structural damage
- ➢ Flow towards houses potentially affects occupants outside
- ➢ Desirable overtopping limit should be based on pedestrian safety – Proposed limit 0.003 ft^3/sec/ft.

South High Wall (Area 4A) – STA 117+00 – 122+00:

- Maximum house set-back is 105’
  - Significant setback will reduce potential impacts of structural damage
  - Large setback will reduce potential impacts of structural damage
  - Desirable overtopping limit should be based on minimizing erosion of grassed areas – Proposed limit 0.02 ft^3/sec/ft.

South High Wall (Area 4A) – STA 122+00 – 127+00:

- Typical house set-back is 30’-40’
  - Close proximity of houses to wall increase potential impacts of structural damage
  - Desirable overtopping limit should be based on minimizing potential for structural damage – Proposed limit 0.0003 ft^3/sec/ft.

South High Wall (Area 4A) – STA 127+00 – 129+00:

- Typical house set-back is 40’-50’
  - Flow towards houses potentially affects occupants outside
  - Desirable overtopping limit should be based on pedestrian safety – Proposed limit 0.003 ft3/sec/ft.

North High Wall (Area 4B) – STA 200+00 – 208+50:

- Houses are typically on grade along this stretch of wall.
- Decks are raised and attached to the houses.
- Minimum house set-back is 18’
- Maximum house set-back is 53’
- Typical house set-back is 20’-30’

Typical condition STA 200+00 – 208+00

  - Grade sloping away behind wall will reduce impact of flood water over wall
  - Construction on grade increases potential flood impact
  - Significant setback will reduce potential impacts of structural damage
  - Flow towards houses potentially affects occupants outside
  - Desirable overtopping limit should be based on pedestrian safety – Proposed limit 0.003 ft^3/sec/ft

The above overtopping criteria were used as a guide to establish suitable rehabilitation alternatives and can be summarized as shown in Table 9.2 below:

Table 9.2 – Desirable Overtopping Limits by Station

Station			**Desirable Overtopping Limit**
From	**To**	**Length (ft)**	
South Wall			
100+00	110+50	1050	0.0003 ft^3/sec/ft
110+50	115+50	500	0.02 ft^3/sec/ft
115+50	117+00	150	0.003 ft^3/sec/ft
117+00	122+00	500	0.02 ft^3/sec/ft
122+00	127+00	500	0.0003 ft^3/sec/ft
127+00	129+00	200	0.003 ft^3/sec/ft
Area with No Wall			
129+00	132+20	320	0.003 ft^3/sec/ft
North Wall			
200+00	208+50	850	0.003 ft^3/sec/ft

9.2 REVETMENT ARMOR STONE SIZING

Several methods to determine armor stone size requirements for dikes and revetments are presented in the CEM. This study compared the method of Van der Meer (1988) and the Hudson equation (1961). At this stage in the study the more conservative of the two results was used.

Stones were sized assuming a single armor layer in most cases with a 0.1 permeability factor (corresponding to an impermeable core), varying slope, and a structural damage level of 2 (corresponding to 0-5% allowable damage). The number of waves in the storm was set to 7000 as recommended by CEM. Using a single layer of armor requires a more conservative assessment of stone size. With two layers of stone, protection is not severely impacted if a single stone is lost from the layer. If there is only a single layer of armor stone, loss of a single stone opens the smaller core stone up to erosion and can lead to more extensive deterioration of the revetment. Two layers of stone can also offer additional benefit in absorbing wave energy. Two layers provide more voids within the revetment creating a more permeable surface which better absorbs the waves.

Required revetment stone size was only estimated for the 100 year storm event combined with the 100 year plus one foot stillwater elevation. Regardless of the level of flood protection eventually selected, any armor stone should be designed to resist the more extreme event.

Table 9.3 – Revetment Armor Stone Sizing for 100 year Storm Event

Revetment Slope	**Individual Armor Weight**	
	Two Layers	**Single Layer**
1 : 2	4 tons	5 tons
1 : 3	2 tons	3 tons
1 : 10	1 ton	2 tons

10 REHABILITATION ALTERNATIVES

Eight alternatives for repair or rehabilitation of the Duxbury Seawalls are presented below together with a review of their initial costs, maintenance costs, construction advantages and disadvantages and property, regulatory and environmental issues. Comparison of flood protection in terms of runup elevation and overtopping discharge is based on analysis for the 100 year return period flood elevation plus 1 foot. Sketches of Alternatives 2 to 10 are included in Appendix I.

The eight alternatives are as follows:

Alternative 1 – No Build

Alternative 2 – Raise Revetment to Existing Top of Wall Elevation +21.5

Alternative 3 – Increase Wall Height for a Toe at Elevation +9.0

Alternative 4 – Increase Wall Height for a Toe at Elevation +12.6

Alternative 5 – Increase Wall Height to Elevation +26.5 & Raise Beach Elevation to +17.0

Alternative 6 – Increase Wall Height to Elevation +26.5 & Raise Revetment to Elevation +19.4

Alternative 7 – Increase Wall Height to Elevation +26.5 & Raise Revetment to Elevation +26.5

Alternative 8 – Revetment in Area 5 between Seawalls

10.1 ALTERNATIVE 1 – NO BUILD (EXISTING CONDITIONS)

This alternative would consist of doing nothing other than maintenance of the existing seawall. There are really four different configurations for the existing conditions:

Alternative 1A – South Low Wall STA 100+00 to 116+00 (Area 3)
Alternative 1B – South High Wall STA 116+00 to 130+00 (Area 4A)
Alternative 1C – North High Wall STA 200+00 to 211+80 (Area 4B)
Alternative 1D – No wall (Area 5)

The existing seawall cross sections for these areas are shown in Exhibits 1 to 3 in Appendix I.

Runup and overtopping values were calculated for these areas as follows:

Table 10.1 – Runup and Overtopping
Existing Conditions 100 year plus 1 ft Condition

	Runup Elevation	Existing Crest El.	Av. Overtopping Discharge $ft^3/s/ft$
Alternative 1A	+40.0’MLW	+19.7’MLW	14.7
Alternative 1B	+39.4’MLW	+21.5’MLW	9.04
Alternative 1C	+36.0’MLW	+21.6’MLW	3.48
Alternative 1D	+26.0’MLW	+18’MLW ±	-

Runup elevations significantly exceed the existing top of wall or grade elevations and overtopping discharges are orders of magnitude larger than even the lowest recommended value of 0.02 $ft^3/s/ft$.

For the same seawall configurations, for a 50 year return period, runup and overtopping rates are as shown in Table 10.2.

Table 10.2 – Runup and Overtopping Existing Conditions 50 year Flood Condition			
	Runup Elevation	Existing Crest El.	Av. Overtopping Discharge $ft^3/s/ft$
Alternative 1A	+30.7’MLW	+19.7’MLW	1.6
Alternative 1B	+30.1’MLW	+21.5’MLW	0.7
Alternative 1C	+26.6’MLW	+21.6’MLW	0.05
Alternative 1D	+20.0’MLW	+18’MLW $\pm$	-

The overtopping discharges for this condition also significantly exceed recommended values but the discharge for Alternative 1C (High Wall with Riprap outshore) is close to the recommended value for protection of erosion to grassed areas. Even for this alternative the discharge is an order of magnitude larger than recommended for pedestrian safety.

The seawall is now in poor condition with significant movements, major vertical and horizontal cracking (with efflorescence present in some locations), scaling and abrasion damage.

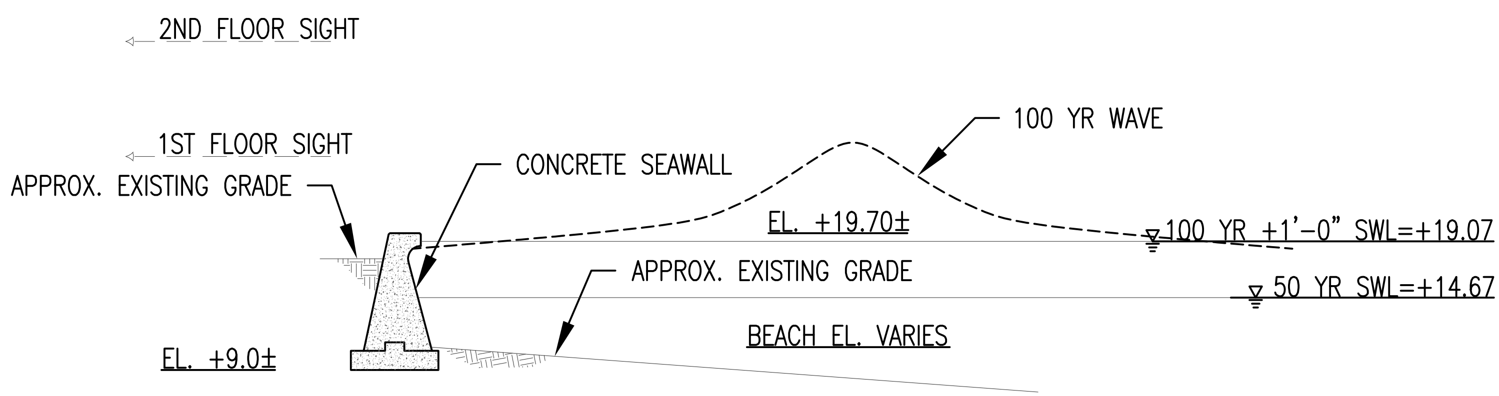
Beach elevations outshore of the seawall varied significantly on the different inspection dates, and on 11/11/10, the beach elevations were so low that the wall was being undermined. If no repairs are performed, the seawall stability will continue to deteriorate due to the lack of support and the seawall is clearly at risk of undermining and collapse.

A summary of the advantages and disadvantages of this option are as follows:

Advantages	*Disadvantages*
• *Zero cost* • *No new resource area impacts* • *No additional land required* • *No impacts on beach amenity*	• *Seawall is unsafe during 100 year + 1 ft storm events due to large overtopping discharge* • *Seawall is unstable and has potential for scour leading to extensive failure* • *Wall is overtopped in less severe storm events (evident during site inspection as rocks and debris were observed on the inland side of the seawall)* • *Houses behind the seawall have the potential for damage due to large overtopping discharge*

10.2 <u>ALTERNATIVE 2 – CONSTRUCT REVETMENT TO ELEVATION +21.5</u>

This alternative consists of construction of a new revetment in front of the seawall up to the existing high wall crest elevation which was assumed to be at elevation +21.5 MLW for the entire length of seawall. Exhibit 4 shows the proposed cross section. The outshore face of the revetment is sloped at 1:2 and the crest is 8 feet wide. The revetment extends approximately 38 feet outshore



NOTE:
1. BEACH CONSISTS OF SAND & STONE (<6"ø)
2. FROM SITE INVESTIGATION ON 11/11/10 EXPOSED HEIGHT RANGES FROM 4.5' TO 11.3'
3. BEACH ELEVATION LESS THAN +11.0± FROM STA 104+00 TO 112+00

A/1 NO BUILD SOUTH LOW WALL (STA 100+00 TO 116+00) – ALTERNATIVE 1A

SCALE: 1"=15'

50 YR (WAVE HEIGHT=4.9 FT)
OVERTOPPING = 1.6 FT^3/S/FT

100 YR + 1'-0" (WAVE HEIGHT=8.3 FT)
OVERTOPPING = 14.7 FT^3/S/FT
COST:
$0.00

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EXHIBIT 1

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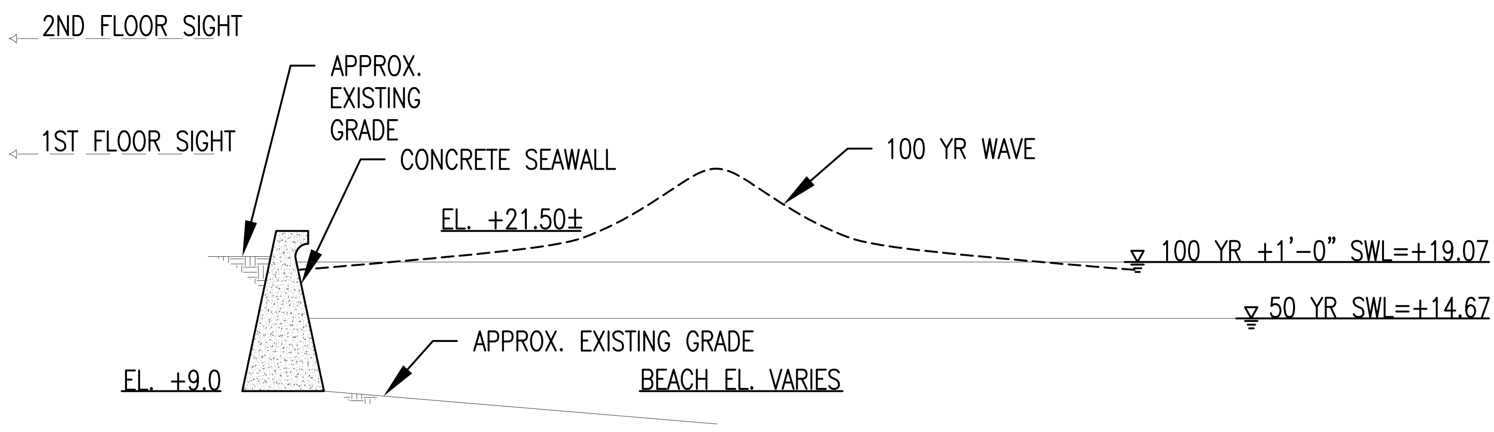

NOTE:

1. REVETMENT (½ TON–4 TON) LOCATED AT BASE OF WALL FROM STA 116+50 TO 119+50.
2. BEACH CONSISTS OF SAND & STONE (<6"ø)
3. FROM SITE INVESTIGATION ON 11/11/10 EXPOSED HEIGHT RANGES FROM 5.5' TO 11.7'
4. BEACH ELEVATION LESS THAN +11.0± FROM STA 120+00 TO 129+00

A/2 NO BUILD SOUTH HIGH WALL (STA 116+00 TO 130+00) – ALTERNATIVE #1B

SCALE: 1"=15'

50 YR (WAVE HEIGHT=4.4 FT)
OVERTOPPING = 0.71 $FT^3/S/FT$

100 YR +1'-0" (WAVE HEIGHT=7.9 FT)
OVERTOPPING = 9.03 $FT^3/S/FT$

COST:
$0.00

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EXHIBIT 2

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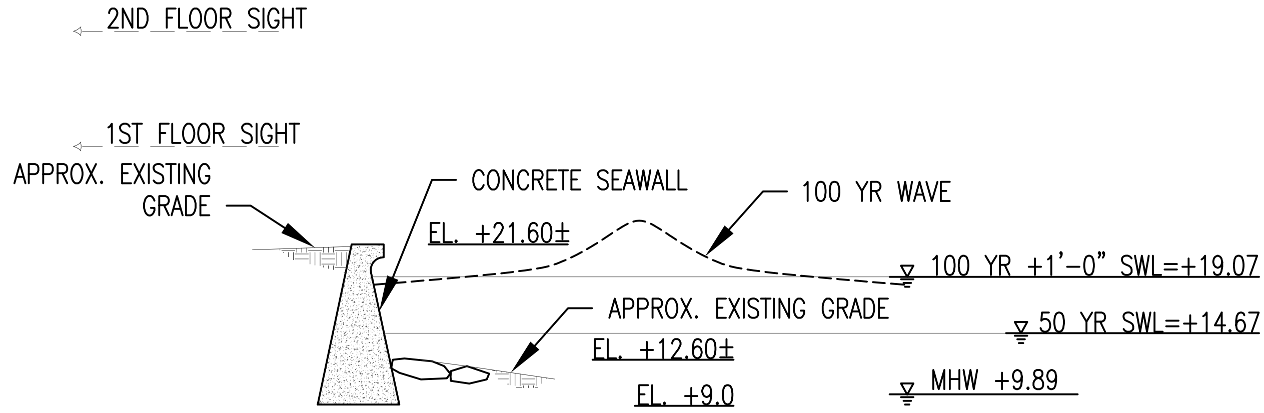

NOTE:
1. REVETMENT (1 TON TO 7 TON) LOCATED AT BASE OF WALL FROM STA 203+50 TO 211+80.
2. BEACH CONSISTS OF SAND & STONE (<6"ø)
3. FROM SITE INVESTIGATION ON 1/11 10 EXPOSED HEIGHT RANGED FROM 6.2' TO 12.0'

A/3 NO BUILD NORTH HIGH WALL (STA 200+00 TO 211+80) – ALTERNATIVE #1C

SCALE: 1"=15'

50 YR (WAVE HEIGHT=1.6 FT)
OVERTOPPING = 0.05 FT^3/S/FT

100 YR +1'-0" (WAVE HEIGHT=5.0 FT)
OVERTOPPING = 3.5 FT^3/S/FT

COST:
$0.00

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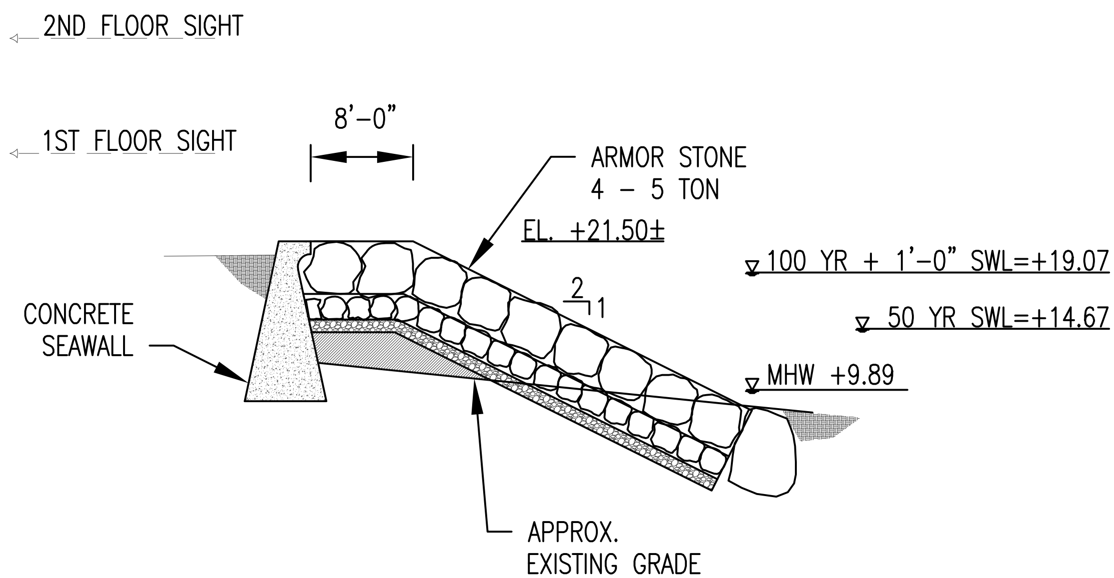
EXHIBIT 3



ALTERNATIVE #2-REVETMENT TO TOP OF WALL EL.+21.5

A/4

SCALE: 1"=15'

<u>50 YR</u>
OVERTOPPING = 0.5 FT^3/S/FT
<u>100 YR + 1'-0"</u>
OVERTOPPING = 10 FT^3/S/FT
<u>COST:</u>
$1,821/LF

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EXHIBIT 4

of the existing seawall. The estimated construction cost of this alternative is $1,821 per linear foot of wall.

For the 100 year plus 1 ft condition, the estimated overtopping rate was excessive. The overtopping rate for the 50 year return period was calculated to be 0.5 ft3/s/ft which is much greater than recommended values. The calculated overtopping rate is an order of magnitude larger than the highest recommended overtopping flow rate of 0.02 ft3/s/ft and is a value which could cause damage to the grassed areas and homes close behind it and place pedestrians at risk.

Adding the revetment to the top of the existing wall crest elevation reduces the amount of overtopping compared to the existing conditions but the values of overtopping are still considered to be too high. Therefore, further option development was performed.

Three additional alternatives 2A, 2B and 2C were developed using the same revetment configuration but adding a crest wall at the top of the revetment. Crest walls of 2 feet, 4 feet and 5 feet were considered respectively. The crest walls would be constructed of concrete founded on the upper portion of the existing wall. This approach is considered acceptable because the existing wall will be completely buried by the new revetment. Overtopping rates and costs for each of these additional alternatives are presented in the Table below:

Alternative	**Description**	**Overtopping Rates *ft3/s/ft***		**Cost $/LF**
		50 year	100 year +1’	
2	Revetment to +21.5	0.5	10	$1,821
2A	Revetment to +21.5, 2 ft crest wall	0.04	7.5	$2,034
2B	Revetment to +21.5, 4 ft crest wall	0.008	5.3	$2,294
2C	Revetment to +21.5, 5 ft crest wall	0.004	2.6	$2,892

All of the 100 year overtopping rates are excessive but the 50 year overtopping rates for Alternatives 2A, 2B and 2 C represent acceptable levels for some of the scenarios considered in Section 9 above. These alternatives are shown in Exhibits 4A, 4B and 4C.

Because any of these alternatives consist of maintenance and expansion of an existing structure, the anticipated regulatory requirements are as follows:

- ENF for MEPA due to alteration of barrier beach and bank
- Notice of Intent to Town of Duxbury Conservation Commission
- US Army Corps of Engineers
- DEP Waterways Chapter 91 Permit
- DEP Waterways Water Quality Certificate

A summary of the advantages and disadvantages of this alternative are as follows:

Advantages	*Disadvantages*
• *Overtopping rates acceptable for 50 year storm condition* • *Wall stability will have significant improvement with the revetment structure in front* • *Costs are mid range*	• *Overtopping rates are still much higher than recommended rates for 100 year storm condition* • *Permitting will be more difficult due to expansion of structure outshore of the wall* • *Revetment structure will cover beach, leaving little or no room for pedestrian beach access at high tide* • *Houses behind the seawall have the potential for damage due to high overtopping discharge*

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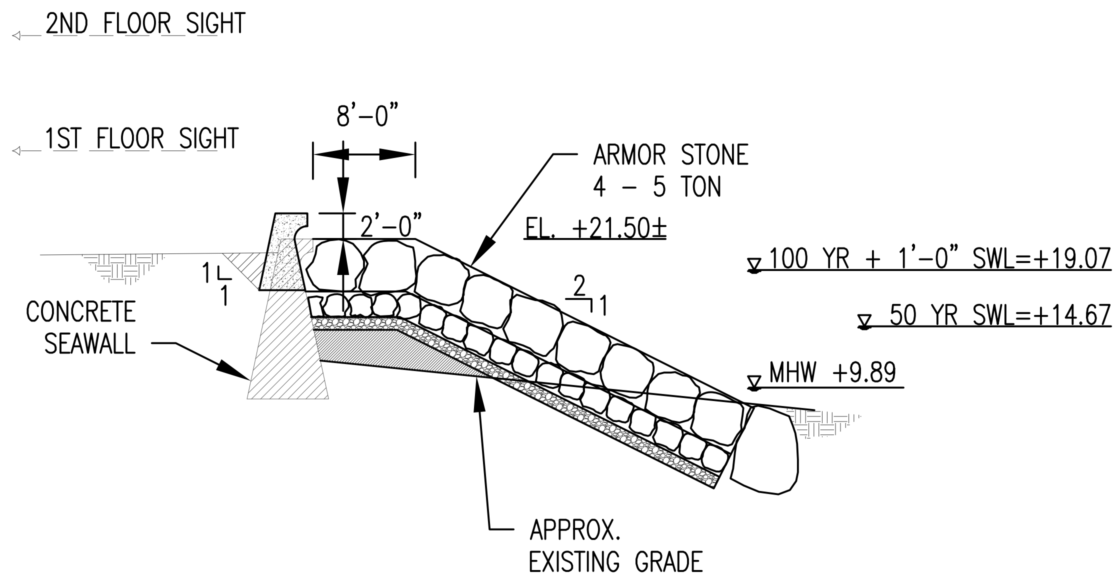

ALTERNATIVE #2A-REVETMENT TO TOP OF WALL EL.+21.5, 2' CREST WALL

A
4A

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.04 $FT^3/S/FT$

100 YR + 1'-0"
OVERTOPPING = 7.5 $FT^3/S/FT$

COST:
$2,034/LF

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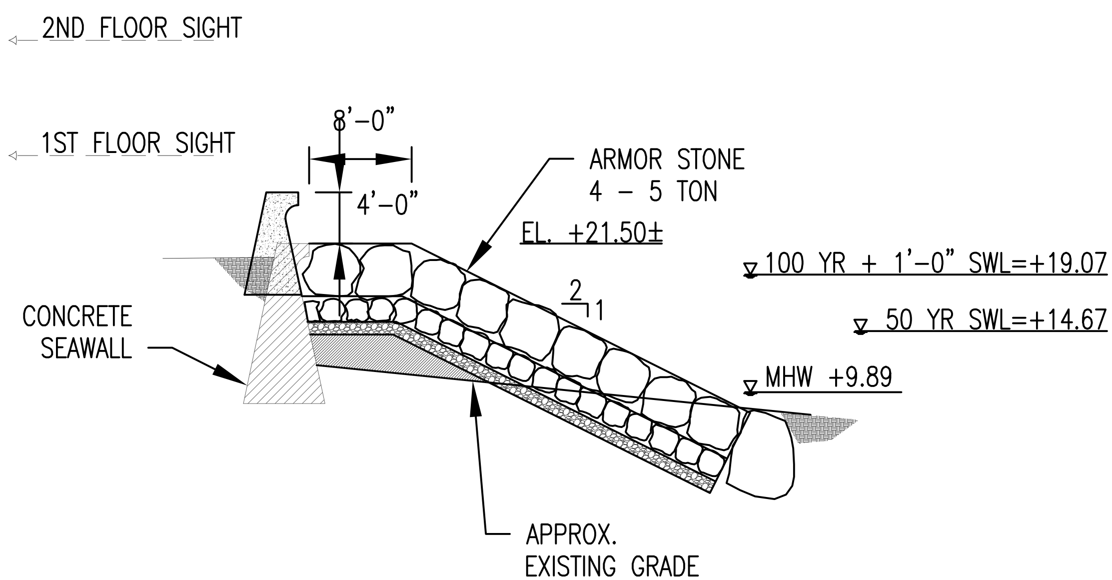
EXHIBIT 4A



A
4B

ALTERNATIVE #2B-REVETMENT TO TOP OF WALL EL.+21.5, 4' CREST WALL

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.008 $FT^3/S/FT$

100 YR + 1'-0"
OVERTOPPING = 5.3 $FT^3/S/FT$

COST:
$2,294/LF

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EXHIBIT 4B

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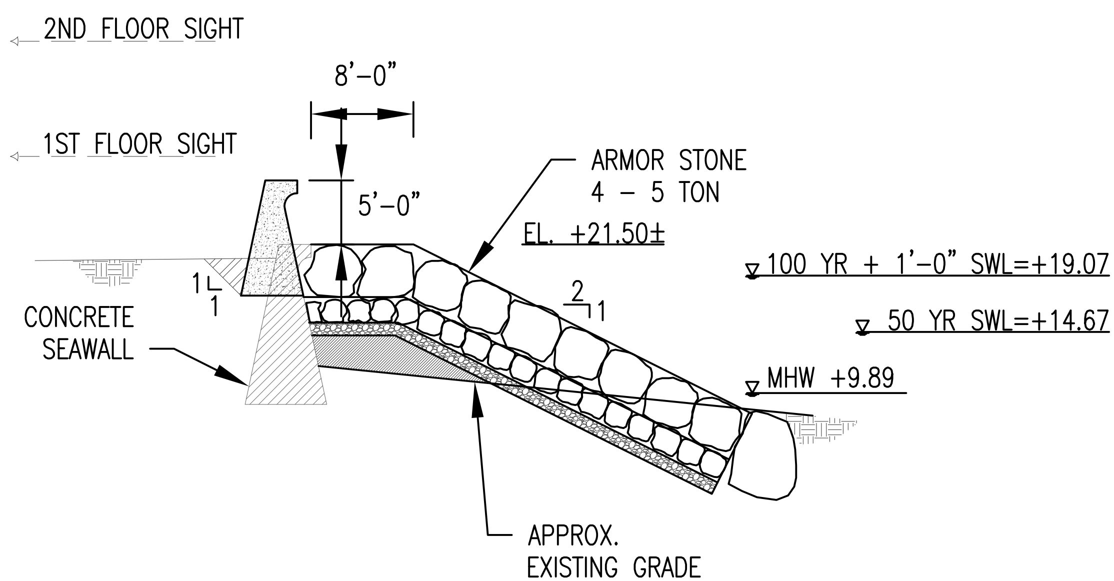

A 4C ALTERNATIVE #2C-REVETMENT TO TOP OF WALL EL.+21.5, 5' CREST WALL

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.004 $FT^3/S/FT$
100 YR + 1'-0"
OVERTOPPING = 2.6 $FT^3/S/FT$
COST:
$2,892/LF

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EXHIBIT 4C

10.3 ALTERNATIVE 3 – RAISE WALL TO ELEVATION +39.0 MLW

This alternative consists of reconstructing the wall to raise the crest height to the required elevation that would allow overtopping discharge rates to meet the 0.0003 ft3/s/ft recommended rate to avoid structural damage for a 50 year storm event. The crest height to achieve this is elevation +39.0 MLW. No attempt was made to evaluate the height required for a 100 year storm event because of the already excessive height. This alternative is shown in Exhibit 5 in Appendix I.

For the 100 year plus 1 ft condition, assuming that the crest height stays at the same elevation of +39.0 MLW, the run-up elevation was determined to be +39.4 MLW. Therefore as a result of the run-up elevations being slightly higher than the crest elevations of the seawall, this results in an overtopping discharge rate of 0.09 ft3/s/ft. This overtopping rate is higher than recommended values and would have the potential to cause minor damage to the areas behind the seawall. The estimated construction cost for this alternative is $6,378 per linear foot.
Anticipated regulatory requirements are as follows:

- ENF for MEPA due to alteration of barrier beach and bank
- Notice of Intent to Town of Duxbury Conservation Commission
- US Army Corps of Engineers
- DEP Waterways Chapter 91 Permit
- DEP Waterways Water Quality Certificate

A summary of the advantages and disadvantages of this option are as follows:

Advantages	*Disadvantages*
• *Overtopping rates decrease to an acceptable level for 50 year storm event* • *Still allows pedestrian beach access*	• *Homeowners ocean view will be significantly affected* • *Beach access very difficult* • *Impacts during construction on abutters will be significant* • *Excessive cost to construct a wall to this height* • *Houses close behind the seawall have the potential for some damage due to overtopping discharge from a storm event over 50 year return period*

10.4 ALTERNATIVE 4 – RAISE WALL TO ELEVATION OF +31.5'MLW, MAINTAIN BEACH ELEVATION AT +12.6'MLW

This alternative consists of reconstructing the wall to raise the wall crest height to the required elevation that would reduce overtopping discharge rates to the recommended 0.0003 ft3/s/ft for a 50 year storm event and stabilizing the beach grade outshore of the wall at elevation +12.6' MLW. Maintaining a higher beach elevation causes larger waves to break further from the wall which reduces loads on the wall and improves the flood protection performance. The required crest height to achieve the recommended overtopping rate is elevation +31.5' MLW.

Two potential methods are considered to maintain the required beach elevations – use of a toe revetment laid to match existing beach grades or beach nourishment and maintenance only. These alternatives are shown in Exhibits 6 and 6A in Appendix I. The revetment extends approximately 28 feet outshore of the existing seawall.

For the 100 year plus 1 ft condition, the estimated overtopping discharge is 0.19 ft3/s/ft. This overtopping rate is high than recommended and may cause some damage to the seawall and homes behind it but is a major improvement on existing conditions.

The major difficulty with beach renourishment is providing an accurate estimate of the useful life and the frequency and volume of material required for maintenance will vary with the number of major storms.

Initial construction cost for the wall and revetment option (Alternative 4) is $5,888.

Although the initial construction cost for the wall with beach nourishment only (Alternative 4A) would be expected to be lower, the large volume of sand required results in a comparable cost of $5,868 per linear foot. The anticipated maintenance costs for the beach nourishment option would be much higher. The estimated volume of material required for initial beach nourishment is 64 cubic yards per linear foot of beach. This volume does not allow any additional sacrificial material for erosion and it should be assumed that up to 3 feet of material would need to be replaced every 5 years giving an additional estimated annual maintenance cost of $55 per linear foot. However, given the sudden dramatic beach changes associated with a single storm event during this project, the annual maintenance cost for any particular year could be much higher depending on the number and direction of storms.

Normal beach renourishment consists of placement of material matching the grading of the existing beach. The existing beach includes a significant volume of cobbles and gravel and public acceptance of such a material may prove difficult. However, unless the beach renourishment is undertaken with a matching sized material, the erosion rates will be much higher.

Anticipated regulatory requirements are as follows:

- ENF for MEPA due to alteration of barrier beach and bank
- Notice of Intent to Town of Duxbury Conservation Commission
- US Army Corps of Engineers
- DEP Waterways Chapter 91 Permit
- DEP Waterways Water Quality Certificate

A summary of the advantages and disadvantages of this option are as follows:

Advantages	*Disadvantages*
• *Overtopping rates decrease to an acceptable level for 50 year storm event* • *Wall stability will improve with the higher grade or riprap in front of seawall* • *Still allows beach use at high tide*	• *Homeowners ocean view will be significantly affected* • *Houses behind the seawall have the potential for some damage due to overtopping discharge from a storm event over 50 year return period* • *Impacts during construction on abutters will be significant* • *High cost to construct a wall to this height and perform beach renourishment* • *Permitting will be more difficult due to constructing a structure outshore of the wall* • *Large areas impacted by proposed work on barrier beach will increase regulatory review.* • *If beach nourishment only is used, maintenance requirement will be very high and difficult to maintain in a sequence of storms over a short period*

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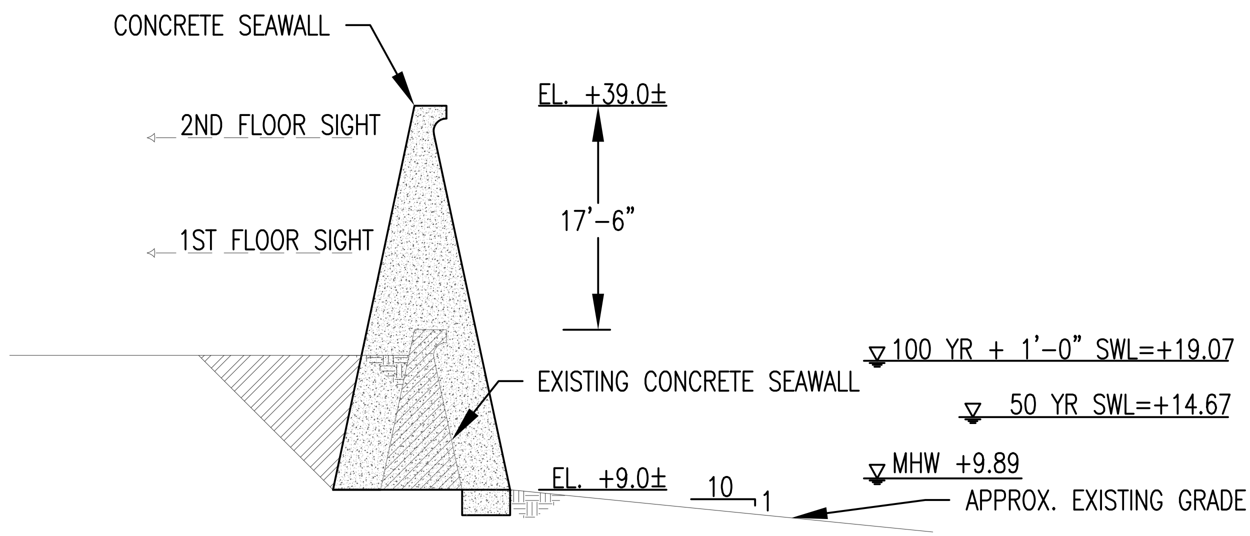

A/5 ALTERNATIVE #3-RAISE WALL TO EL. +39.0

SCALE: 1"=15'

50 YR

OVERTOPPING = 0.0003 FT^3/S/FT

100 YR + 1'-0"

OVERTOPPING = 0.09 FT^3/S/FT

COST:

$6,378/LF

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EXHIBIT 5

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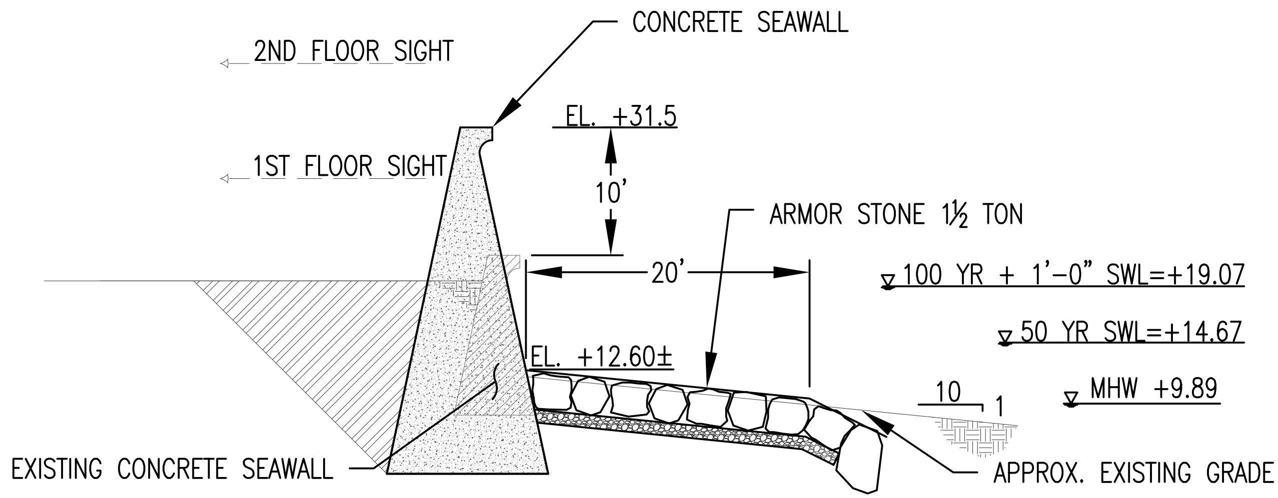

ALTERNATIVE #4- RAISE WALL TO EL. +31.5, RIP RAP TOE

A/6

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0003 FT^3/S/FT
100 YR +1'-0"
OVERTOPPING = 0.19 FT^3/S/FT
COST:
$5,888/LF

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EXHIBIT 6

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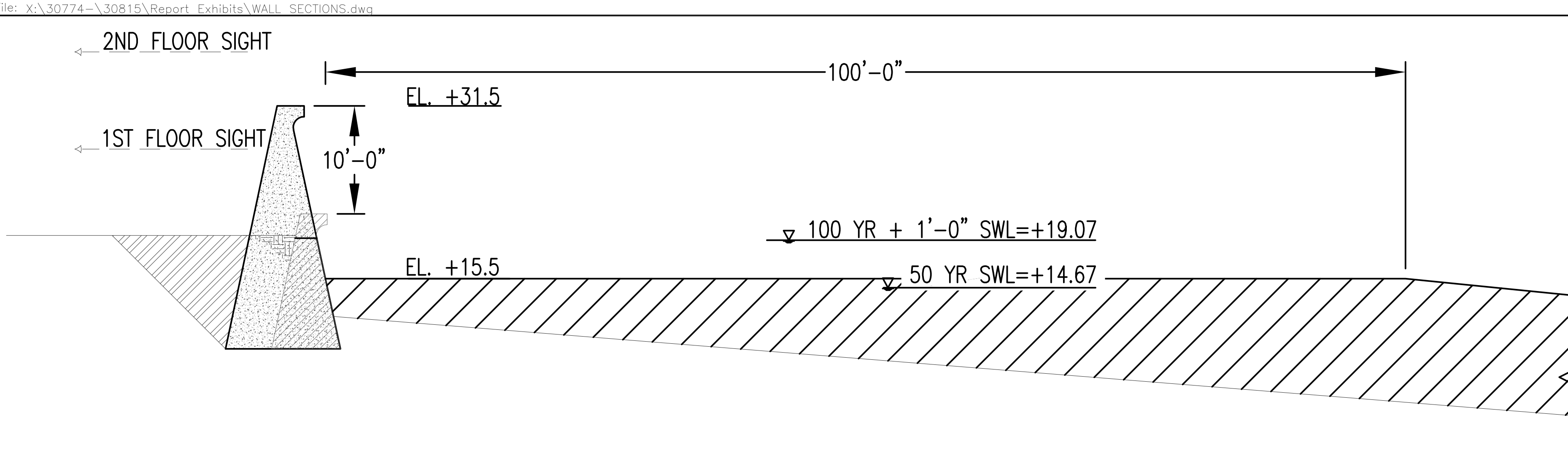
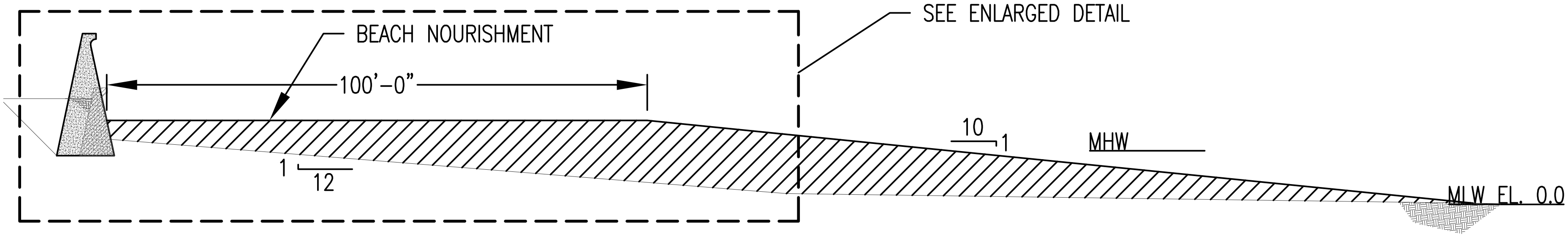


ENLARGED DETAIL

SCALE: 1"=15'



B/6A ALTERNATIVE #4A– INCREASE WALL HT. TO EL. +31.5, BEACH NOURISHMENT

SCALE: 1"=30'

50 YR
OVERTOPPING = 0.0003 $FT^3/S/FT$
100 YR +1'-0"
OVERTOPPING = 0.19 $FT^3/S/FT$
COST:
$5,868/LF

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EXHIBIT 6A

10.5 ALTERNATIVE 5 – RAISE WALL HEIGHT TO +26.5 MLW AND RAISE BEACH GRADE TO +17.0 MLW

This alternative is similar in concept to Alternative 4 above. It consists of raising the wall crest height to elevation +26.5' MLW and raising the beach grade outshore of the seawall to elevation +17.0 by use of riprap or beach nourishment. These alternatives are shown in Exhibits 7 and 7A in Appendix I.

Initial construction cost for Alternative 5 Raise Wall with revetment is $3,303 per linear foot. The revetment extends approximately 38 feet outshore of the existing seawall.

The initial construction cost for the wall with beach nourishment only (Alternative 5A) is higher at $5,015 per linear foot and, as for Alternative 4A, the anticipated maintenance costs would be much higher. The higher beach elevation allows a reduction in the height of seawall but results in a significant increase in the volume of material required and the areas of impact.

Anticipated regulatory requirements are as follows:

- ENF for MEPA due to alteration of barrier beach and bank
- Notice of Intent to Town of Duxbury Conservation Commission
- US Army Corps of Engineers
- DEP Waterways Chapter 91 Permit
- DEP Waterways Water Quality Certificate

Advantages	*Disadvantages*
• *Overtopping rates decrease to recommended level for 50 year storm event* • *Wall stability will improve with the higher grade in front of seawall* • *Allows beach use* • *Lower wall in front of houses* • *Lower wall allows easier pedestrian beach access*	• *Homeowners ocean view will be affected as wall height increases approximately 5'-0"* • *Houses behind the seawall have the potential for some damage due to overtopping discharge from a storm event over 50 year return period* • *High cost to construct a wall to this height and perform beach renourishment* • *Permitting will be more difficult due to constructing a structure out shore of the wall* • *Large areas impacted by proposed work on barrier beach will increase regulatory review.* • *If beach nourishment only is used, maintenance requirement will be very high and difficult to maintain in a sequence of storms over a short period*

10.6 ALTERNATIVE 6 – RAISE WALL TO ELEVATION +26.5' MLW AND REVETMENT TO +19.4' MLW

This alternative consists of raising the wall crest height to elevation +26.5 MLW and constructing revetment out shore of the seawall to elevation +19.4. The increased revetment crest elevation allows partial reconstruction of the existing wall instead of complete reconstruction. A cross section for this alternative is shown in Exhibit 8. The revetment extends approximately 55 feet outshore of the existing seawall. The estimated initial construction cost of this alternative is $4,208 per linear foot.

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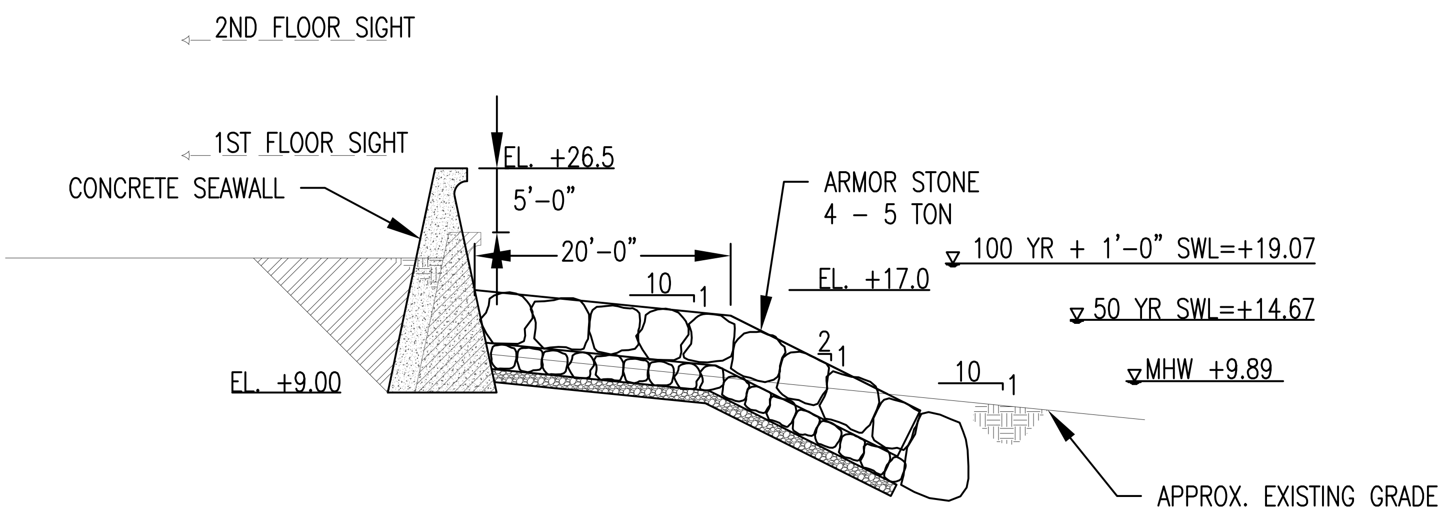

A/7 ALTERNATIVE #5-TOP OF WALL EL. +26.5 & REVETMENT TO EL. +17.0

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0005 $FT^3/S/FT$

100 YR +1'-0"
OVERTOPPING = 0.05 $FT^3/S/FT$

COST:
$4,571/LF

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EXHIBIT 7

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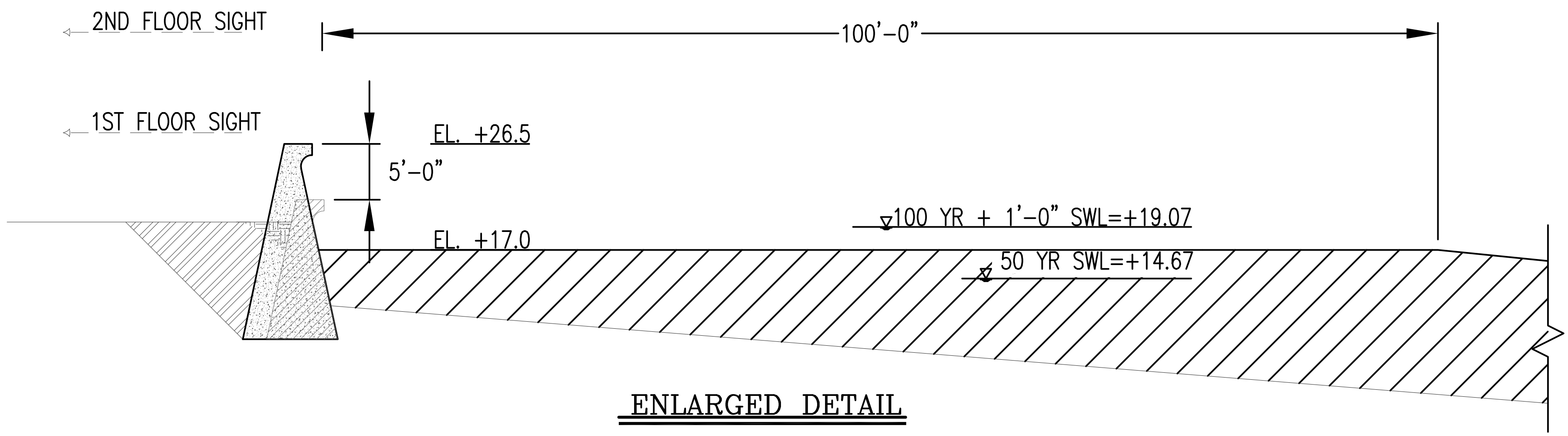
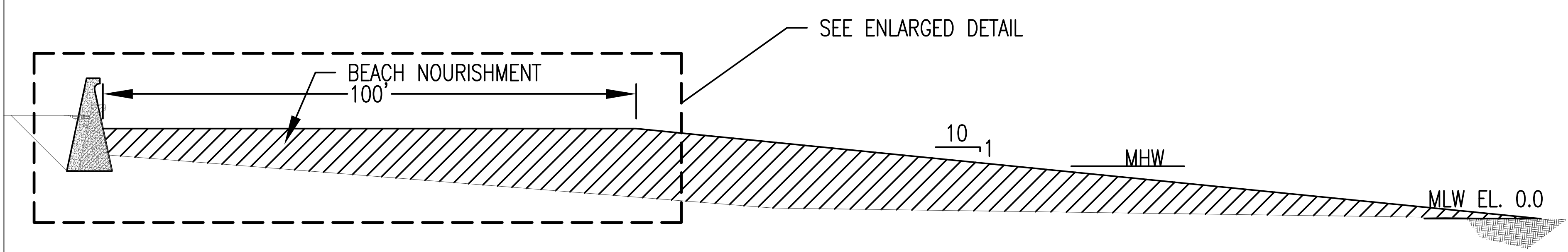


ENLARGED DETAIL

SCALE: 1"=15'



A/7A ALTERNATIVE #5A-TOP OF WALL EL. +26.5 & BEACH TO EL. +17.0

SCALE: 1"=30'

50 YR
OVERTOPPING = 0.000 $FT^3/S/FT$
100 YR +1'-0"
OVERTOPPING = 0.08 $FT^3/S/FT$
COST:
$5,015/LF

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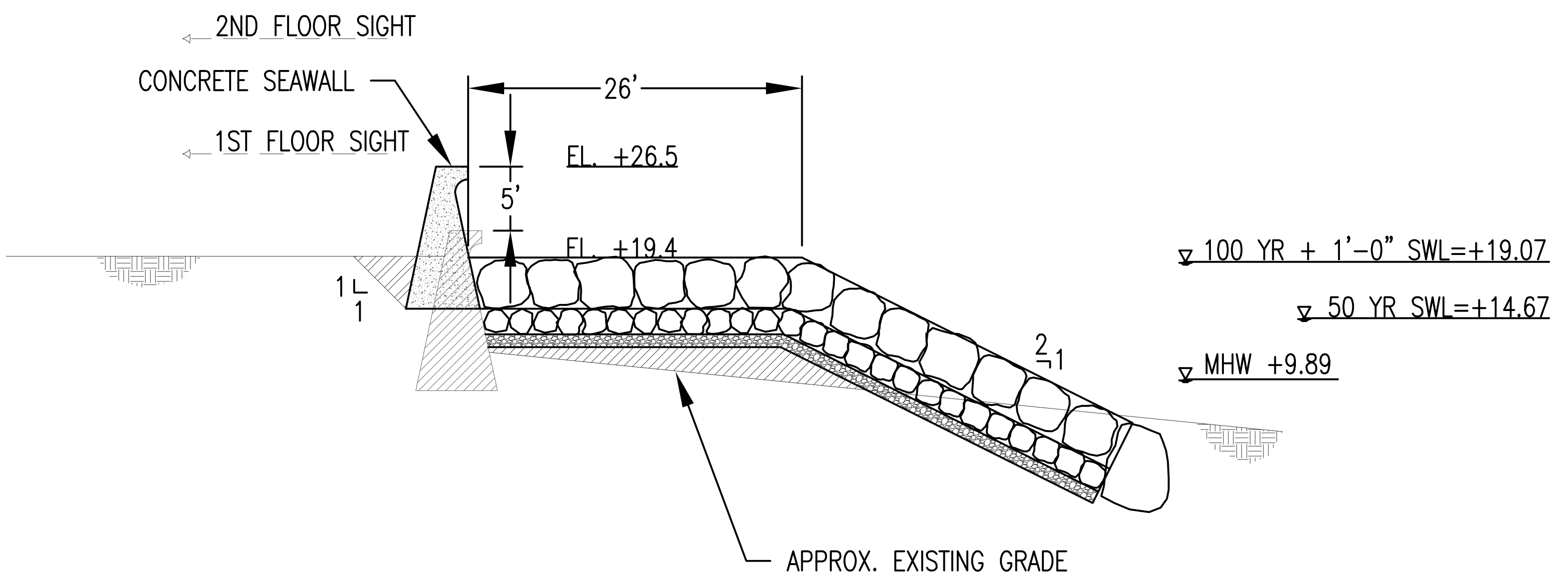
EXHIBIT 7A



A 8 ALTERNATIVE #6– TOP OF WALL EL. +26.5 & REVETMENT TO EL. +19.4

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0004 $FT^3/S/FT$
100 YR + 1'-0"
OVERTOPPING = 0.04 $FT^3/S/FT$
COST:
$4,208/LF

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EXHIBIT 8

For this configuration, the 50 year return period overtopping rate was determined to be 0.0004 ft3/s/ft, and for the 100 year plus 1 ft condition, the overtopping discharge rate was determined to be 0.04 ft3/s/ft which may result in some damage to homes close behind the seawall.

Anticipated regulatory requirements are as follows:

- ENF for MEPA due to alteration of barrier beach and bank
- Notice of Intent to Town of Duxbury Conservation Commission
- US Army Corps of Engineers
- DEP Waterways Chapter 91 Permit
- DEP Waterways Water Quality Certificate

A summary of the advantages and disadvantages of this option are as follows:

Advantages	*Disadvantages*
• *Overtopping rates decrease to an acceptable level for 50 year storm event* • *Wall stability will improve with the higher grade in front (out shore) of seawall* • *Cost is slightly reduced over Alternative 5.*	• *Homeowners ocean view will be slightly affected as wall height increases approximately 5 ft-0"* • *Houses behind the seawall have the potential for damage due to overtopping discharge from a storm event over 50 year return period* • *High cost to construct a wall to this height and raise revetment to this elevation* • *Permitting will be more difficult due to constructing a structure out shore of the wall* • *Revetment structure will cover beach eliminating beach use at high tide*

10.7 ***ALTERNATIVE 7 – RAISE WALL HEIGHT TO +26.5 MLW AND RAISE REVETMENT TO +26.5 MLW***

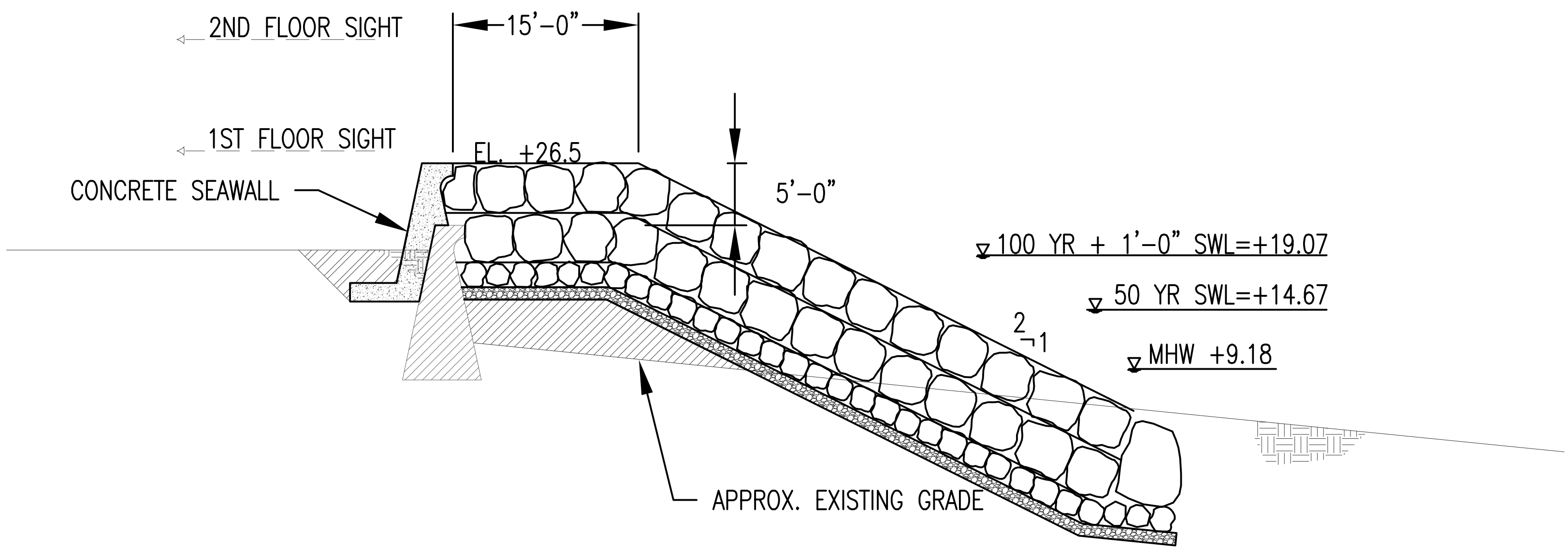
This alternative constructs a new revetment to elevation +26.5' MLW with a new wall to the same elevation to support the inshore edge of the revetment. This alternative is shown in Exhibit 9 in Appendix I. The revetment extends approximately 60 feet outshore of the existing seawall. The cost of this alternative is significantly higher at $5,921 per linear foot and the overtopping performance is worse than for Alternative 6.

For this configuration, the 50 year return period overtopping rate was determined to be 0.005 ft3/s/ft, and for the 100 year plus 1 ft condition, the overtopping discharge rate was determined to be 1.8 ft3/s/ft.

Given the worse hydraulic performance compared to Alternative 6 and the higher costs and greater impacts, this alternative was not explored any further.

10.8 ***ALTERNATIVE 8 – DUNE RECONSTRUCTION IN AREA WITH NO WALL***

This alternative reconstructs the dune in the area between the North and South walls. The core of the new dune will consist of sand filled coir envelopes which will be buried using sand matching the existing beach grading. The top elevation of the new dune will be elevation +24' MLW which is based on the 50 year run up elevation. This alternative is shown in Exhibit 10 in Appendix I. The cost of this alternative is significantly higher at $538 per linear foot.



A 9 ALTERNATIVE #7–REVETMENT TO EL. +26.5

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.005 FT^3/S/FT
100 YR
OVERTOPPING = 1.8 FT^3/S/FT
COST:
$5,921/LF

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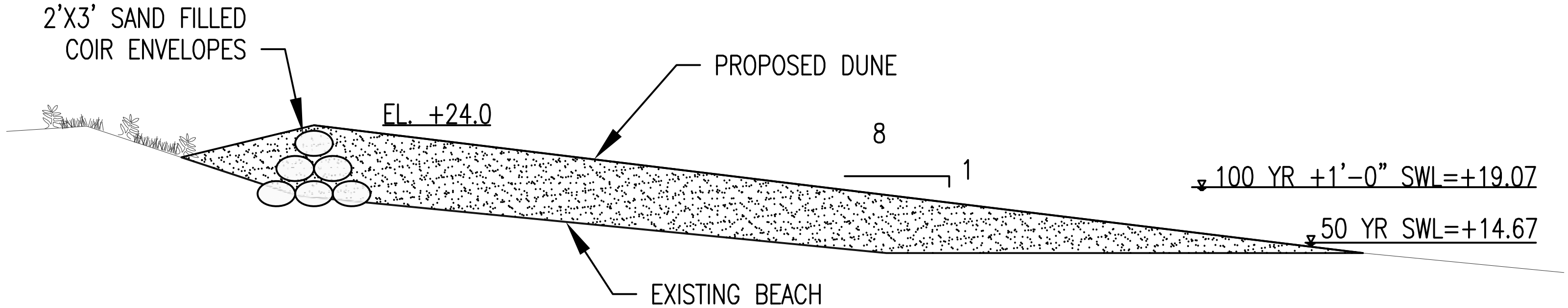
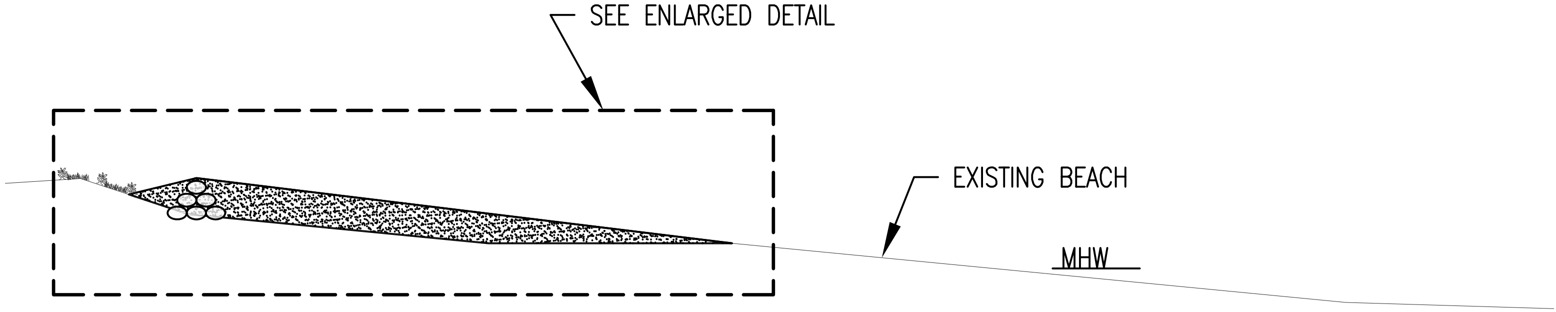
EXHIBIT 9

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



ENLARGED DETAIL

SCALE: 1"=15'



A/10 ALTERNATIVE #8 – PROPOSED DUNE SECTION

SCALE: 1"=30'

50 YR
OVERTOPPING = 0.003 $FT^3/S/FT$
100 YR
OVERTOPPING = 0.9 $FT^3/S/FT$
COST:
$538/LF

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EXHIBIT 10

Some overtopping of the new dune would be expected to occur for storms more severe than the 50 year storm but the crest of the new dune will be built outshore of the existing dune crest to allow additional space for flood water.

As discussed for the beach nourishment options above, this option will require regular monitoring and maintenance but it offers a number of potential benefits:

Advantages	*Disadvantages*
• *Provides a soft solution for this area* • *Overtopping rates decrease to an acceptable level for 50 year storm event* • *Initial cost is much lower.* • *Beach access is much easier to achieve with the flatter slopes.*	• *Houses behind the dune have the potential for damage due to overtopping discharge from a storm event over 50 year return period* • *Maintenance requirement will be high and may be difficult to maintain in a sequence of storms over a short period*

11 COMPARISON AND SELECTION OF ALTERNATIVES

11.1 <u>Comparison of Alternatives</u>

Initial Construction cost estimates for each of the alternatives are included in Appendix J and are summarized below:

Table 11.1 – Summary of Construction Costs	
Alternative	**Cost per Linear foot**
1	$0
2	$1,821
2A	$2,034
2B	$2,294
2C	$2,892
3	$6,378
4	$5,888
4A	$5,868
5	$4,571
5A	$5,015
6	$4,208
7	$5,921
8	$538

Alternative 1 – Do Nothing is considered an unreasonable approach. The existing seawall is in poor condition and will continue to deteriorate if repairs are not made. The wall is very susceptible to undermining by the rapid changes in beach elevation and partial failure of this seawall would directly impact a significant number of homes along the length of this seawall. The existing seawall is also heavily overtopped during 50 year or higher storm events and does not provide adequate coastal flood protection given the densely packed homes and infrastructure behind the walls. This option is not recommended for further consideration.

Alternative 2 provides a new revetment with the top at the existing top of wall elevation therefore reducing the amount of overtopping of the seawall. This option would stabilize the existing wall by adding support outshore of the seawall, but the amount of overtopping during 50 year storm events and over, is still significant and may result in damage to the homes close behind it.

Adding a crest wall to the Alternative 2 revetment significantly improves flood protection for 50 year storm events and various height crest walls have been incorporated in Alternatives 2A, 2B and 2C. The higher the crest wall, the better the flood protection. The crest walls in these alternatives are assumed to be constructed on top of the existing concrete wall which may impact the long term durability. The primary benefit of building on the existing concrete is reduction in cost associated with removal and reconstruction of the existing wall and, given that the existing wall will be completely below finished grade, the concern over long term durability is reduced.

Alternative 3 raises the wall height sufficiently to reduce the overtopping rate to the recommended 0.0003 $ft^3/s/ft$ assuming that the toe of the wall remains at elevation +9.0 MLW and no revetment. This alternative results in a very high wall which significantly reduces the overtopping but at very high cost and with major visual and beach access impacts. This option is not recommended for further consideration.

Alternative 4 raises the wall height sufficiently to reduce the overtopping rate to the recommended 0.0003 $ft^3/s/ft$ while assuming that the toe of the wall will be maintained at +12.6 MLW by construction of stone paving outshore of the wall. This alternative significantly reduces the overtopping and, due to the higher beach elevation in front of the wall, the overall wall height is lower than in Alternative 3 which reduces the visual impact. However, the cost is significantly higher than Alternatives 5 and 6 which offer similar flood protection standard. Due to the high cost, this option is not recommended for further consideration.

Alternative 4A raises the wall height in order to reduce the overtopping rate to the recommended 0.0003 $ft^3/s/ft$ and uses beach nourishment outshore. However there is no cost advantage over the basic Alternative 4 and the maintenance requirement for the beach nourishment will be much higher. Prediction of the life of the beach nourishment in this highly dynamic requirement is extremely difficult. The major advantage of beach renourishment is no impact on beach amenity and little impact on natural resources. In order to provide reasonable life expectancy, the gradation of any proposed beach nourishment would need to be significantly coarser than the existing beach. Use of coarser material would change the natural beach environment and amenity reducing the potential benefits of this option. Due to the high cost and potential maintenance, this option is not recommended for further consideration.

Alternative 5 increases the top of wall elevation to +26.5 MLW and provides a revetment outshore of the seawall to elevation +17.0 MLW. This method significantly reduces overtopping rates and limits the increase in wall height reducing visual impacts for homeowners behind the wall. This alternative has significantly lower cost than alternatives 4 and 6 while offering similar levels of flood protection. The area of impact outshore of the seawall is less than for Alternative 6 for almost equivalent flood protection. This alternative would be preferred over Alternatives 4 and 6 due to lower cost and impacts.

Alternative 5A increases the wall height to +26.5 MLW and uses beach nourishment to raise the beach grade outshore of the seawall to elevation +17.0 MLW. However there is major cost disadvantage because the wall foundation must be lower and the maintenance requirement will be much higher. The major advantage of beach renourishment is no impact on beach amenity and little impact on natural resources. Due to the higher cost, this option is not recommended for further consideration.

Alternative 6 raises the wall height to +26.5 and provides new revetment to elevation +19.4 MLW. This alternative significantly reduces overtopping rates and increase in the wall height is reasonable for homeowners behind the wall. Revetment outshore is extensive, making the permitting process more difficult and reducing beach amenity at high tide. This alternative would stabilize the existing wall as the grade outshore of the wall would be increased significantly.

Alternative 7 raises the wall height to +26.5 and also provides a revetment to elevation +26.5 MLW.

This alternative reduces the amount of overtopping, however the cost is higher and the overtopping performance is not as good as other alternatives. The revetment outshore is extensive, making the permitting process more difficult and reducing beach amenity at high tide. Due to the high cost and relatively poor overtopping performance, this option is not recommended for further consideration.

11.2 Selection of Preferred Alternatives

Selection of the most appropriate alternative for each area depends on the level of desired flood protection to suit the local conditions and budgetary limits. Use of Alternative 2A for the entire length would stabilize the walls and slightly improve the level of flood protection. The total length of both walls is 3,750 feet and, using the Alternative 2A estimated cost per foot of $2,034 gives a total construction cost of $7.6 million. However, this would not meet desirable levels of flood protection.

As discussed in Section 9 above, the design overtopping criteria for a wall of this length vary due to the proximity of houses and the topography behind the wall. Suitable alternatives which meet the criteria set out in Section 9 are presented in Table 11.2 and the less desirable alternatives are eliminated based on the discussion in this section above.

Table 11.2 – Suitable Alternatives to meet 50 Year Desirable Overtopping Limits by Station

Station		**Length (ft)**	**Desirable Overtopping Limit**	**Suitable Alternatives**
From	**To**			
South Wall				
100+00	110+50	1050	0.0003 ft^3/sec/ft	**~~3, 4, 4A~~, 5, 5A, 6**
110+50	115+50	500	0.02 ft^3/sec/ft	**2A, 2B, 2C, ~~3, 4, 4A~~, 5, 5A, 6, ~~7~~**
115+50	117+00	150	0.003 ft^3/sec/ft	**2C, ~~3, 4, 4A~~, 5, 5A, 6**
117+00	122+00	500	0.02 ft^3/sec/ft	**2A, 2B, 2C, ~~3, 4, 4A~~, 5, 5A, 6, ~~7~~**
122+00	127+00	500	0.0003 ft^3/sec/ft	**~~3, 4, 4A~~, 5, 5A, 6**
127+00	129+00	200	0.003 ft^3/sec/ft	**2C, ~~3, 4, 4A~~, 5, 5A, 6**
Area with No Wall				
129+00	132+20	320	0.003 ft^3/sec/ft	**2C, ~~3, 4, 4A~~, 5, 5A, 6**
North Wall				
200+00	208+50	850	0.003 ft^3/sec/ft	**2C, ~~3, 4, 4A~~, 5, 5A, 6**

Based on the criteria outlined in Section 9 above and the process of elimination, the lowest initial cost alternatives which provide desirable levels of flood protection for a 50 year event are as follows:

Table 11.3 – Alternatives meeting Desirable Overtopping Limits by Station (50 year Storm Condition)						
Station			**Desirable Overtopping Limit**	**Preferred Alternative**	**$/LF**	**Total Cost**
From	**To**	**Length (ft)**				
South Wall						
100+00	110+50	1050	0.0003 ft^3/sec/ft	5	$3,303	$3.47 m
110+50	115+50	500	0.02 ft^3/sec/ft	2A	$2,034	$1.02 m
115+50	117+00	150	0.003 ft^3/sec/ft	2C	$2,892	$0.43 m
117+00	122+00	500	0.02 ft^3/sec/ft	2A	$2,034	$1.02 m
122+00	127+00	500	0.0003 ft^3/sec/ft	5	$3,303	$1.65 m
127+00	129+00	200	0.003 ft^3/sec/ft	2C	$2,892	$0.58 m
Area with No Wall						
129+00	132+20	320	0.003 ft^3/sec/ft	8	$538	$0.18 m
North Wall						
200+00	208+50	850	0.003 ft^3/sec/ft	2C	$2,892	$2.46 m
						$10.81 m

The above alternatives would appear to offer a reasonable level of flood protection at the most reasonable cost for the Town of Duxbury and these are shown on Exhibit 11.1. Further combinations may be considered which meet other desired goals but higher levels of flood protection would appear to be cost prohibitive.

11.3 PRIORITIZATION OF REPAIRS

Prioritization of repairs for these seawalls is difficult due to the dense housing and infrastructure behind the walls. All areas should be considered high priority but, in order to allow phasing of the work to reduce the size, value and impact of individual construction projects, relative priorities have been established. Relative priorities from 1 to 3 have been established with the most urgent areas being rated priority 1 and the least urgent rated priority 3. Based on the condition survey of these walls, the most likely mode of failure will be collapse due to undermining and the following criteria were developed to review the relative priority:

- Presence of riprap outshore of wall – if present, priority 3.

  The presence of riprap (even in poor condition) will improve the stability of the existing seawall and reduce the risk of failure by undermining.

- Homes further from the back of the seawall – priority 2

  The further buildings are from the seawall, the lower the safety hazard and the risk of structural impacts even in the event of partial wall failure.

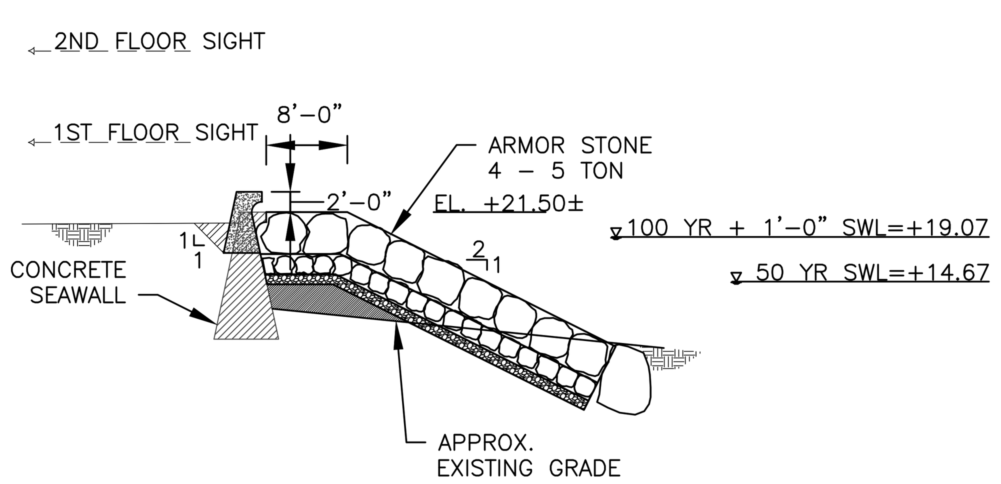
- Homes close to back of wall – priority 1.

  If homes are close to the back of the wall, they are likely to be directly impacted by a partial wall failure. The more densely packed the homes, the greater the risk.

Using these criteria, priorities have been established as shown on Exhibit 11.2 and the tables below.

WALL ALTERNATIVE LAYOUT PLAN

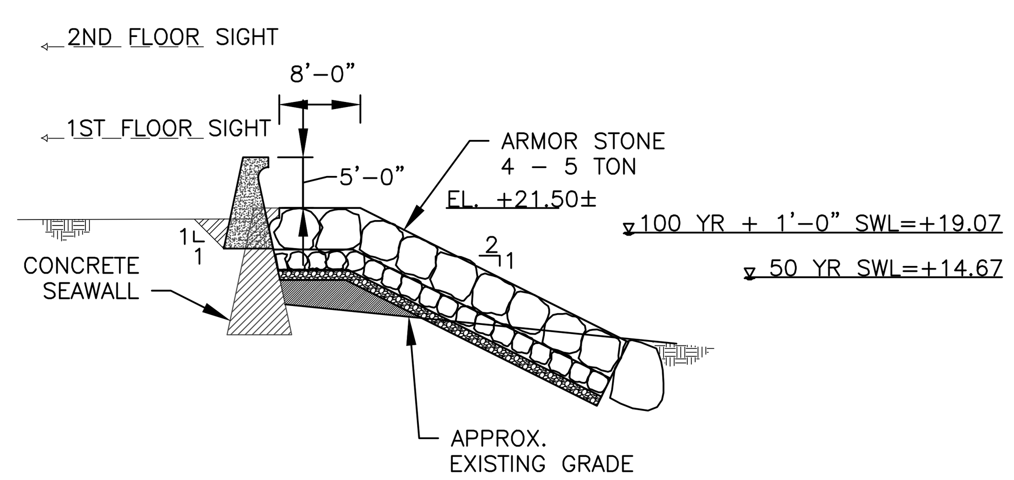
SCALE: 1"=150'-0"



ALTERNATIVE 2A DETAIL

SCALE: 1"=15'-0"

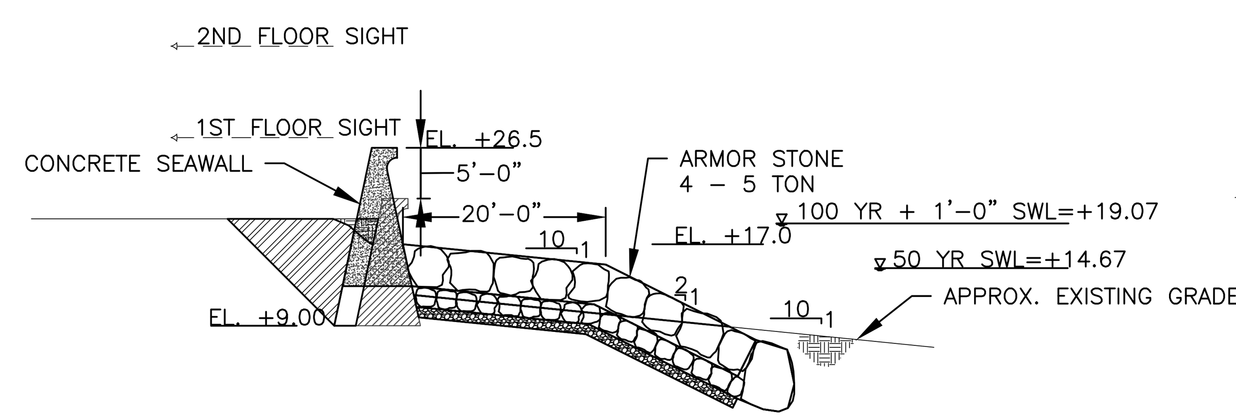
ALTERNATIVE 2A –



ALTERNATIVE 2C DETAIL

SCALE: 1"=15'-0"

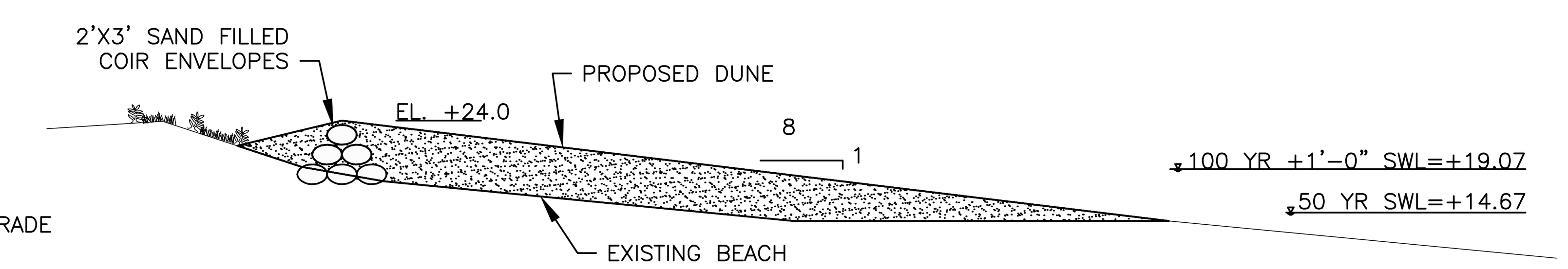
ALTERNATIVE 2C –



ALTERNATIVE 5 DETAIL

SCALE: 1"=15'-0"

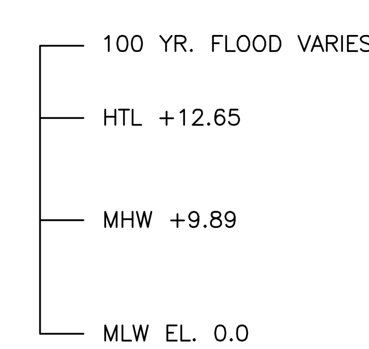
ALTERNATIVE 6 –



ALTERNATIVE 8 DETAIL

SCALE: 1"=15'-0"

ALTERNATIVE 8 –



0 10 20
SCALE: 1" = 10'-0"

50 YEAR STORM WALL ALTERNATIVES

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

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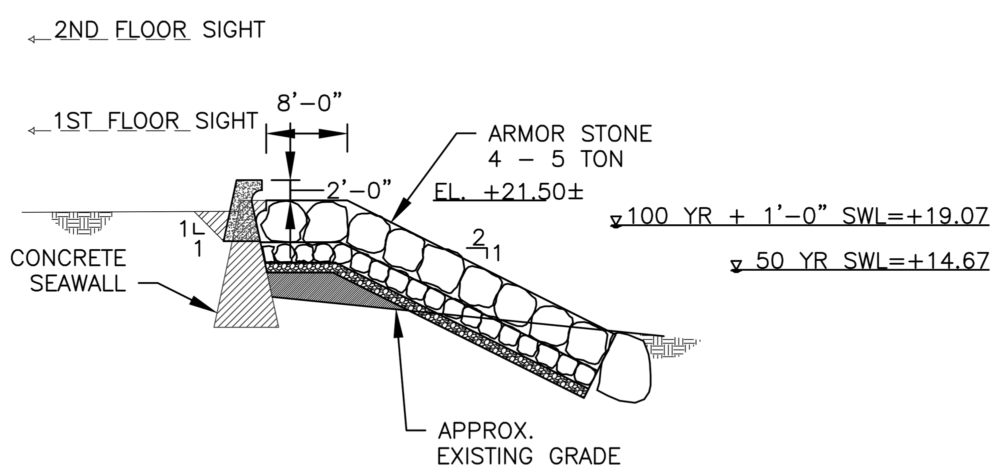
11.1

1 – HIGHEST PRIORITY
2 – INTERMEDIATE PRIORITY
3 – LOWEST PRIORITY

A/1 WALL ALTERNATIVE LAYOUT PLAN

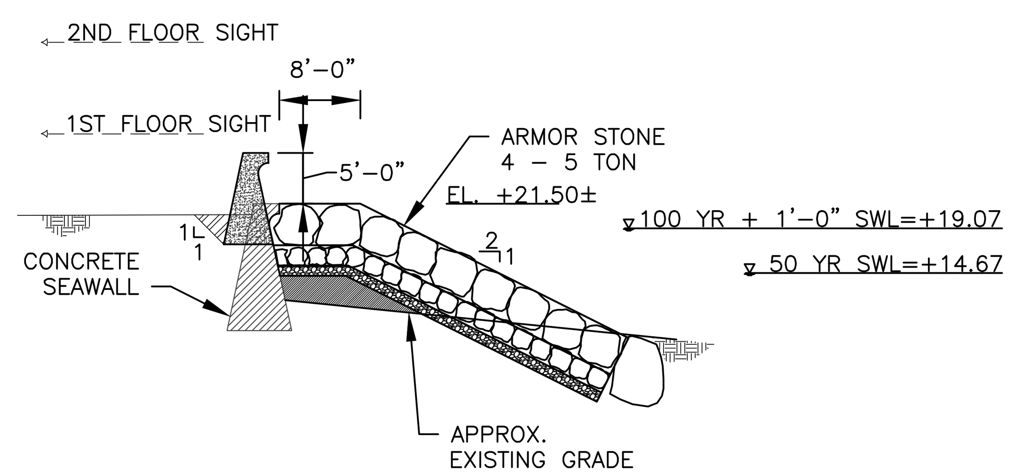
SCALE: 1"=150'-0"



B/1 ALTERNATIVE 2A DETAIL

SCALE: 1"=15'-0"

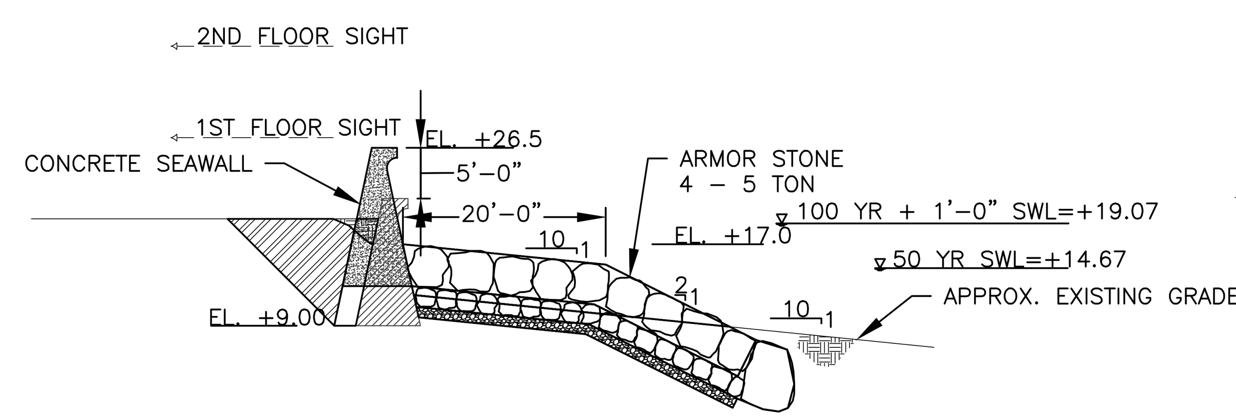
ALTERNATIVE 2A –



C/1 ALTERNATIVE 2C DETAIL

SCALE: 1"=15'-0"

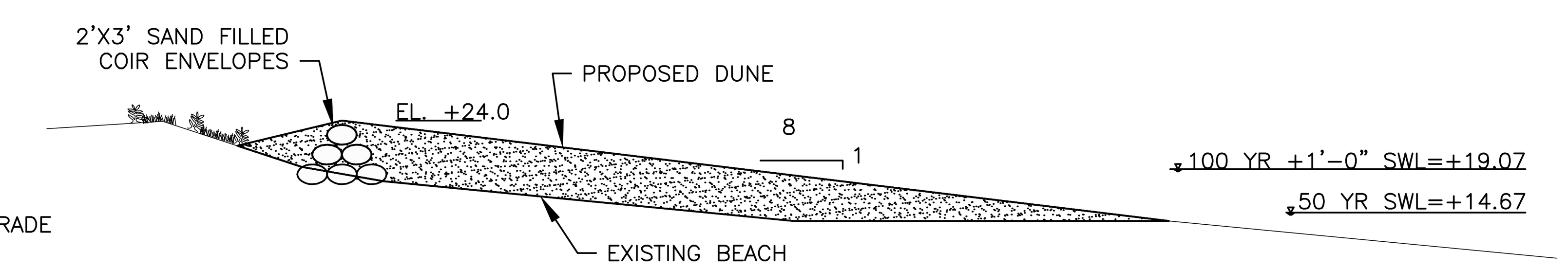
ALTERNATIVE 2C –



D/1 ALTERNATIVE 5 DETAIL

SCALE: 1"=15'-0"

ALTERNATIVE 6 –



E/1 ALTERNATIVE 8 DETAIL

SCALE: 1"=15'-0"

ALTERNATIVE 8 –

100 YR. FLOOD VARIES

HTL +12.65

MHW +9.89

MLW EL. 0.0

0 10 20

SCALE: 1" = 10'-0"

PRIORITIZED 50 YEAR STORM WALL ALTERNATIVES

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

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11.2

Table 11.4 – Priority 1 (Highest Priority)						
Station			**Desirable Overtopping Limit**	**Alternative**	**$/LF**	**Total Cost**
From	**To**	**Length (ft)**				
South Wall						
100+00	110+50	1050	0.0003 ft^3/sec/ft	5	$3,303	$3.47 m
110+50	111+50	100	0.02 ft^3/sec/ft	2A	$2,034	$0.20 m
122+00	127+00	500	0.0003 ft^3/sec/ft	5	$3,303	$1.65 m
						$5.32 m

Table 11.5 – Priority 2 (Medium Priority)						
Station			**Desirable Overtopping Limit**	**Alternative**	**$/LF**	**Total Cost**
From	**To**	**Length (ft)**				
South Wall						
127+00	129+00	200	0.003 ft^3/sec/ft	2C	$2,892	$0.58 m
Area with No Wall						
129+00	132+20	320	0.003 ft^3/sec/ft	8	$538	$0.18 m
North Wall						
200+00	204+00	400	0.003 ft^3/sec/ft	2C	$2,892	$1.16 m
						$1.92 m

Table 11.6 – Priority 3 (Lower Priority)						
Station			**Desirable Overtopping Limit**	**Alternative**	**$/LF**	**Total Cost**
From	**To**	**Length (ft)**				
South Wall						
111+50	115+50	400	0.02 ft^3/sec/ft	2A	$2,034	$0.81 m
115+50	117+00	150	0.003 ft^3/sec/ft	2C	$2,892	$0.43 m
117+00	122+00	500	0.02 ft^3/sec/ft	2A	$2,034	$1.02 m
North Wall						
204+00	208+50	450	0.003 ft^3/sec/ft	2C	$2,892	$1.30 m
						$3.56 m

12 SUMMARY

The primary concern with the Duxbury Seawalls is their ongoing stability. The longshore (along the coastline) sediment movement in this area is from north to south and the shoreline north of this site is mostly armored resulting in “sediment starvation” and long term erosion of the beach. The beach also undergoes rapid changes in elevation due to cross shore (inshore/outshore) sediment movement associated with coastal storm events. The combination of the long term erosion with the rapid short term loss of material outshore is leading to periodic wall undermining and significant concerns for long term wall stability.

The condition of the existing concrete in the seawalls varies but, typically, the concrete seawall has significant vertical cracking separating the wall into shorter structural units which allows each piece to move independently and makes the seawall more susceptible to local undermining and movement. This movement is clearly exhibited at many locations along the seawall.

The level of flood protection offered by the existing seawalls is also less than desirable. There are many homes close behind the wall and flood protection should be designed to limit structural damage to these houses. The long term erosion of the beach is now allowing larger waves to reach the seawall resulting in higher levels of overtopping and greater risk of damage to property. Options to improve flood protection include raising the seawall, providing riprap to absorb wave energy or adding beach nourishment to prevent larger waves from reaching the seawalls.

The long term solution for these seawalls also needs to prevent undermining to ensure continued wall stability. This could include adding beach nourishment, providing riprap erosion protection and/or making a deeper foundation. The lifespan of beach nourishment will be very difficult to predict at this highly dynamic beach location and a deeper foundation will not improve levels of flood protection.

This report presents options which address the undermining by adding a revetment and improves flood protection for up to a 50 year return period storm event. Although higher levels of storm protection would be desirable, the associated costs appear to be prohibitive and the construction impacts would be excessive.

The preferred long term approach is to provide an option which includes a revetment in front of the seawall to stabilize the walls and improve flood protection by raising the height of the seawall. The prioritized repairs showing this approach are illustrated on Exhibit 11.2.

Appendix A – Survey Plans

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.
2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON JUNE 21, 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.
3) COORDINATES, IN U.S. SURVEY FEET, ARE IN MASSACHUSETTS STATE PLANE COORDINATE SYSTEM REFERENCED TO THE NORTH AMERICAN DATUM OF 1983, CORS ADJUSTMENT (NAD83/CORS).
4) SOUNDINGS AND ELEVATIONS ARE SHOWN IN FEET AND TENTHS BASED ON A MLW DATUM (MLW). POSITIVE VALUES REPRESENT AN ELEVATION ABOVE THAT SAME PLANE.
5) ELEVATIONS, IN U.S. SURVEY FEET, ARE REFERENCED TO A NAIL SET IN THE WOOD WALKING DECK ON THE SOUTH SIDE OF THE POWDER POINT BRIDGE, UNDER THE RAILING, APPROX. 400 FT FROM THE WEST END AT ELEVATION +21.52 MLW

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY

TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

REVISIONS

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
PH. (508) 533-6666 FAX. (508) 533-6690

DRAWN: JSF
CHECKED:
APPROVED:
DATE: 06/06/11

DRAWING NO. 30815-01-01

SHEET 1 OF 10

File: x:\30774-\30815\SURVEY\EXISTING CONDITIONS\EXISTING CONDITIONS.DWG - 8/22/2006 2:06 PM

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.

2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON JUNE 21, 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.

100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY

TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

REVISIONS

Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
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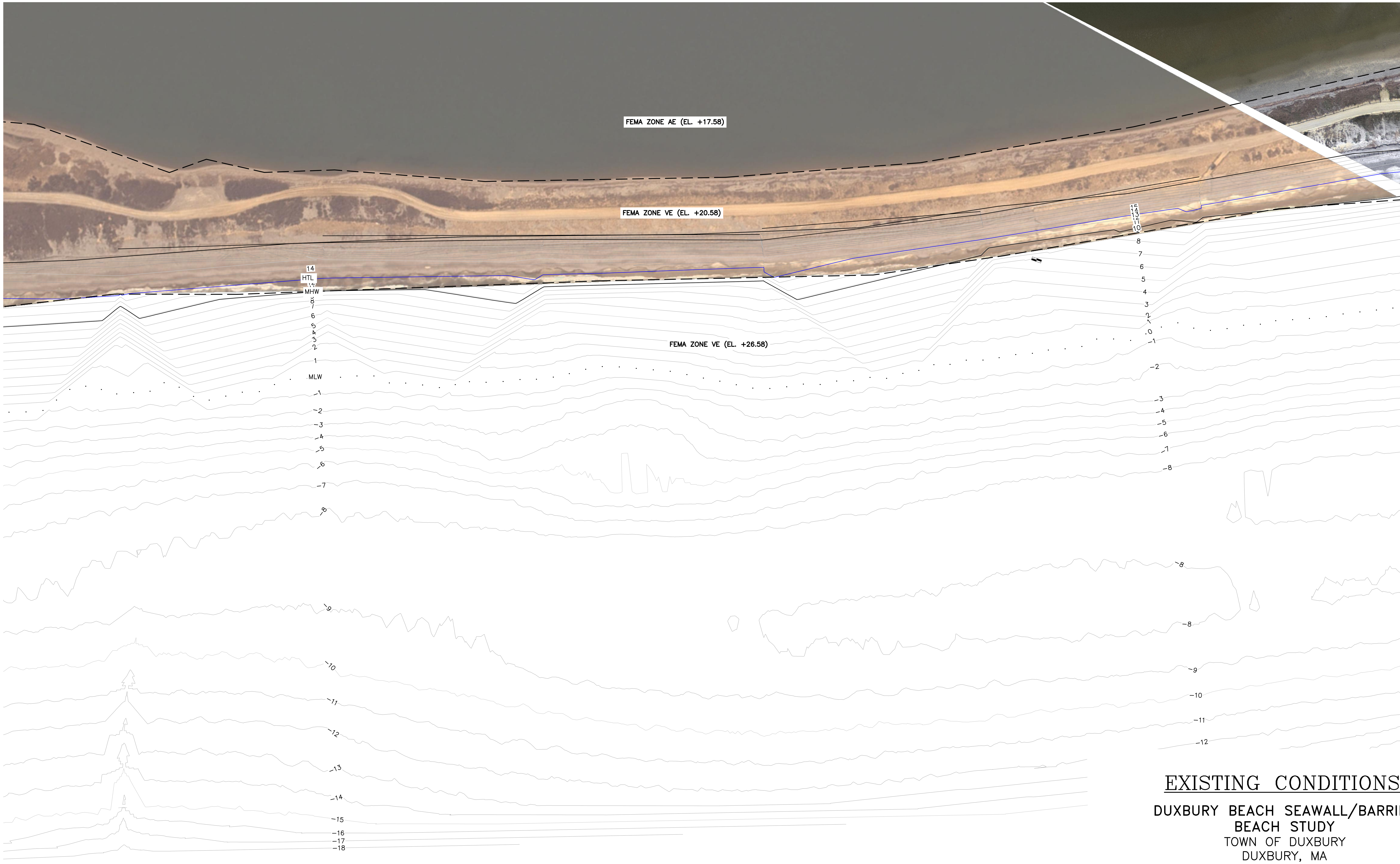
DRAWN: JSF
CHECKED:
APPROVED:
DATE: 06/06/11

DRAWING NO. 30815-01-02

SHEET 2 OF 10



EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY

TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.
2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON MARCH 17 & JUNE 21, 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.

100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

REVISIONS

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
PH. (508) 533-6666 FAX. (508) 533-6690

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SHEET 3 OF 10

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EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.
2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON MARCH 17 & JUNE 21, 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.

0 100 200
SCALE: 1" = 100'

100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

REVISIONS

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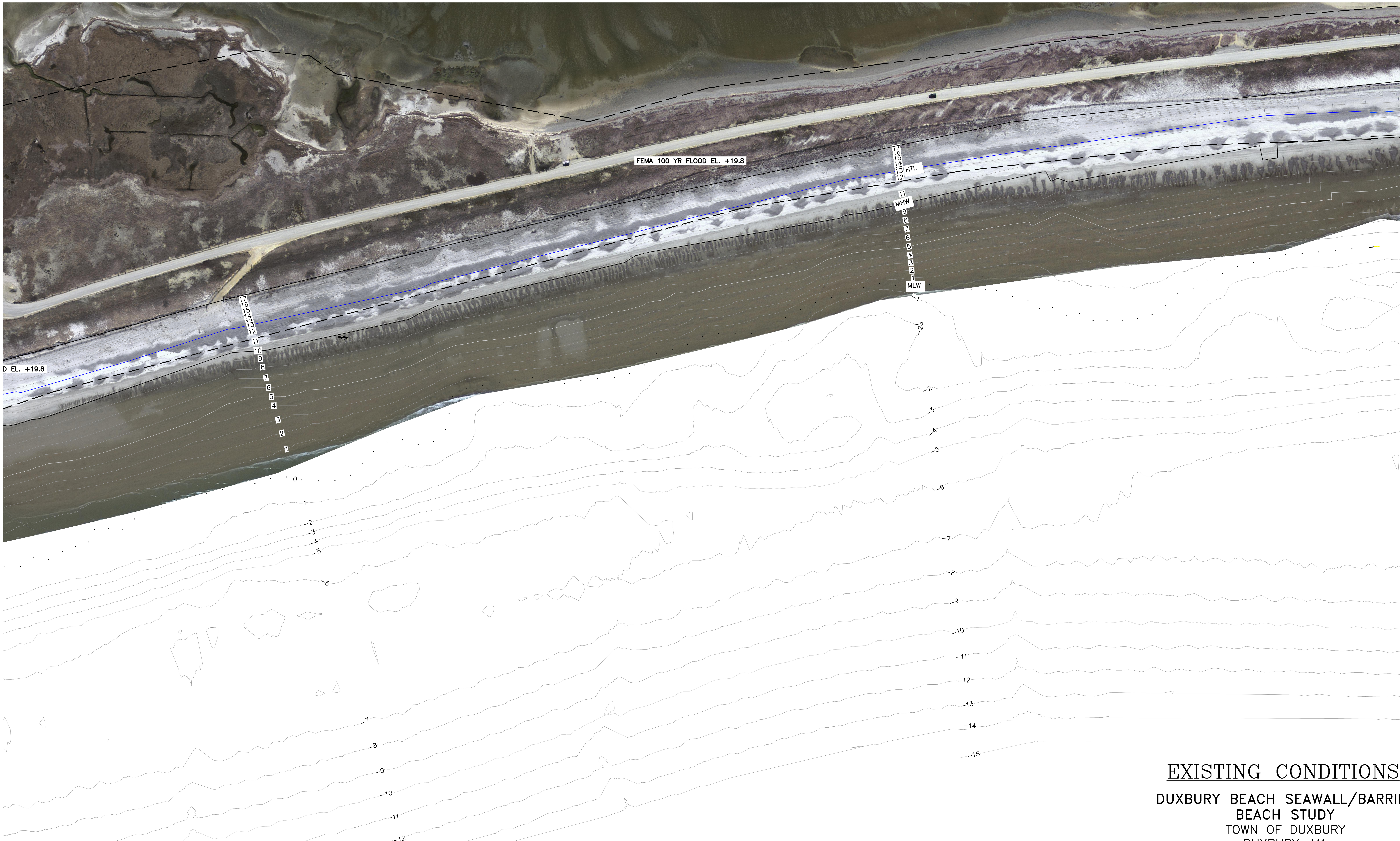
DRAWING NO. 30815-01-04
SHEET 4 OF 10



EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY

TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.

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HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

REVISIONS

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PH. (508) 533-6666 FAX. (508) 533-6660

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SHEET 5 OF 10

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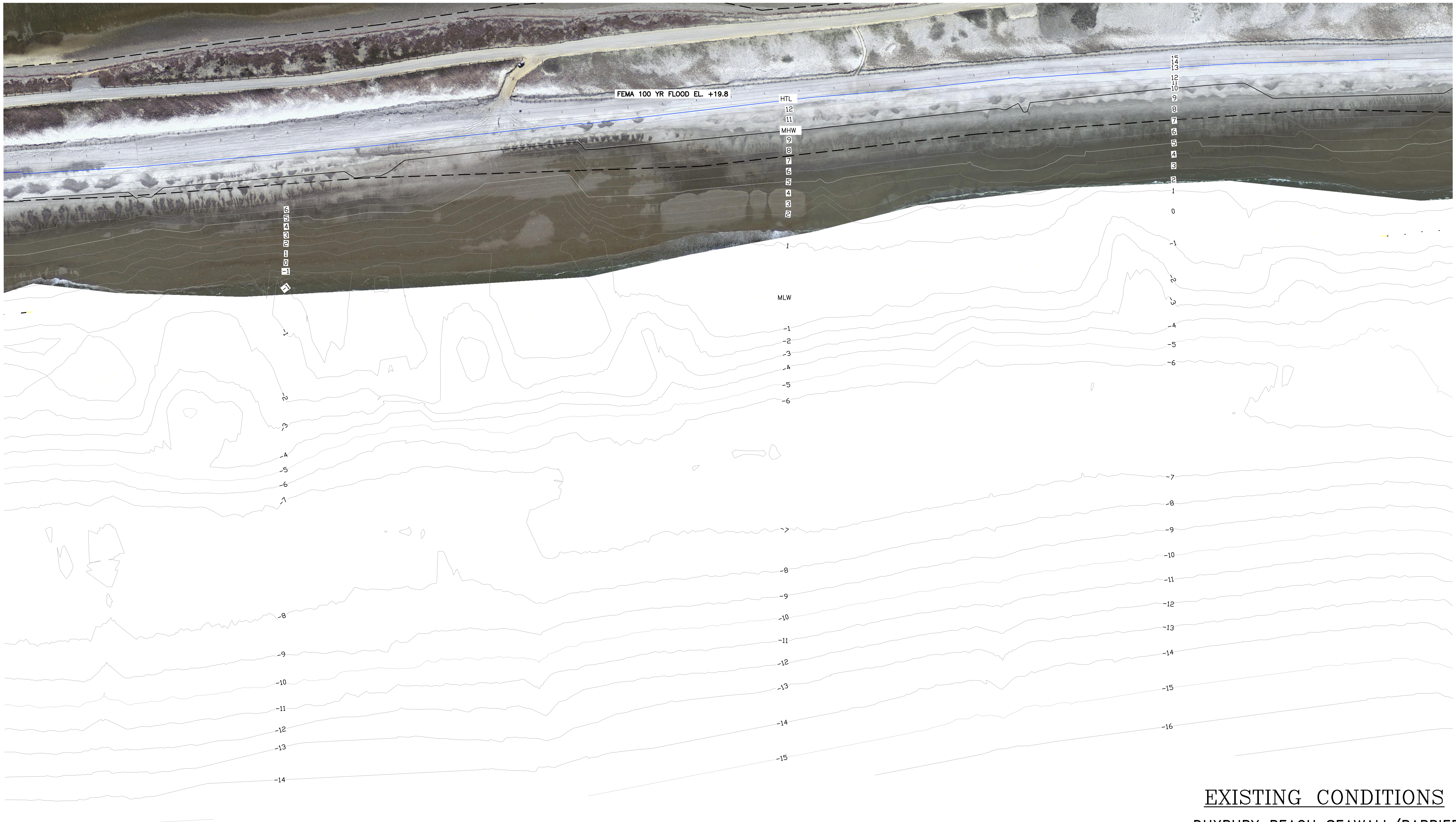

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.
2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON MARCH 4 & MARCH 17 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.

100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

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SHEET 6 OF 10

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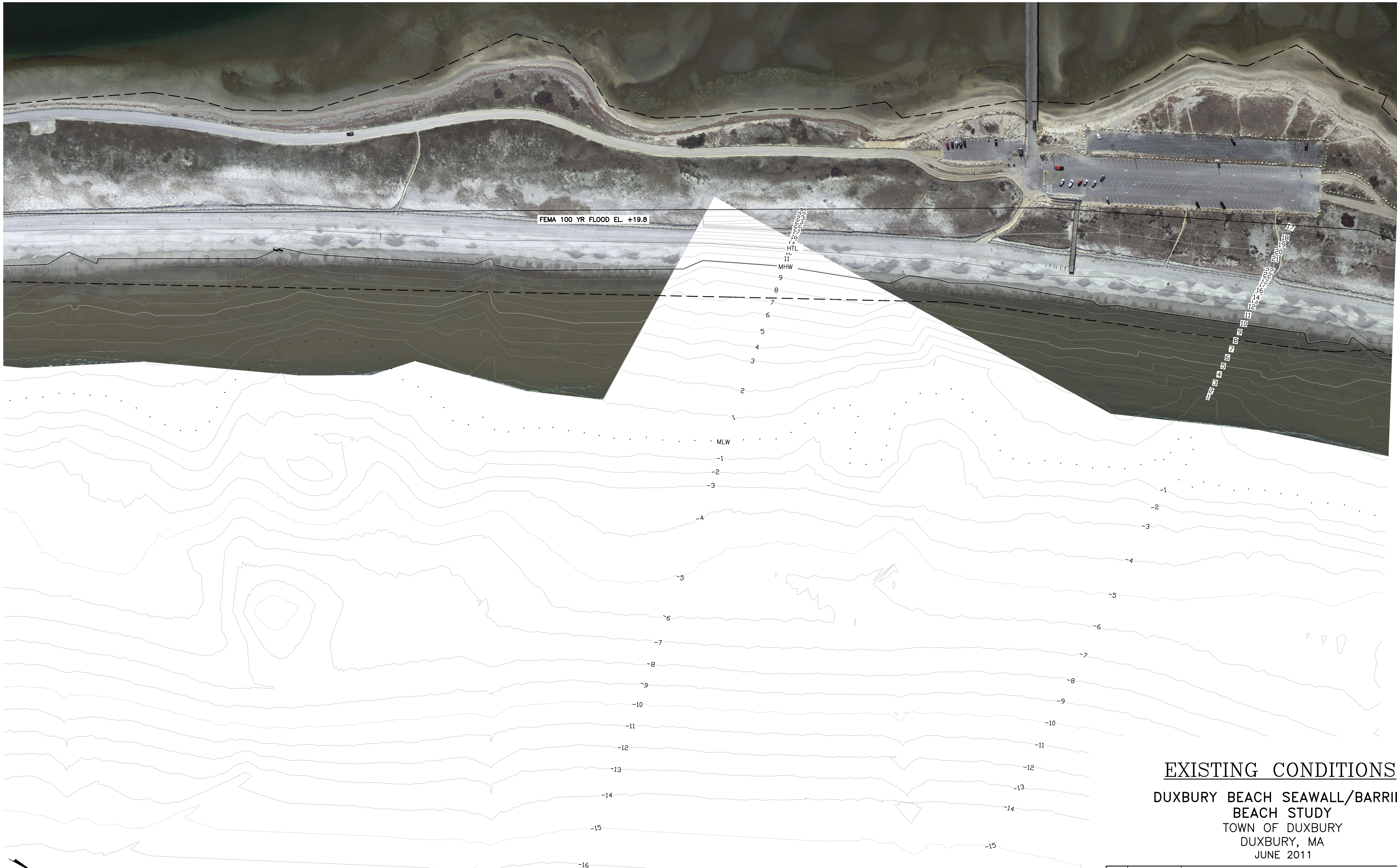

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

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100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

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DATE: 06/06/11

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SHEET 7 OF 10

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EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY

TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

NOTES:

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2) HYDROGRAPHIC SURVEY DATA AS SHOWN HEREIN WAS COLLECTED ON JANUARY 6, 2011 BY BOURNE CONSULTING ENGINEERING AND CAN ONLY REFLECT CONDITIONS AS THEY EXISTED DURING THE TIME OF SURVEY.

0 100 200
SCALE: 1" = 100'

- 100 YR. FLOOD (SEE PLAN)
- HTL +12.65
- MHW +9.89
- NAVD +5.58
- MLW EL. 0.0

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Franklin, MA 02038
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DATE: 06/06/11

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SHEET 8 OF 10

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER
BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

100 YR. FLOOD (SEE PLAN)
HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

NOTES:

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SHEET 9 OF 10

NOTES:

1) TOPOGRAPHIC SURVEY WAS COLLECTED BY ALPHA SURVEYING IN NOVEMBER 2010 AND CAN ONLY REFLECT CONDITIONS AT TIME OF SURVEY.

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HTL +12.65
MHW +9.89
NAVD +5.58
MLW EL. 0.0

0 100 200
SCALE: 1" = 100'

EXISTING CONDITIONS

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
JUNE 2011

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Appendix B – Condition Survey Plans

CONDITION SURVEY

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
DECEMBER 2010

100 YR. FLOOD VARIES
HTL +12.65
MHW +9.89
MLW EL. 0.0

0 50 100
SCALE: 1" = 50'

NOTES:
1. TOPOGRAPHIC SURVEY PERFORMED BETWEEN NOV. 24 AND DEC. 1, 2010 AND CAN ONLY REFLECT CONDITIONS FOUND BETWEEN THOSE DATES.
2. HYDROGRAPHIC SURVEY PERFORMED ON AND CAN ONLY REPRESENT CONDITIONS FOUND ON THAT DATE.
3. CONDITION SURVEY OF WALL PERFORMED NOV. 11, NOV. 19, AND DEC. 14, 2010 AND CAN ONLY REPRESENT CONDITIONS FOUND ON THOSE DATES.

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SHEET 1 OF 3

NOTES:
1. TOPOGRAPHIC SURVEY PERFORMED BETWEEN NOV. 24 AND DEC. 1, 2010 AND CAN ONLY REFLECT CONDITIONS FOUND BETWEEN THOSE DATES.
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100 YR. FLOOD VARIES
HTL +12.65
MHW +9.89
MLW EL. 0.0

0 50 100
SCALE: 1" = 50'

CONDITION SURVEY

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
DECEMBER 2010

REVISIONS

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
PH. (508) 533-6666 FAX. (508) 533-0600

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SHEET 2 OF 3

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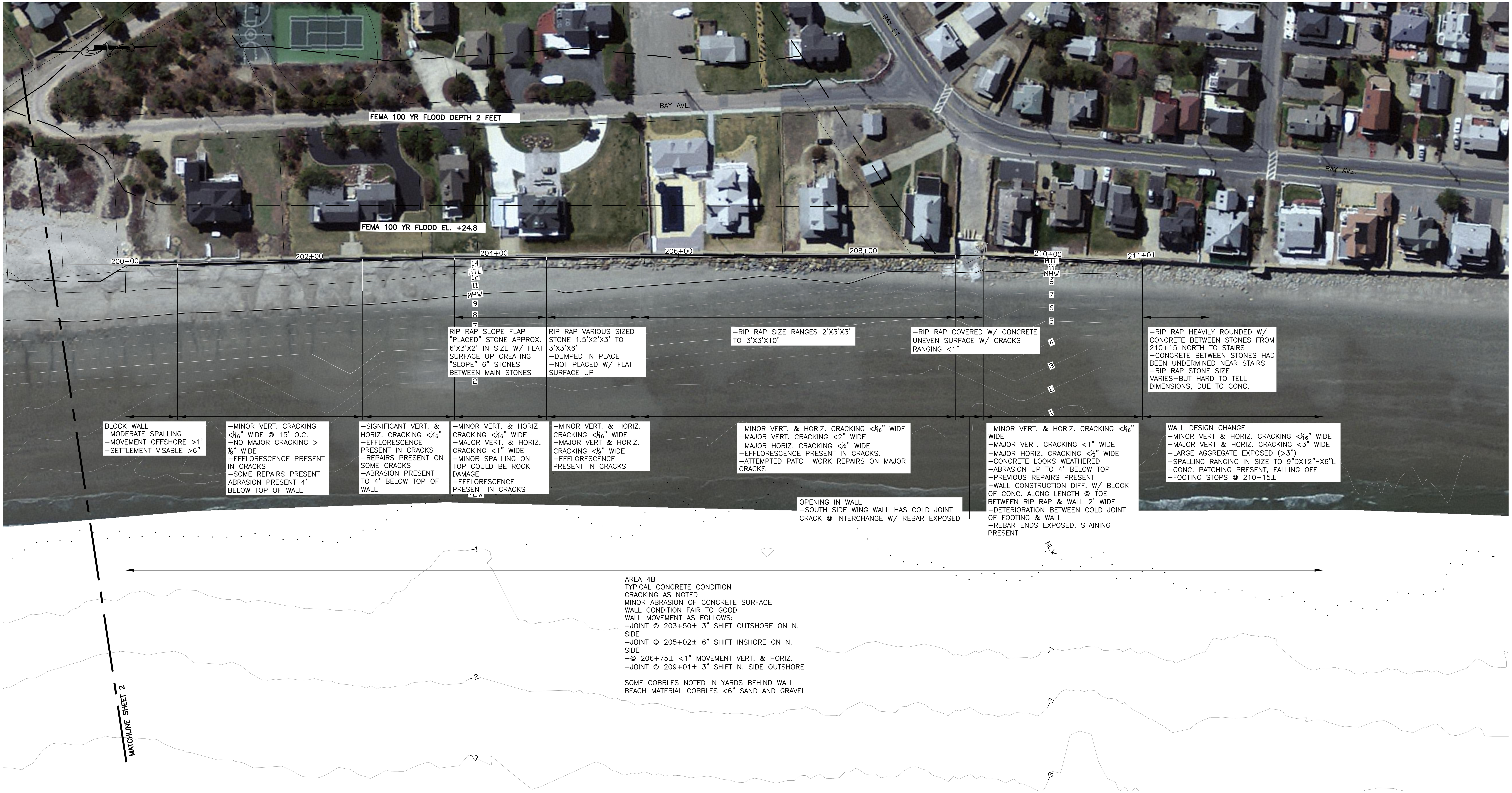

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3. CONDITION SURVEY OF WALL PERFORMED NOV. 11, NOV. 19, AND DEC, 14, 2010 AND CAN ONLY REPRESENT CONDITIONS FOUND ON THOSE DATES.

CONDITION SURVEY

DUXBURY BEACH SEAWALL/BARRIER BEACH STUDY
TOWN OF DUXBURY
DUXBURY, MA
DECEMBER 2010

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
PH. (508) 533-6666 FAX. (508) 533-0600

REVISIONS

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CHECKED: RJT
APPROVED: XXX
DATE: 12/13/10

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SHEET 3 OF 3

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Appendix C – Photographs

PHOTOGRAPH 1 - STA 100+00 START OF SOUTH WALL

PHOTOGRAPH 2 - SOUTH WALL STA 102+00 – TYP MAJOR CRACKING

PHOTOGRAPH 3 - TYPICAL MAJOR VERT. CRACKING IN SOUTH WALL APPROX 106+50

PHOTOGRAPH 4 - ABRASION, CRACKING AND PATCHING ON STAIRS AT 106+00

PHOTOGRAPH 5 - TYP CRACKS IN SOUTHERN WALL ~15' OC

PHOTOGRAPH 7 - BEACH AFTER ACCRETION

PHOTOGRAPH 6 - CRACKING ON NORTH END OF SOUTH WALL
STEP IN WALL HEIGHT 1.95'

PHOTOGRAPH 8 - FROZEN COBBLE AGAINST WALL

PHOTOGRAPH 9 - WALL ELEVATION STA 107+00 ERODED BEACH

PHOTOGRAPH 10 - WALL ELEVATION STA 108+00 ERODED BEACH

PHOTOGRAPH 11 - WALL ELEVATION STA 109+00 ERODED BEACH

PHOTOGRAPH 12 - RIP RAP SOUTH WALL STA 116+00

PHOTOGRAPH 13 - RIP RAP AT WALL "BOW" STA 118+00
ERODED BEACH

PHOTOGRAPH 14 - BEACH AT STA 116+00 AFTER ACCRETION

PHOTOGRAPH 15 - ROTATION IN WALL ~ 119+75 ±

PHOTOGRAPH 16 - WALL CURVATURE STA 117+00 – 120+00

PHOTOGRAPH 17 - WALL CURVATURE AND DEAD GRASS BEHIND (OVER TOPPING)

PHOTOGRAPH 18 - UNDERMINING FOUND ON 11/11/10 STA 122+00

PHOTOGRAPH 19 - UNDERMINING FOUND ON 11/11/10 STA 122+00

PHOTOGRAPH 20 - AREA WAS “REPAIRED” BY TOWN WITH BUCKET LOADER- MOVED SAND IN FRONT OF WALL ON 11/11/10

PHOTOGRAPH 21 - CHANGE IN WALL CONSTRUCTION APPROX. STA 127+00.

PHOTOGRAPH 22 - TYP. CRACKING IN WALL STA 125+00

PHOTOGRAPH 23 - NORTH END OF SOUTH WALL

PHOTOGRAPH 24 - RUST STAINING

PHOTOGRAPH 25 - NORTH END OF SOUTH WALL

PHOTOGRAPH 27 - DEAD GRASS

PHOTOGRAPH 26 - CRACKING IN GROUND SURFACE INDICATING WALL MOVEMENT AT UNDERMINED AREA

PHOTOGRAPH 28 - CRACK IN GROUND BEHIND UNDERMINED AREA

PHOTOGRAPH 29 - BACK LOADER FILLING IN FRONT OF WALL AT UNDERMINING

PHOTOGRAPH 30 - SETTLEMENT AND CRACKING OF GROUND BEHIND

PHOTOGRAPH 31 - CRACK AT END OF LEVEL AREA STA 123+00

PHOTOGRAPH 32 - MOVEMENT OF WALL OUT SHORE

PHOTOGRAPH 33 - SETTLEMENT BEHIND WALL

PHOTOGRAPH 34 - STONE BLOCK WALL AT SOUTHERN END OF NORTH WALL

PHOTOGRAPH 35 - FAILURE OUTWARD ROTATION

PHOTOGRAPH 36 - DETERIORATION OF CONCRETE


PHOTOGRAPH 37 - EROSION OF AREA BEHIND BLOCKS


PHOTOGRAPH 38 - START OF WALL


PHOTOGRAPH 39 - WALL ELEVATION STA 201+00


PHOTOGRAPH 40 - SIGNIFICANT CRACKING 202+00

PHOTOGRAPH 41 - SIGNIFICANT CRACKING STA 203+00

PHOTOGRAPH 42 - MAJOR CRACK IN WALL BEFORE RAMP STA 209+00

PHOTOGRAPH 43 - TYPICAL RIP RAP CONDITION

PHOTOGRAPH 44 - WALL AND RIPRAP STA 203+00

PHOTOGRAPH 45 - WALL AND RIPRAP STA 204+00

PHOTOGRAPH 46 - RIP RAP STA 206+00

PHOTOGRAPH 47 - TYPICAL BEACH CONDITION NORTH WALL

PHOTOGRAPH 48 - RAMP W/ CONC. STA 209+00


PHOTOGRAPH 49 - NORTH WALL FROM STA 209+00


PHOTOGRAPH 50 - NORTH WALL STA 209+00 LOOKING NORTH

PHOTOGRAPH 51 - RAMP STA 209+00

PHOTOGRAPH 52 - WALL W/ RIP RAP STA 210+00

PHOTOGRAPH 53 - WALL TIES EXPOSED W/ STAINING AND CRACKING

PHOTOGRAPH 54 - CHANGE IN CONSTRUCTION

PHOTOGRAPH 55 - HEAVY CRACKING

PHOTOGRAPH 57 - CONC. BETWEEN STONES

PHOTOGRAPH 56 - ROUNDED WEATHERED ROCKS

PHOTOGRAPH 58 - UNDERCUTTING

APPENDIX D – List of Historical Documents

Duxbury Coastal Infrastructure
Structure Forms

Drawings

Size	Title	Date	Notes
24x36	Gurnet Seawall Easement Plan	10-Jun-96	By Bryant Associates, 3 of 4 drawings
11x17	Proposed Shore Protection & Beach Elevations	Oct-46	MA DPW Contract #: 0948
11x17	Proposed Retaining Wall & Beach Elevations	Nov-46	MA DPW Contract #: 0960
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Some Boring Information	Aug-62	MA DPW Contract #: 2357
11x17	Concrete Steps	N/A	No MA DEP Contract #
24x36	Proposed Seawall Repairs (Site #1)	Feb-07	Vine Drawing
24x36	Proposed Revetment Repairs (Site #2)	N/A	Vine Drawing
24x36	Revetment Improvements	Jun-97	Vine Drawing - Site Plan & Details
24x36	Duxbury Seawall Investigation (shows FEMA Flood Limits)	Dec-91	Vine Drawing
24x36	Duxbury Seawall Investigation (Sta 0+00 to 27+00)	Nov-94	Vine Drawing
24x36	Duxbury Seawall Investigation (Sta 27+00 to 42+00)	Nov-94	Vine Drawing - Shows Wall Dimensions
24x36	Site Plan & Details	May-97	Vine Drawing - Drainage & Revetment Improvements
11x17	Site Plan & Details	Sep-94	Vine Drawing
24x36	Site Plan & Details - Revetment Improvements	May-97	Vine Drawing - DRAFT
24x36	Site Plan & Detials - Revetment Improvements	Jun-97	Vine Drawing
24x36	Locus & Site Plan - Seawall Investigation	Dec-94	Vine Drawing - shows FEMA flood limits
24x36	Duxbury Seawall Investigation (Sta 0+00 to 27+00)	Nov-94	Vine Drawing - shows plan of Seawall
24x36	Duxbury Seawall Investigation (Sta 27+00 to 42+00)	Nov-94	Vine Drawing - shows plan of Seawall
24x36	Proposed Seawall Repairs (Site #1)	Feb-07	Vine Drawing - Seawall Rehabilitation
24x36	Proposed Revetment Repairs (Site #2)	Feb-07	Vine Drawing - Foreshore Structure Project
24x36	Proposed Seawall Repair (Site #1)	Feb-07	Vine Drawing - Seawall Rehabilitation
24x36	Proposed Revetment Repairs (Site #2)	N/A	Vine Drawing - Foreshore Structure Project
set of 11x17	"Plans accompanying petition of town of Duxbury for placing stone protection along existing seawall in Massachusetts Bay Duxbury, MA"	Nov-96	Chapter 91 Drawings, DPW License Plan #: 6664, Approved by MA DEP on 07/02/97 - 5 sheets in this set
5 sets of 11x17	Duxbury Beach Seawall Easement Plan	Jun-96	By Bryant Associates, 4 sheets in this set

Duxbury Seawalls List of Existing Information

Drawings

Size	Title	Date	Notes
11x17	Proposed Shore Protection	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Shore Protection @ Property of Louise Mcpherson	Oct-46	MA DPW Contract #: 0948
11x17	Proposed Concrete Retaining Wall	Nov-46	MA DPW Contract #: 0960
11x17	Proposed Shore Protection	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Concrete Seawall, Vicinity of Gurnet Rd.	Aug-62	MA DPW Contract #: 04326
11x17	Proposed Concrete Steps & Fill	N/A	N/A
24x36	Duxbury Seawall Investigation - Seawall Profile	Nov-94	Vine Drawing
8.5x11	Gurnet Seawall Easement Plan	Aug-94	
11x17	Site Plan & Details - Seawall Toe Protection	Sep-96	Vine Drawing
11x17	Wall Profile	Nov-94	
11x17	Map of Duxbury	N/A	
24x36	Site Plan & Details - Seawall Toe Protection	May-96	Vine Drawing
24x36	Site Plan & Details - Seawall Repairs	Jul-94	
8.5x11	Hand Drawn Seawall Detail	N/A	Bay Avenue to Smaller Wall
24x36	Duxbury Seawall Investigation	Nov-94	Vine Drawing - Cross Sections
8.5x11	Proposed Concrete Retaining Wall	Nov-46	MA DPW Contract #: 0960
8.5x11	Locus Plan	Nov-46	
24x36???	Site Plan & Details - Seawall Toe Protection	Sep-96	Vine Drawing
24x36	Site Plan & Details - Seawall Repairs	Mar-95	Vine Drawing - DRAFT
11x17	Gurnet Seawall Easement Plan	Aug-94	
8.5x11	Site Plan	Jun-94	
8.5x11	Existing Conditions	Jun-94	
8.5x11	Repair Details	Jun-94	
set of 8.5x11	"plans accompanying petition of town of Duxbury for placing stone protection along existing seawall in massachusetts bay Duxbury, MA"	Nov-96	Chapter 91 Drawings - 5 sheets in this set
8.5x11	Plans showing transect lines	N/A	5 pages in this set

Memos, Reports, Letters Etc.

Item	Description	Date	Notes
NOI	Duxbury Seawall Repairs	13-Jul-94	Vine - Has wave runup analysis
Memo	Duxbury Seawall Stabilization Investigation Findings	11-Mar-94	Vine - Has some boring information
Letter & DEP Approval	Waterway License #: 4235 - Seawall Repairs	7-Nov-94	Gurnet Road
Memo	Meeting Notes	19-Aug-96	
Letter & DEP Approval & 11x17's (Ch. 91)	Waterway License #: 4235 - Seawall Repairs	Nov-94	Gurnet Road
2 sets of 11x17's	"plan accompanying the petition of the town of Duxbury to repair and maintain an existing seawall and new revetment at Gurnet Rd., Duxbury, MA"	Nov-94	MA DEP License #: 4235 - 3 sheets in this set
Analysis (w/ drawings)	Wave Runup / Overtopping Evaluation	N/A	Gurnet Rd. Seawall Repair
Drawings	One of the drawings in this analysis shows beach elevation of +12.0 per 1946 drawing		
Form	Environmental Notification Form - Seawall Repairs	17-Feb-94	Gurnet Rd. - Emergency Seawall Repair from a storm
Letter	Department of the Army - Letter stating they have reviewed towns application to place toe stone armoring below high tide line	18-Nov-97	
Letter	Letter from Vine to Dep - Toe Protection	11-Nov-97	MA DEP License #: 6664
2 copies - Memo	Site Investigation	4-Aug-08	
Report	Duxbury Beach Morphology & Processes	Apr-99	Ecological type report
Memo	Duxbury Seawall Stabilization Investigation Findings	11-Mar-94	Vine memo - Has some boring information
Report	Vine Report w/ Wall stability calcs. (5 different cases), tieback system calcs, toe revetment calcs. & stone @ toe as passive soil	15-Apr-94	
Letter	ACOE to town of Duxbury - Massachusetts Programmatic General Permit	18-Oct-94	
Letter	MA DEP to Town	2-Jul-97	MA DEP License #: 6664
Letter	Duxbury Beach Seawall Repairs	31-Mar-94	Vine Letter - EOEA #: 9850
Letter	Recording of License Notice	Jul-97	
Letter	Agreement # 9608 - Duxbury - Gurnet Rd. Seawall Repairs	13-Nov-98	Costs
Permit	Department of the Army - Programmatic General Permit, Commonwealth, MA	Sep-95	
2 copies - Letter	MA EOEA, Cert. of the Secretary of Environmental Affairs, on the Environmental Notification Form - Duxbury Seawall Repairs	7-Apr-94	
8.5x11 drawings	Revetment Repair Alternatives	Feb-94	3 sheets in this set
Letter	Vine Letter - Seawall Emergency Stabilization	22-Dec-93	
Appeal	Appeal to FEMA's non-allowance of repairs to seawall	28-Sep-92	
Application	Waterways License Application for Seawall Repairs	29-Jul-94	
Letter	Duxbury DPW - Easements	12-Dec-96	
8.5x11 document	Environmental notification form - Shows some historical background on seawall	Feb-94	
Memo	Vine - Seawall Stabilization Investigation Findings	11-Mar-94	
Letter	Waterways License Application #: W94-3609 / License #: 4235	23-Nov-94	Recorded on 11/18/94, Book #: 13270, Page #: 328
Boring Logs	Gurnet Road	24-Feb-94	
8.5x11 drawings	Fema zones, wall cross section & Elevation Reference Marks	N/A	
Contract Documents	For Seawall Repair Contract, North Duxbury Beach	Aug-95	has specs, but no drawings

Folders

Item	Description	Date
Folder	photos of seawall	N/A
Folder	Wetlands Protection Act - Gurnet Rd. public beach	1992
Folder	Waterways License - 325 King Caesar Rd.	17-Apr-94
Folder	Order of Conditions - Gurnet Rd. Seawall	24-Aug-94
Folder	Wetlands Protection Act, Emergency Certification Form - Gurnet Rd. Seawall & Ocean Rd.	11/9/2010
Folder	Determination of applicability town of Duxbury Wetlands Protection Law - Seawall Ocean Rd. south to Marshfield	15-May-01
Folder	Order of Conditions - Gurnet Rd. Extension - Duxbury Beach Res.	19-Jul-95

Chapter 91 License

Item	Description	Date	Notes
11x17	Proposed Shore Protection & Beach Elevations	Oct-46	MA DPW Contract #: 0948
11x17	Proposed Retaining Wall & Beach Elevations	Nov-46	MA DPW Contract #: 0960
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Retaining Wall	Sep-53	MA DPW Contract #: 1339
11x17	Some Boring Information	Aug-62	MA DPW Contract #: 2357
11x17	Concrete Steps	N/A	No MA DEP Contract #
set of 11x17	"Plans accompanying petition of town of Duxbury for placing stone protection along existing seawall in Massachusetts Bay Duxbury, MA"	Nov-96	Chapter 91 Drawings, DPW License Plan #: 6664, Approved by MA DEP on 07/02/97 - 5 sheets in this set
11x17	Proposed Shore Protection	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Shore Protection @ Property of Louise Mcpherson	Oct-46	MA DPW Contract #: 0948
11x17	Proposed Concrete Retaining Wall	Nov-46	MA DPW Contract #: 0960
11x17	Proposed Shore Protection	Sep-53	MA DPW Contract #: 1339
11x17	Proposed Concrete Seawall, Vicinity of Gurnet Rd.	Aug-62	MA DPW Contract #: 04326
11x17	Proposed Concrete Steps & Fill	N/A	N/A
8.5x11	Proposed Concrete Retaining Wall	Nov-46	MA DPW Contract #: 0960
8.5x11	Locus Plan	Nov-46	
set of 8.5x11	"plans accompanying petition of town of Duxbury for placing stone protection along existing seawall in massachusetts bay Duxbury, MA"	Nov-96	Chapter 91 Drawings - 5 sheets in this set
Letter & DEP Approval & 11x17's (Ch. 91)	Waterway License #: 4235 - Seawall Repairs	Nov-94	Gurnet Road
2 sets of 11x17's	"plan accompanying the petition of the town of Duxbury to repair and maintain an existing seawall and new revetment at Gurnet Rd., Duxbury, MA"	Nov-94	MA DEP License #: 4235 - 3 sheets in this set

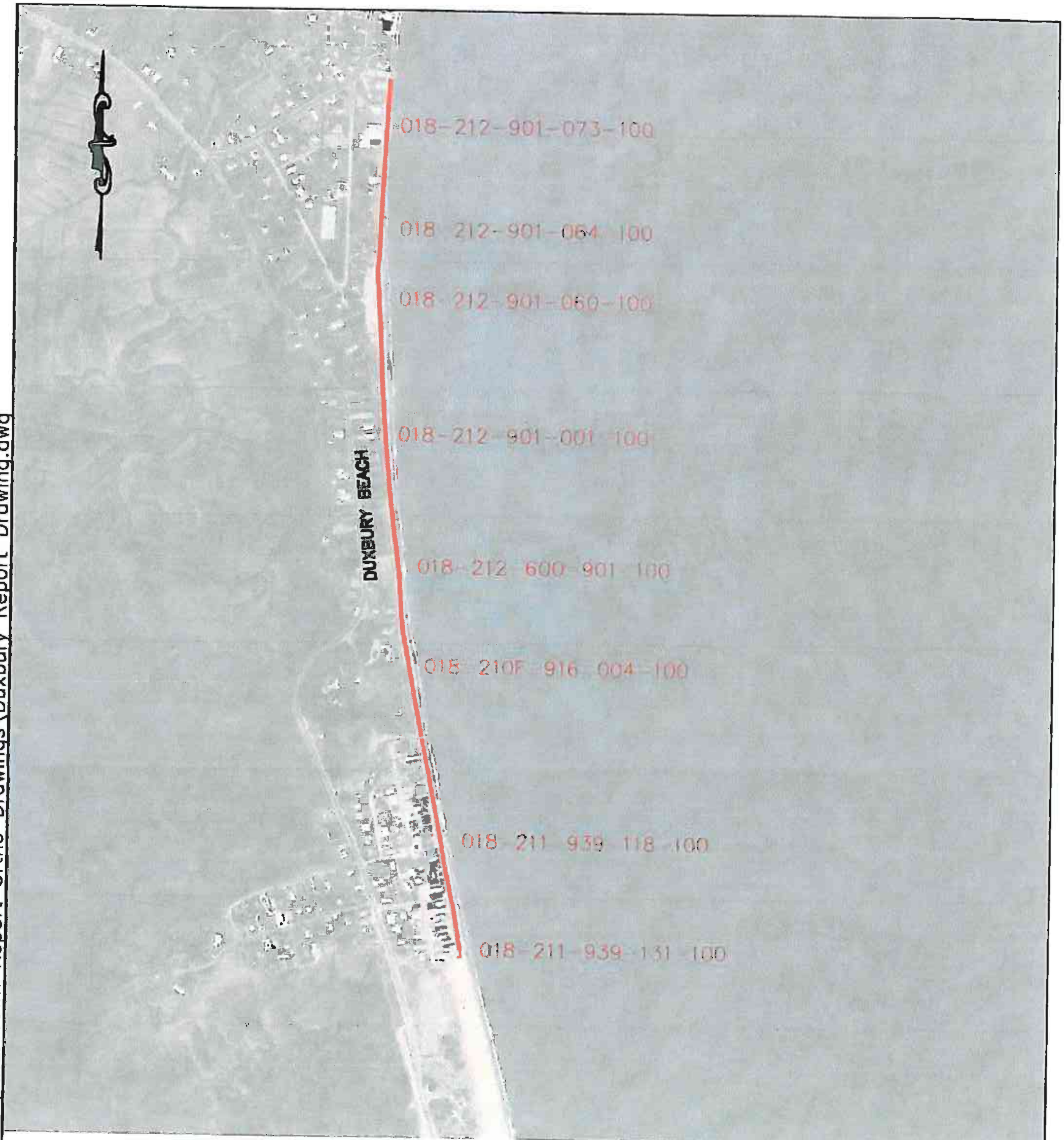
Order Of Conditions

Item	Description	Date
Folder	Order of Conditions - Gurnet Rd. Seawall	24-Aug-94
Folder	Order of Conditions - Gurnet Rd. Extension - Duxbury Beach Res.	19-Jul-95

Army Corp. of Engineers Permits

None Observed

File: X:\26600-\26637\Final Town Report Ortho Drawings\Duxbury Report Drawing.dwg



COASTAL STRUCTURE LOCATION PLAN

TOWN OF DUXBURY

SOUTH SHORE COASTAL INFRASTRUCTURE INVENTORY AND ASSESSMENT DEMONSTRATION PROJECT

AUGUST 2006

0 200

SCALE: 1" = 200'

BCE Bourne Consulting Engineering

SHEET 1 OF 3

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-210F-916-004-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 0

Estimated Reconstruction/Repair Cost: $112,820.00

Length: 518 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 5 to 10 Feet

Secondary Type: Revetment

Secondary Material: Stone

Secondary Height: Under 5 Feet

Structure Summary :

Concrete seawall in satisfactory condition with some cracking for full height of front outshore face. Some deterioration at joints. 30" wide wall with wave return face. 2' high x 6' wide revetment along face (1 ton stone)

Condition	B
Rating	Good
Level of Action	Minor
Description	Structure observed to exhibit very minor problems, superficial in nature. Minor erosion to landform is present. Structure / landform adequate to provide protection from a major coastal storm with no damage. Actions taken to prevent / limit future deterioration and extend life of structure.

Priority	IV
Rating	High Priority
Action	Consider for Next Project Construction Listing
Description	High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images:

018-210F-916-004-100-PHO1A.jpg

018-210F-916-004-100-PHO1B.jpg

Structure Documents:

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-211-939-118-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 0

Estimated Reconstruction/Repair Cost: $86,001.00

Length: 1018 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: Under 5 Feet

Secondary Type:

Secondary Material:

Secondary Height:

Structure Summary :

Concrete seawall in satisfactory condition with some vertical cracks for full height of front face. 30 inch wide wall with wave return face.

Condition Rating: B, Good

Level of Action: Minor

Description: Structure observed to exhibit very minor problems, superficial in nature. Minor erosion to landform is present. Structure / landform adequate to provide protection from a major coastal storm with no damage. Actions taken to prevent / limit future deterioration and extend life of structure.

Priority Rating: IV, High Priority

Action: Consider for Next Project Construction Listing

Description: High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images:

018-211-939-118-100-PHO1A.jpg

018-211-939-118-100-PHO1B.jpg

Structure Documents:

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-211-939-131-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 0

Estimated Reconstruction/Repair Cost: $21,252.00

Length: 50 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: Under 5 Feet

Secondary Type:

Secondary Material:

Secondary Height:

Structure Summary :

Concrete seawall in fair condition with cracking and spalling. Built 30 inch wide with wave return face.

Condition Rating: C, Fair

Level of Action: Moderate

Description: Structure is sound but may exhibit minor deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure adequate to withstand major coastal storm with little to moderate damage. Actions taken to reinforce structure to provide full protection from major coastal storm and for extending life of structure. Moderate wind or wave damage to landform exists. Landform may not be sufficient to fully protect shoreline during a major coastal storm. Actions taken to provide addition material for full protection and extended life.

Priority Rating: IV, High Priority

Action: Consider for Next Project Construction Listing

Description: High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images: 018-211-939-131-100-PHO1A.jpg

Structure Documents:

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-212-600-901-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 1962

Estimated Reconstruction/Repair Cost: $519,621.00

Length: 476 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 5 to 10 Feet

Secondary Type: Revetment

Secondary Material: Stone

Secondary Height: Under 5 Feet

Structure Summary :

Concrete wall in fair condition. Evidence of lateral movement and slight tilt to outshore. Appeared to have failed previously and revetment (average 1 to 2 ton stone) placed along outshore face to stabalize.

Condition	C
Rating	Fair
Level of Action	Moderate
Description	Structure is sound but may exhibit minor deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure adequate to withstand major coastal storm with little to moderate damage. Actions taken to reinforce structure to provide full protection from major coastal storm and for extending life of structure. Moderate wind or wave damage to landform exists. Landform may not be sufficient to fully protect shoreline during a major coastal storm. Actions taken to provide addition material for full protection and extended life.

Priority	IV
Rating	High Priority
Action	Consider for Next Project Construction Listing
Description	High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of s horeline)

Structure Images:

- 018-212-600-901-100-PHO1A.jpg
- 018-212-600-901-100-PHO1B.jpg
- 018-212-600-901-100-PHO1C.jpg

Structure Documents:

MA DPW	AUG 1962	PROPOSED	018-212-600-901-100-DCR1A
DEP CH.91	NOV. 4 1994	PLAN	018-212-600-901-100-LIC1A
DEP CH.91	JULY 02, 19	PLANS	018-212-600-901-100-LIC1B
USACE	NOV 14 199	PETITION TO	018-212-600-901-100-COE1A

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-212-901-001-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 1953

Estimated Reconstruction/Repair Cost: $137,683.00

Length: 907 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 5 to 10 Feet

Secondary Type:

Secondary Material:

Secondary Height:

Structure Summary :

Concrete seawall in satisfactory condition with some minor cracking. Wall built with 30" wide cap and wave return face.

Condition Rating: B

Good

Level of Action: Minor

Description: Structure observed to exhibit very minor problems, superficial in nature. Minor erosion to landform is present. Structure / landform adequate to provide protection from a major coastal storm with no damage. Actions taken to prevent / limit future deterioration and extend life of structure.

Priority Rating: IV

High Priority

Action: Consider for Next Project Construction Listing

Description: High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images:

018-212-901-001-100-PHO1A.jpg

018-212-901-001-100-PHO1B.jpg

Structure Documents:

MA DPW	SEPT. 1953	PROPOSED	018-212-901-001-100-DCR1A

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-212-901-060-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR – Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 0

Estimated Reconstruction/Repair Cost: $1,024,650.00

Length: 345 Feet

Top Elevation: 0 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 10 to 15 Feet

Secondary Type:

Secondary Material:

Secondary Height:

Structure Summary :

Historic DCR documents indicate bulkhead construction at location. No evidence of bulkhead found. Currently, cobble beach with dune (approximately 10 feet high) inshore. Erosion of material landward of historic bulkhead line. Temporary stabablization to prevent fill loss at ends of adjacent structures.

Condition	F
Rating	Critical
Level of Action	Immediate
Description	Conditions of structure/landform may warrant emergency stabilization as failure may result in potential loss of property and/or life. Landform eroded, loss of integrity. Structure exhibits critical levels of deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure provides little or no protection from a major coastal storm. Actions taken to totally reconstruct structure to regain full capacity. Landform stability is severely compromised, rate of erosion/material loss may be increasing, and landform does not provide adequate protection from a major coastal storm. Actions taken to recreate landform to adequate limits for full protection from a major coastal storm.

Priority	IV
Rating	High Priority
Action	Consider for Next Project Construction Listing
Description	High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images: 018-212-901-060-100-PHO1A.jpg

Structure Documents:

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-212-901-064-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 1946

Estimated Reconstruction/Repair Cost: $268,686.00

Length: 354 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 5 to 10 Feet

Secondary Type:

Secondary Material:

Secondary Height:

Structure Summary :

First 50' is precast concrete seawall in fair condition with horizontal joint at mid-height. Concrete cracking and spalling near wall top and apex of curve. Remainder of structure is condition "B" with minor cracking (construction similar to adjacent structures)

Condition	C
Rating	Fair
Level of Action	Moderate
Description	Structure is sound but may exhibit minor deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure adequate to withstand major coastal storm with little to moderate damage. Actions taken to reinforce structure to provide full protection from major coastal storm and for extending life of structure. Moderate wind or wave damage to landform exists. Landform may not be sufficient to fully protect shoreline during a major coastal storm. Actions taken to provide addition material for full protection and extended life.

Priority	IV
Rating	High Priority
Action	Consider for Next Project Construction Listing
Description	High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images:

018-212-901-064-100-PHO1A.jpg

018-212-901-064-100-PHO1B.jpg

Structure Documents:

MA DPW	NOV 1946	PROPOSED	018-212-901-064-100-DCR1A

Prepared By: Bourne Consulting Engineering

CZM South Shore Coastal Infrastructure Inventory and Assessment

Structure Assessment Form

Town: Duxbury

Structure ID: 018-212-901-073-100

Key: community-map-block-parcel-structure

Property Owner: Local

Location: Duxbury Beach

Date: 7/26/2006

Presumed Structure Owner: Local

Based On Comment: DCR - Contract Drawings

Owner Name: Duxbury

Earliest Structure Record: 1946

Estimated Reconstruction/Repair Cost: $593,852.00

Length: 544 Feet

Top Elevation: 9 Feet NAVD 88

FIRM Map Zone: VE

FIRM Map Elevation: 21 Feet NGVD

Primary Type: Bulkhead/ Seawall

Primary Material: Concrete

Primary Height: 5 to 10 Feet

Secondary Type: Revetment

Secondary Material: Stone

Secondary Height: Under 5 Feet

Structure Summary :

Concrete seawall with 30" cap and wave return face. Revetment is 3' to 4' high x 6' to 8' wide with stone size 1 ton to 2 ton. Horz. Movement of about 3 wall sections (40'ea = 120' total) Horizontal cracking at wall mid-Height

Condition: C

Rating: Fair

Level of Action: Moderate

Description: Structure is sound but may exhibit minor deterioration, section loss, cracking, spalling, undermining, and/or scour. Structure adequate to withstand major coastal storm with little to moderate damage. Actions taken to reinforce structure to provide full protection from major coastal storm and for extending life of structure. Moderate wind or wave damage to landform exists. Landform may not be sufficient to fully protect shoreline during a major coastal storm. Actions taken to provide addition material for full protection and extended life.

Priority: IV

Rating: High Priority

Action: Consider for Next Project Construction Listing

Description: High Value Inshore Structures with Potential for Infrastructure Damage and/or Moderate Density Residential Dwellings (1-10 dwellings impacted / 100 feet of shoreline)

Structure Images:

018-212-901-073-100-PHO1A.jpg

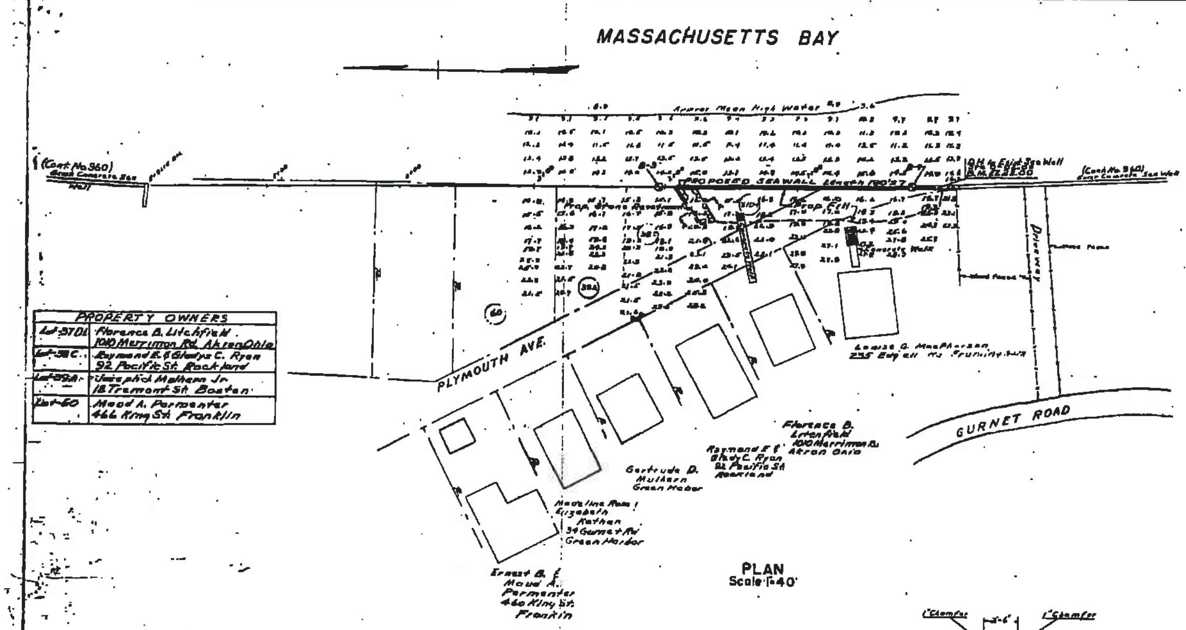
018-212-901-073-100-PHO1B.jpg

Structure Documents:

MA DPW	NOV 1946	PROPOSED	018-212-901-073-100-DCR1A
DEP CH.91	JULY 02, 19	PLANS	018-212-901-073-100-LIC1A

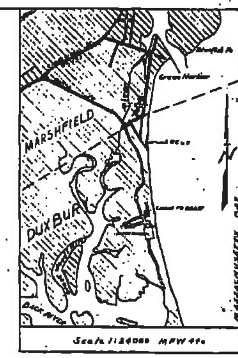
Prepared By: Bourne Consulting Engineering

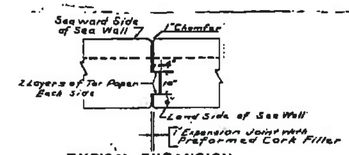
APPENDIX E – Existing Geotechnical Information



PLAN
Scale 1"=40'

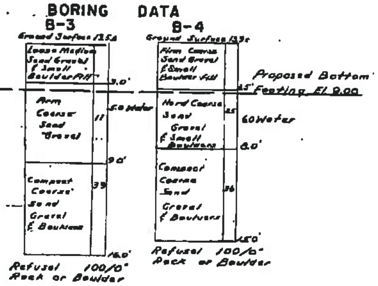
PROPERTY OWNERS	
Lot 37DL	Florence B. Litchfield 1010 Merriman Rd. Akron Ohio
Lot 38C	Raymond E. & Gladys C. Ryan 92 Pacific St. Rockland
Lot 39A	Joseph A. Mulhern Jr. 18 Tremont St. Boston
Lot 60	Maud A. Parmenter 466 King St. Franklin





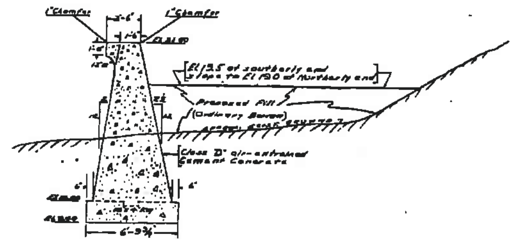
TYPICAL EXPANSION JOINT DETAIL
Scale 1/2" = 1'-0"

BORING DATA



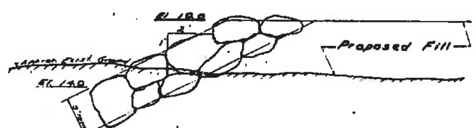
BORING NOTES

Location of borings shown thus ◉ B-3 Plan.
Borings taken for purpose of Design and show conditions @ Boring Points only, but do not necessarily show materials to be encountered during construction.
Figures in right hand column indicate number of blows required to drive 2" Sampling pipe, one foot using 140 lb. weight falling 30 inches.
Boring were taken December, 1960 by Raymond Concrete Pile Co.



TYPICAL WALL SECTION
Scale 1/4" = 1'-0"

LOCATION OF PROPOSED WORK SHOWN IN RED



SECTION "A-A"
Scale 1"-4'

NOTE: ELEVATIONS ARE IN FEET AND TENTHS ABOVE THE PLANE OF MEAN LOW WATER
REFERENCE: TRANSIT BOOK NO. 526

PROPOSED CONCRETE SEA WALL DUXBURY BEACH VICINITY OF GURNET ROAD DUXBURY	
DEPARTMENT OF PUBLIC WORKS of MASSACHUSETTS DIVISION OF WATERWAYS	
DESIGN: [illegible] DRAWN: [illegible] CHECKED: [illegible]	SCALE: AS SHOWN DATE: AUGUST 1962 SHEET NO. 1 of 1
R. B. MacKinnon, Chief Waterways Engineer	John D. Crawford, Director Division of Waterways
CONT. NO. 2357	ACC. NO. 04326

0200

Waterfront Engineering Consultants
Nucci Vine
ASSOCIATES

MEMORANDUM

TO: Walter Tonaszuck
FROM: David Vine
DATE: March 11, 1994
RE: Duxbury Seawall Stabilization
Investigation Findings

The following outlines investigations performed to evaluate methods for improving the structural stability of the 300 foot section of moved wall at Duxbury Beach. Further description of the emergency work, site conditions and regulatory requirements is referenced to the February 17, 1994 Environmental Notification Form submittal.

A. Investigations

Field investigations consisted of performing measurements and visually observing the existing condition of the wall. In addition, subsurface investigations, consisting of four soil test borings, were performed behind the seawall at the locations shown by attached Figure 2. The driller's logs are attached to this submittal.

Field investigations indicated that approximately 215 linear feet of stone was placed. Placement is relatively random, with some areas not having stone in direct contact with the wall. As there were no as-built plans of wall available, it is difficult to determine the extent of wall movement that occurred due to the December storm. Based on present survey, it is estimated that the wall may have moved seaward as much as 4 to 6 feet. Some wall movement appears to have occurred over about 300 linear feet. See preliminary site plan, Figure 2.

The test borings indicated medium to stiff to stiff peat material, encountered 14 to 21 feet below the existing ground surface (corresponding to approximate Mean Low Water Datum elevation -1 to +7). The thickness of the peat layer varied from 4.5 to 6 feet. Above the peat, soils were generally medium to dense fine to coarse sand with trace of inorganic silt, gravel and cobbles. Below the peat, the soils were generally similar dense to very dense fine to coarse sands. Figure 3 illustrates the generalized subsurface conditions encountered.

The presence of the peat layer is not considered a factor in the stability of the wall due to the following:

o Encountering the peat behind the wall does not mean that there is necessarily peat below the wall. Peat material in close proximity to the wall could have been removed during construction. The areas where the peat is significantly below the bottom of the wall (estimated 7 to 9 feet),

251 Low Street
Suite 232
Newburyport
Massachusetts
01950
(508) 465-1428
FAX
(508) 465-2640

probably represent areas where the peat is in place. The only way to confirm the presence of peat below the wall would be by coring through the wall, angular exploration drilling or test pits.

- o The elevation of the top of wall within the area of the site appears to be at a relatively uniform level. This would indicate that the wall has not experienced major past settlement.

- o The dense nature of the peat, demonstrated by the test borings, and the 48 years the wall has been in place would indicate that future settlement should be minor.

B. Alternates

1. Tieback System

The option of stabilizing the failed seawall with tieback anchors has been investigated and analyzed. This approach may be technically feasible, but it is unconventional and may be an expensive repair.

Summary of findings for the analyses of stabilization of the seawall by tiebacks include the following:

- o The 1946 seawall is apparently an unreinforced concrete gravity wall, unable to take bending stresses.

- o Use of a conventional steel tierod wale (as with sheet pile bulkheads) is ineffective due to the rigid nature of the mass concrete seawall. A steel wale would have to be over-designed to be rigid (no deflection under loading) to prevent seawall cracking. This would be further complicated by the existing wall alignment no longer being straight.

- o Private property behind the seawall and proximity of houses to the wall prevent use of conventional deadman-type tieback anchors in some areas. Tieback anchors could be grouted soil anchors, angled downward to remain below any houses or structures. Grouted soil anchors could be installed from the beach-side of the seawall. A reinforced concrete facing would encapsulate the tierod heads and form a wale on the oceanside face of the wall. Based on expected soil loadings and the unreinforced nature of the seawall, the tiebacks would be located about 8 feet on center.

- o Wall toe protection would still be needed with a tieback type of wall repair. Undermining of the toe could still result in movement of the wall. Toe protection could be steel sheet piling about 10 feet long driven at the toe of the wall and encased in a concrete cap fastened to the seawall. The cap would also serve as the wale for distributing horizontal loads. See sketch Figure 4.

- o The wall has expansion joints every 40 to 45 feet. The force required to move the wall into alignment is estimated to be in the order of 155 tons. To physically move the wall, some type of distribution system to prevent cracking of the wall in tension during construction operations would be required. Some demolition at the ends of the wall would be required to prevent segments from binding up against each other. The process would need to be tide-coordinated and would probably necessitate unconventional costly equipment. The stability of the wall in its present leaning condition is estimated to reduce the present factor of safety in the order of 5 percent. Areas where the wall has slid, but is still in general vertical alignment, would not have reduced stability, due to the present condition.

- o The estimated cost for this tieback seawall repair with steel sheeting toe protection is about $600 per linear foot, based on 300 linear feet of wall to be repaired. The total cost would be $180,000. This amount would not include efforts to move the wall into alignment.

- o As the tieback system would be behind the wall, the work would have minimal impact on the resource areas and permitting of the work should be relatively straightforward. Placement of tiebacks or anchors on private property would require consent of homeowners.

2. Increasing Toe Armor

An alternate to the tieback investigated is to increase the amount of stone toe protection to form a revetment. The top of the stone revetment was analyzed at elevation +16, approximately 6.5 feet below the top of the seawall. The crest of the revetment was assumed to be 3 feet wide with a 1.5(H):1.0(V) front slope to the revetment (see Figure 5). Top of wall elevation has been assumed at elevation 22.5. New and existing revetment stone would be buried in the beach to elevation +4 (MLW) to provide toe protection from undercutting.

Concerns and benefits with this toe revetment method of seawall stabilization are as follows:

NUCCI VINE ASSOC TEL No.508-465-2640 Mar 11.94 12:43 No.002 P.04

- The revetment could influence wave overtopping of the seawall, possibly increasing the amount of wave overtopping (not yet investigated analytically). It would be recommended that consent be obtained from the adjacent homeowners for this alteration.

- Reduction in wave reflection off the face of the seawall may cause the sand level on the beach to rise (reduction in beach erosion).

- The estimated cost for this revetment stabilization of the seawall is about $230 per linear foot, based on 300 linear feet of wall to be repaired. This total considers reusing the approximate 280 cubic yards of stone, presently on the beach, supplemented by an additional 650 cubic yards of stone, per the Figure 5 section. Contractor bids should be competitive, as many local contractors have the equipment to complete this type of repair.

- The revetment would have some impact in reducing the area of existing barrier beach. Figure 5 illustrates the total width of placed stone as 21 feet of which only about 12 feet would be placed above the level of the existing beach (assumed +12). Though the width reduction to the beach is only in the order of 12 feet (approximately 30 percent of the total beach width at high tide and about 10 percent at low tide), regulatory agencies would require more detailed review of the project than for the tieback alternate, or for maintaining the beach to the initial construction level of +12.

C. Conclusions and Recommendations

1. The alternate of tying back the seawall is not appropriate or economically feasible for the site conditions. Placement of stone seaward of the wall is a more appropriate solution. In order to improve stability and prevent further undermining of the wall, it is recommended that the stone be placed above the original beach level to approximate elevation +16, which is approximately 6.5 feet below the top of wall.

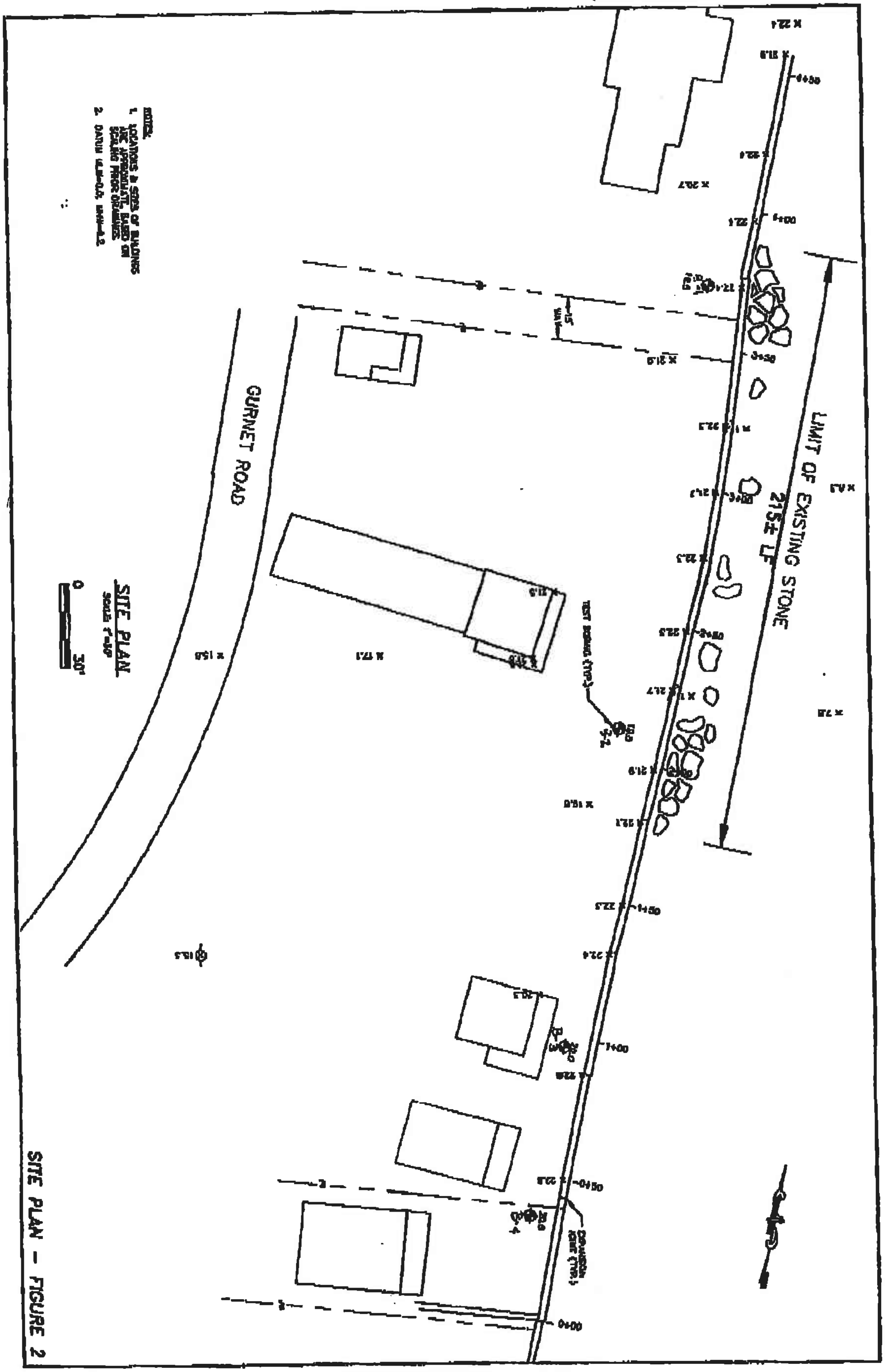
2. Forces on the seawall, due to buildup of hydrologic pressures under extended storm conditions, can be reduced by placement of weepholes and scuppers. It is recommended that weepholes be drilled through the seawall, connecting to a new trench drain (geotextile wrapped crushed stone) in the seawall backfill. This weephole system should help to prevent excess hydrostatic pressure buildup in the backfill and limit lateral loading on the seawall. It is further recommended that scuppers be provided just above the final landside backfill level. It is estimated that the weepholes

and scuppers, along with repair to broken concrete sections will cost approximately $20,000.

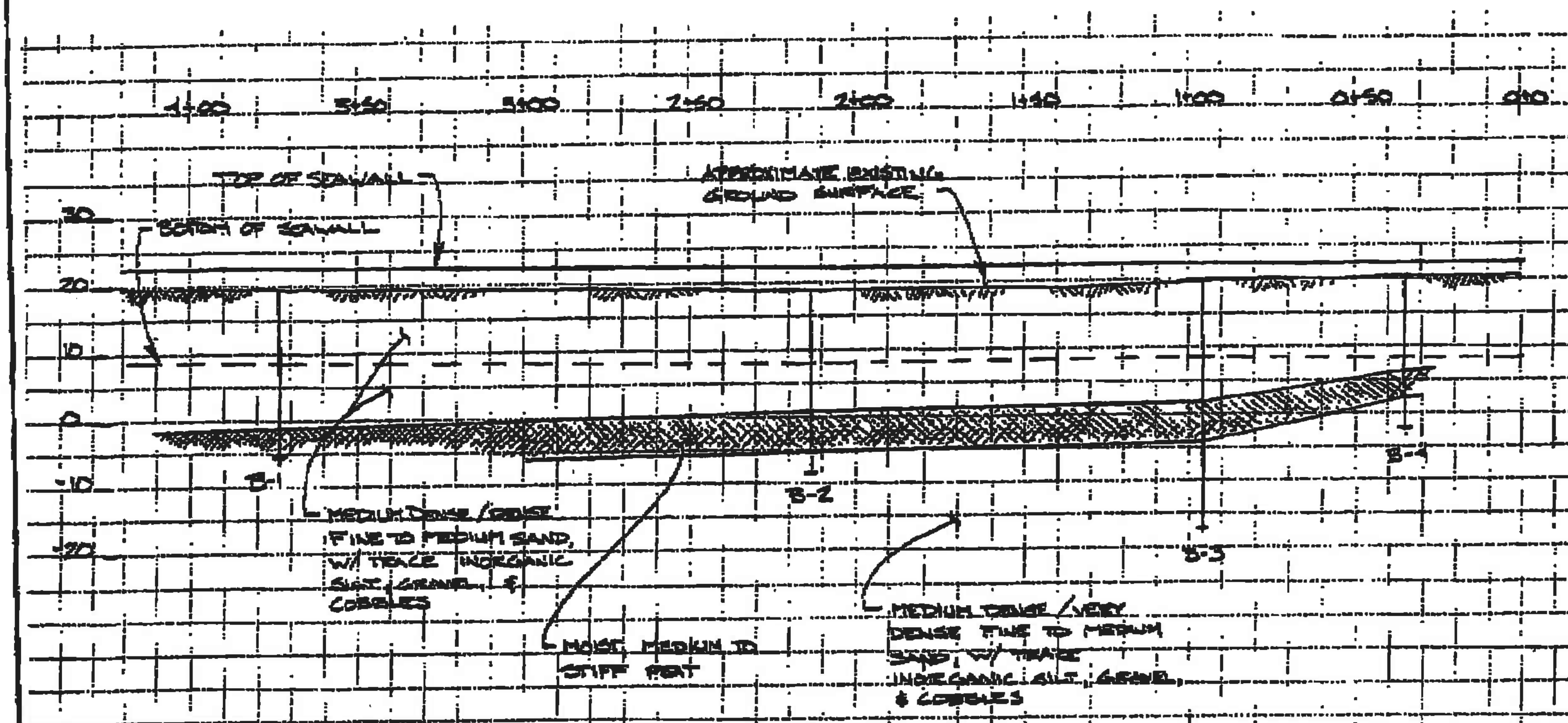
3. The total cost of the recommended revetment alternate, plus the cost of the weepholes and scuppers, and some miscellaneous concrete repairs is $90,000.

4. The placement of stone above the prior beach level (approximate elevation +12) will have impact on wave runup of water under storm conditions. It is recommended that the homeowners be assessed and grant consent for this work. The current MEPA filing and Corps permit are only for restoring the stone in front of the wall to elevation +12, revision of these permits, as well a change in the MEPA filing will be required. As the MEPA filing is currently being reviewed, approval for modifications to the project would be the most expeditious at this time.

5. Should the proposed revetment repair not be permitted due to cost, environmental concerns or concerns from adjacent homeowners, we would recommend that, at a minimum, work proceed on installing weepholes and scuppers, repairing concrete, and rehabilitating the existing stone, similar to attached Figure 6 (as submitted in the ENF filing). The estimated cost of these repairs is $42,000.



SITE PLAN – FIGURE 2

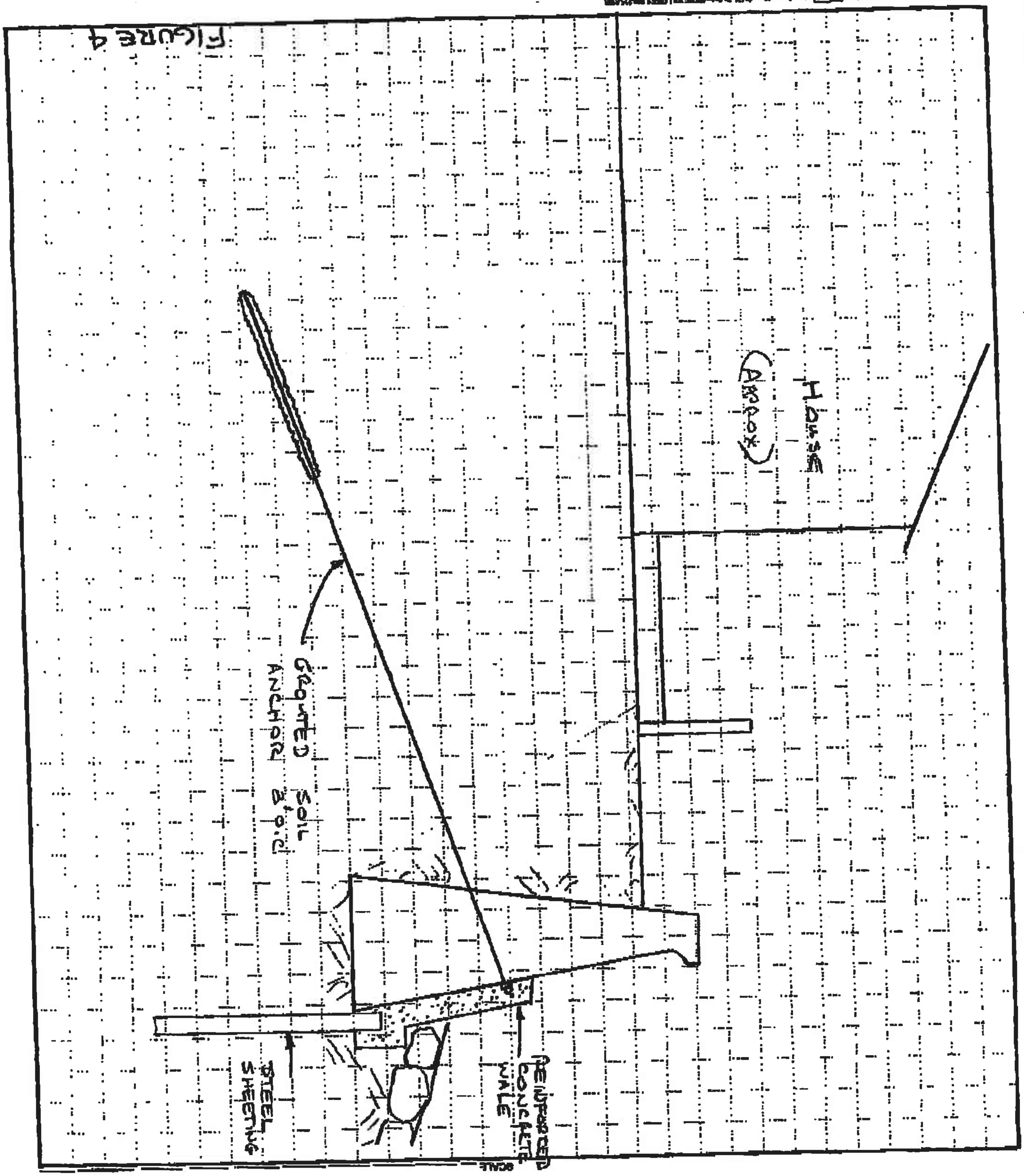


DUXBURY SEAWALL EXISTING SOIL PROFILE

SCALE AS SHOWN

FIGURE 3

FIGURE 4



SCALE

NUCCI VINE ASSOCIATES, INC.
253 Low Street
NEWBURYPORT, MASSACHUSETTS 01950
(508) 465-1428

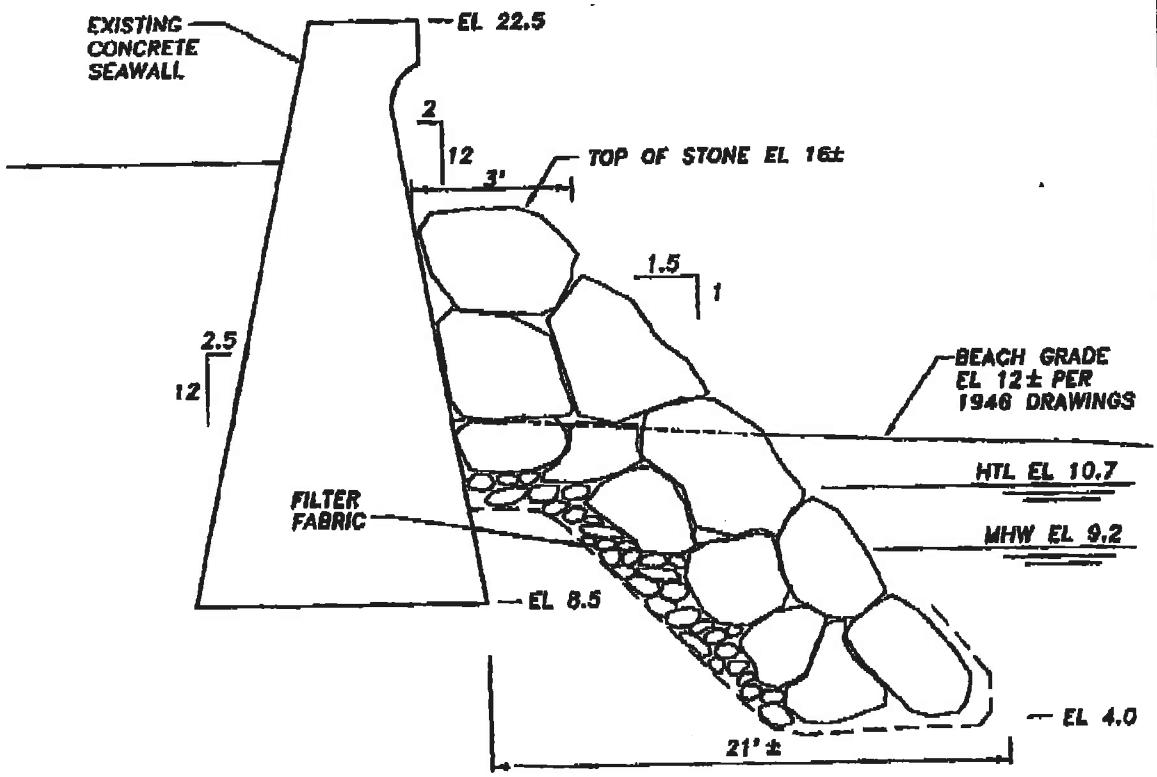
JOB Dunn Seawall

SHEET NO. 4 OF 5

CALCULATED BY DM DATE 2-17-94

CHECKED BY DATE

NOTES:
1. DATUM MLW=0.0; MHW=9.2; HIGH WATER LEVEL (HWL)=10.7
2. STABILIZATION WORK INCLUDES PLACEMENT OF STONE FILL ADJACENT TO CONCRETE SEAWALL, OVER 300 L.F.



TYPICAL REPAIR
REVETMENT ALTERNATE

SCALE: 1" = 4'

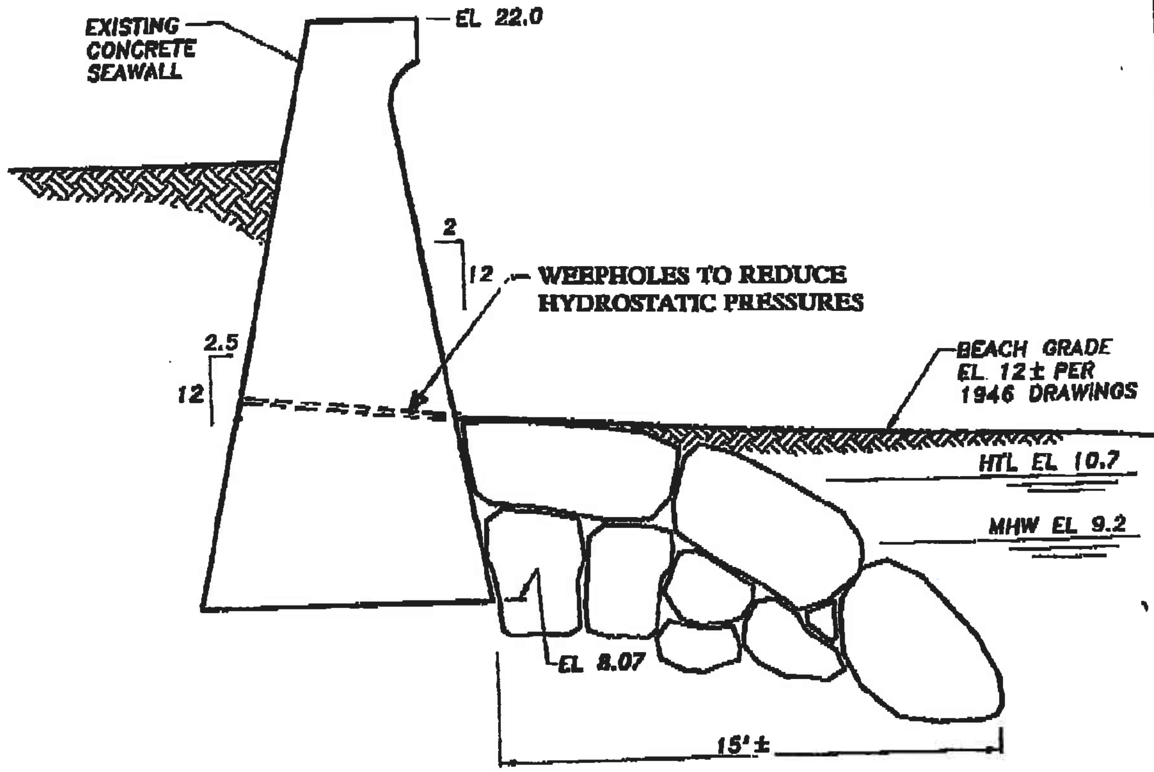
0 2' 4' 8'

REVETMENT ALTERNATE– FIGURE 5

NUCCI VINE ASSOC TEL No.508-465-2640 Mar 11,94 12:43 No.002 P.10

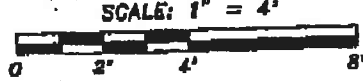
NOTES:

1. DATUM MLW=0.0; MHW=9.2; HIGH WATER LEVEL (HWL)=10.7
2. STABILIZATION WORK INCLUDES PLACEMENT OF STONE FILL ADJACENT TO CONCRETE SEAWALL, OVER 300 L.F.
3. TOTAL VOLUME OF FILL = 580 C.Y. VOLUME BELOW MHW=150 C.Y., VOLUME BELOW HTL= 200 C.Y.
4. TOTAL AREA OF STONE FILL IS APPROX. 4500 S.F.



TYPICAL REPAIR SECTION A–A

SCALE: 1" = 4'



REPAIR SECTION – FIGURE 6

Sheet # ____ of ____

148 Pioneer Dr.
Leominster, MA 01453
(508) 840-0391

SOIL EXPLORATION CORPORATION
Geotechnical Drilling and Groundwater Monitor Wells

5 Monson Place
Milford, NH 03055
(603) 672-2135

Client: Town of Duxbury — Date: 02/24/94 — Job No. 94-0227

Location: Gurnet Road, Duxbury, Massachusetts

BORING NO. B-1 — Ground Elev. — Date Start 02/24/94 — Date Complete 02/24/94 — Drilling Foreman M.C. — Eng./Hydrol. Geologist

DEPTH	Sample No.	Sample Depth (ft.)	Blows 6" Penetration	Rec. Inches	Casing Blows Per ft.	Strata Change Depth	Visual Identification of Soil and/or Rock Strata
	1	0'0"- 2'0"	sample taken from flight				Dry to wet, medium dense, FINE TO MEDIUM SAND, some inorganic silt, trace coarse sand, trace fine to medium gravel, cobbles.
5	2	5'0"- 7'0"	7-15-13-13				
10	3	10'0"-12'0"	7-8-10-10				
15	4	15'0"-17'0"	5-5-7-8				
20	5	20'0"-21'0"	7-10			21'0"	
	5A	21'0"-22'0"	4-4			22'0"	Moist, medium, PEAT.
25							End of boring at 22'0" Water level at 10'0" upon completion. Water level taken at 9:30 a.m.
30							
35							
40							

Type of Boring — Casing Size: — Hollow Stem Auger Size:

Proportion Percentages
Trace 0 to 10%
Some 10 to 40%
And 40 to 50%

Granular Soils (blows per ft.)
0 to 4 Very Loose
4 to 10 Loose
10 to 30 Medium Dense
30 to 50 Dense
Over 50 Very Dense

Cohesive Soils (blows per ft.)
0 to 2 Very Soft
2 to 4 Soft
4 to 8 Medium Stiff
8 to 15 Stiff
15 to 30 Very Stiff
Over 30 Hard

Standard penetration test (SPT) = 140# hammer falling 30"
Blows are per 6" taken with an 18" long x 2" O.D. x 1 3/8" I.D. split spoon sampler unless otherwise noted.

The terms and percentages used to describe soil and or rock are based on visual identification of the retrieved samples. ■ Moisture content indicated may be affected by time of year and water added during the drilling process. ■ Water levels indicated may vary with seasonal fluctuation and the degree of soil saturation when the boring was taken. ■ The stratification lines represent the approximate boundaries between soil types, the actual transitions may be gradual. ■

Sheet # ____ of ____

148 Pioneer Dr.
Leominster, MA 01453
(508) 840-0391

SOIL EXPLORATION CORPORATION

Geotechnical Drilling and Groundwater Monitor Wells

5 Monson Place
Milford, NH 03055
(603) 672-2135

Client: Town of Duxbury | Date: 02/24/94 | Job No. 94-0227

Location: Gurnet Road, Duxbury, Massachusetts

BORING NO.: B-2 | Ground Elev.: | Date Start: 02/24/94 | Date Complete: 02/24/94 | Drilling Foreman: M.C. | Eng./Hydrol. Geologist:

DEPTH	Sample No.	Sample Depth (ft.)	Blows 6" Penetration	Rec. Inches	Casing Blows Per ft.	Strata Change Depth	Visual Identification of Soil and/or Rock Strata
	1	0'0"- 2'0"	27-17-17-15				Dry to wet, FINE TO COARSE SAND, trace inorganic silt, trace fine to medium gravel, cobbles.
5	2	5'0"- 7'0"	2-7-8-8				
10	3	10'0"-12'0"	10-11-12-15				
15	4	15'0"-17'0"	10-10-14-17				
						18'0"	Wet, stiff, PEAT.
20	5	20'0"-22'0"	4-5-7-7				
						24'0"	Wet, medium dense, FINE TO MEDIUM SAND, some inorganic silt, trace cobbles.
25	6	25'0"-27'0"	9-10-10-10				
						27'0"	End of boring at 27'0" Water level at 13'0" upon completion. Water level taken at 3:30 p.m.
30							
35							
40							

Type of Boring | Casing Size: | Hollow Stem Auger Size:

Proportion Percentages	Granular Soils (blows per ft.)	Cohesive Soils (blows per ft.)
Trace 0 to 10% Some 10 to 40% And 40 to 50%	0 to 4 Very Loose 4 to 10 Loose 10 to 30 Medium Dense 30 to 50 Dense Over 50 Very Dense	0 to 2 Very Soft 2 to 4 Soft 4 to 8 Medium Stiff 8 to 15 Stiff 15 to 30 Very Stiff Over 30 Hard

Standard penetration test (SPT) = 140# hammer falling 30"
Blows are per 6" taken with an 18" long x 2" O.D. x 1 3/8" I.D. split spoon sampler unless otherwise noted.

The terms and percentages used to describe soil and or rock are based on visual identification of the retrieved samples. ■ Moisture content indicated may be affected by time of year and water added during the drilling process. ■ Water levels indicated may vary with seasonal fluctuation and the degree of soil saturation when the boring was taken. ■ The stratification lines represent the approximate boundaries between soil types, the actual transitions may be gradual. ■

Sheet # ____ of ____

148 Pioneer Dr.
Leominster, MA 01453
(508) 840-0391

SOIL EXPLORATION CORPORATION

Geotechnical Drilling and Groundwater Monitor Wells

5 Monson Place
Milford, NH 03055
(603) 672-2135

Client: Town of Duxbury | Date: 02/24/94 | Job No. 94-0227

Location: Gurnet Road, Duxbury, Massachusetts

BORING NO. B-3 | Ground Elev. | Date Start 02/24/94 | Date Complete 02/24/94 | Drilling Foreman M.C. | Eng./Hydrol. Geologist

DEPTH	Sample No.	Sample Depth (ft.)	Blows 6" Penetration	Rec. Inches	Casing Blows Per ft.	Strata Change Depth	Visual Identification of Soil and/or Rock Strata
	1	0'0"- 2'0"	2-1-1-2				Dry to wet, very loose to medium dense, FINE TO MEDIUM SAND, trace to some inorganic silt, trace cobbles.
5	2	5'0"- 7'0"	4-6-6-6				
10	3	10'0"-12'0"	6-7-10-10				
15	4	15'0"-17'0"	7-10-9-12				
						18'0"	Moist, medium, PEAT.
20	5	20'0"-22'0"	3-4-4-4				
						24'0"	Wet, dense to very dense, FINE TO COARSE SAND, some fine to coarse gravel, some inorganic silt, cobbles and boulders.
25	6	25'0"-27'0"	10-17-17-24				
30	7	30'0"-32'0"	17-30-35-37				
35	8	35'0"-37'0"	25-30-29-39				
						37'0"	End of boring at 37'0" Water level at 13'0" Water level taken at 12:45 p.m.
40							

Type of Boring | Casing Size: | Hollow Stem Auger Size:

Proportion Percentages	Granular Soils (blows per ft.)	Cohesive Soils (blows per ft.)
Trace 0 to 10% Some 10 to 40% And 40 to 50%	0 to 4 Very Loose 4 to 10 Loose 10 to 30 Medium Dense 30 to 50 Dense Over 50 Very Dense	0 to 2 Very Soft 2 to 4 Soft 4 to 8 Medium Stiff 8 to 15 Stiff 15 to 30 Very Stiff Over 30 Hard

Standard penetration test (SPT) = 140# hammer falling 30"
Blows are per 6" taken with an 18" long x 2" O.D. x 1 3/8" I.D. split spoon sampler unless otherwise noted.

The terms and percentages used to describe soil and or rock are based on visual identification of the retrieved samples. ■ Moisture content indicated may be affected by time of year and water added during the drilling process. ■ Water levels indicated may vary with seasonal fluctuation and the degree of soil saturation when the boring was taken. ■ The stratification lines represent the approximate boundaries between soil types, the actual transitions may be gradual. ■

148 Pioneer Dr.
Leominster, MA 01453
(508) 840-0391

SOIL EXPLORATION CORPORATION
Geotechnical Drilling and Groundwater Monitor Wells

5 Monson Place
Milford, NH 03055
(603) 672-2135

Client: Town of Duxbury | Date: 02/24/94 | Job No.: 94-0227

Location: Gurnet Road, Duxbury, Massachusetts

BORING NO.: B-5 | Ground Elev.: | Date Start: 02/24/94 | Date Complete: 02/24/94 | Drilling Foreman: M.C. | Eng./Hydrol. Geologist:

DEPTH	Sample No.	Sample Depth (ft.)	Blows 6" Penetration	Rec. Inches	Casing Blows Per ft.	Strata Change Depth	Visual Identification of Soil and/or Rock Strata
	1	0'0"- 2'0"	4-5-5-5				TOPSOIL
						0'3"	Dry to wet, medium dense, FINE TO MEDIUM SAND, trace inorganic silt, trace sand, cobbles.
5	2	5'0"- 7'0"	6-6-7-7				
10	3	10'0"-12'0"	7-8-10-10				
						14'0"	Moist, stiff, PEAT.
15	4	15'0"-17'0"	4-5-6-6				
						18'6"	Wet, medium dense, FINE TO COARSE SAND, some inorganic silt, trace clay, trace fine to medium gravel, cobbles.
20	5	20'0"-21'0"	10-10				
	5A	21'0"-22'0"	10-15			21'0"	*
						22'0"	End of boring at 22'0" Water level at 13'0" upon completion. Water level taken at 2:15 p.m.
25							
30							* Wet, medium dense, FINE TO COARSE SAND, trace inorganic silt, cobbles.
35							
40							

Type of Boring | Casing Size: | Hollow Stem Auger Size:

Proportion Percentages
Trace 0 to 10%
Some 10 to 40%
And 40 to 50%

Granular Soils (blows per ft.)
0 to 4 Very Loose
4 to 10 Loose
10 to 30 Medium Dense
30 to 50 Dense
Over 50 Very Dense

Cohesive Soils (blows per ft.)
0 to 2 Very Soft
2 to 4 Soft
4 to 8 Medium Stiff
8 to 15 Stiff
15 to 30 Very Stiff
Over 30 Hard

Standard penetration test (SPT) = 140# hammer falling 30"
Blows are per 6" taken with an 18" long x 2" O.D. x 1 3/8" I.D. split spoon sampler unless otherwise noted.

The terms and percentages used to describe soil and or rock are based on visual identification of the retrieved samples. ■ Moisture content indicated may be affected by time of year and water added during the drilling process. ■ Water levels indicated may vary with seasonal fluctuation and the degree of soil saturation when the boring was taken. ■ The stratification lines represent the approximate boundaries between soil types, the actual transitions may be gradual. ■

APPENDIX F – Natural Resource Data

Zoom to a scale Identify duxbury Clear location Export data Help

Measure 0 m

Permalink Scale settings Map units Basemaps

Available data layers

Select / search data layers

- State Facilities
- MassGIS Basemap
- Census 1990
- Census 2000
- Coastal and Marine Features
  - Bathymetry
  - Barrier Beaches
    - Barrier Beaches
  - Coastal Barrier Resource Units
  - Coastal Zone

Active data layers

Check all Uncheck all Remove all

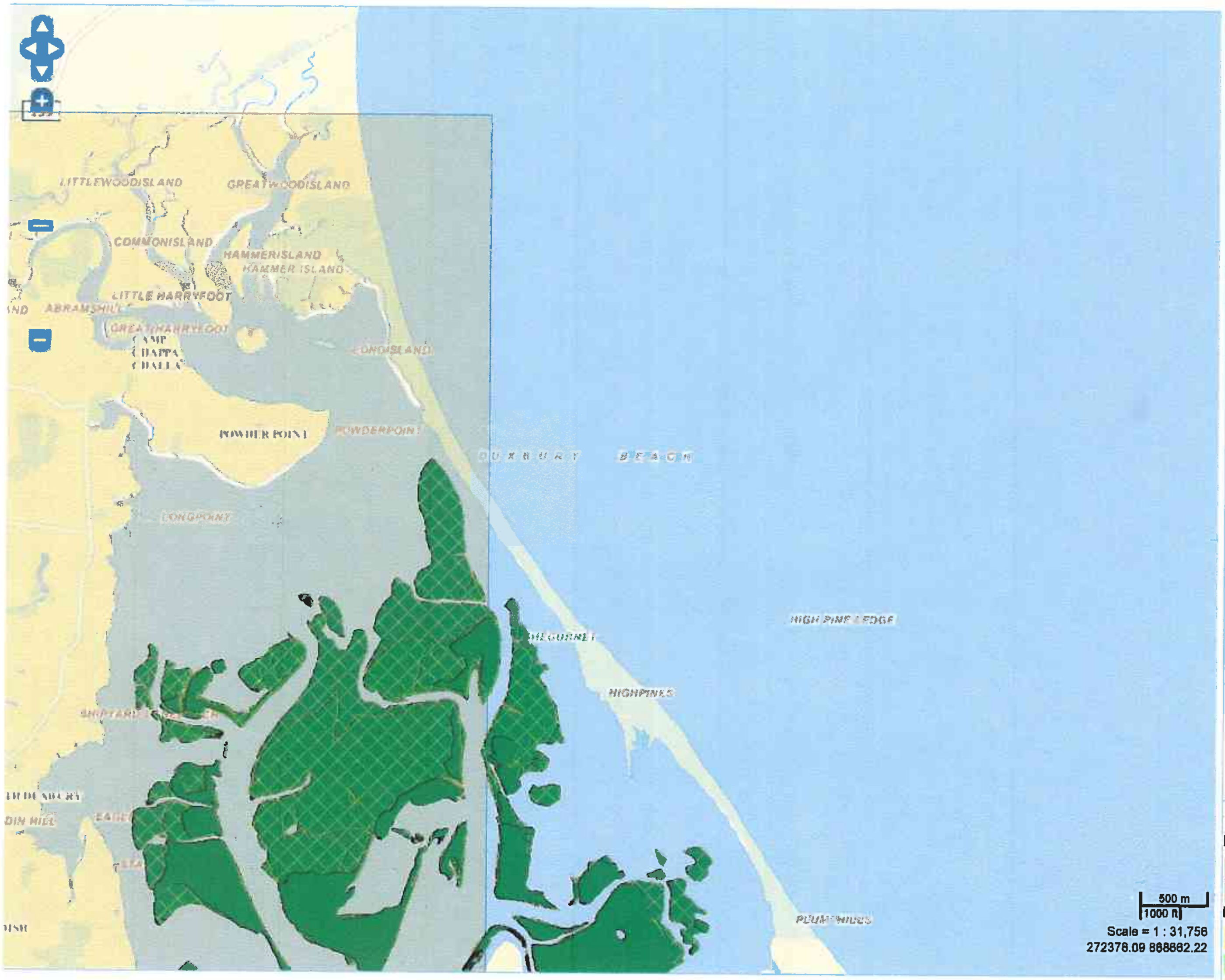
- [x] Barrier Beaches
- [ ] DEP Eelgrass for Selected Embayments
- [ ] DEP Seagrass Year Mapped
- [ ] DEP Seagrass 2001 Mapping
- [ ] DEP Seagrass 1995 Mapping
- [ ] NHESP Priority Habitats of Rare Species
- [ ] NHESP Estimated Habitats of Rare Wildlife
- [ ] Areas of Critical Environmental Concern ACECs
- [x] MassGIS Basemap

Active data legends

Barrier Beaches

MassGIS Basemap

Zoom to a scale | Identify | duxbury | Clear location | Export data | Help



Measure 0 m

Permalink | Scale settings | Map units | Basemaps

Available data layers

Select / search data layers

- State Facilities
- MassGIS Basemap
- Census 1990
- Census 2000
- Coastal and Marine Features
- Conservation / Recreation
  - Areas of Critical Environmental Concern ACECs
    - Areas of Critical Environmental Concern ACI
    - Areas of Critical Environmental Concern ACI
  - Community Preservation Act

Active data layers

Check all Uncheck all Remove all

- [x] DEP Eelgrass for Selected Embayments
- [x] DEP Seagrass Year Mapped
- [x] DEP Seagrass 2001 Mapping
- [x] DEP Seagrass 1995 Mapping
- [ ] NHESP Priority Habitats of Rare Species
- [ ] NHESP Estimated Habitats of Rare Wildlife
- [ ] Areas of Critical Environmental Concern ACECs
- [x] MassGIS Basemap

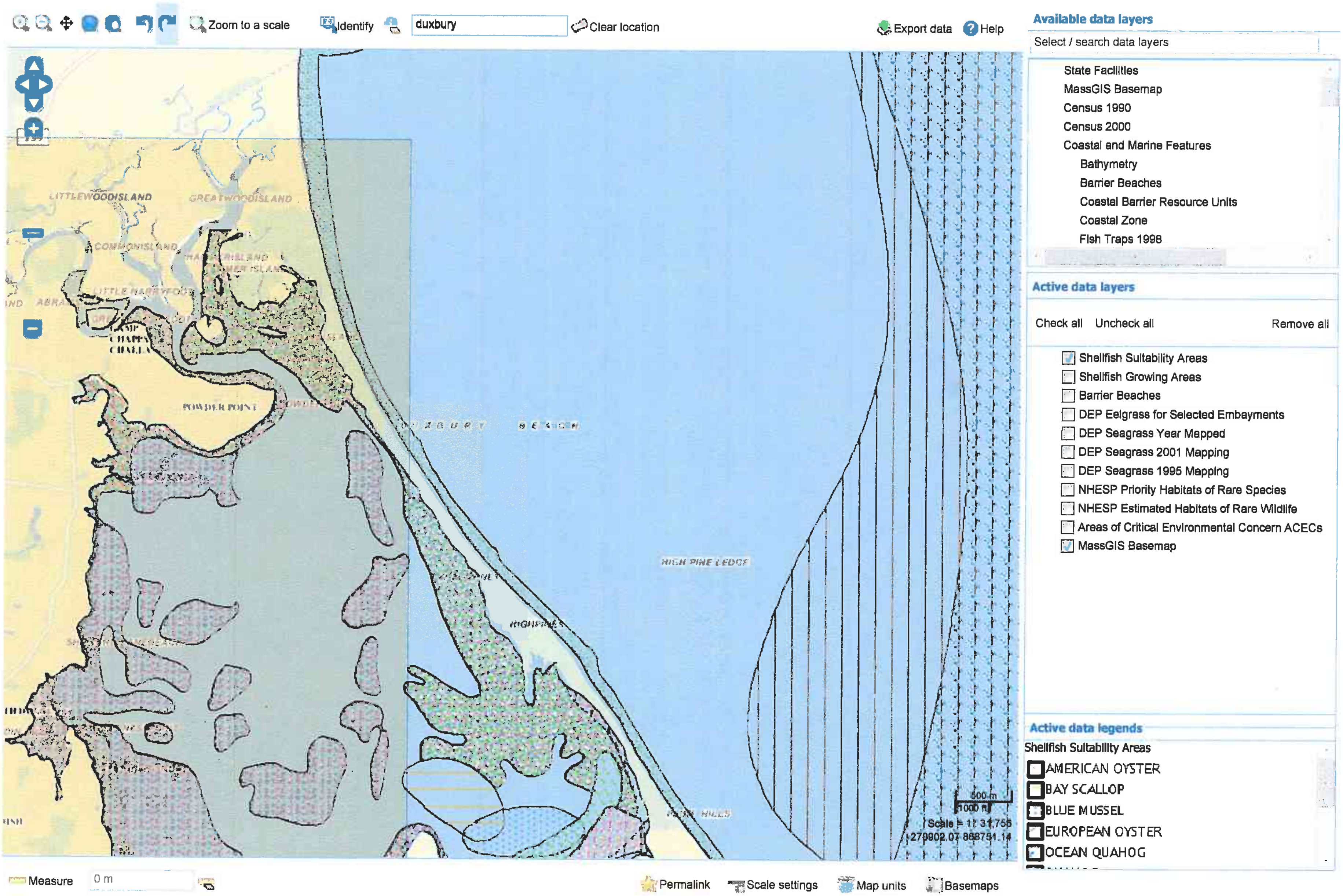
Active data legends

DEP Eelgrass for Selected Embayments

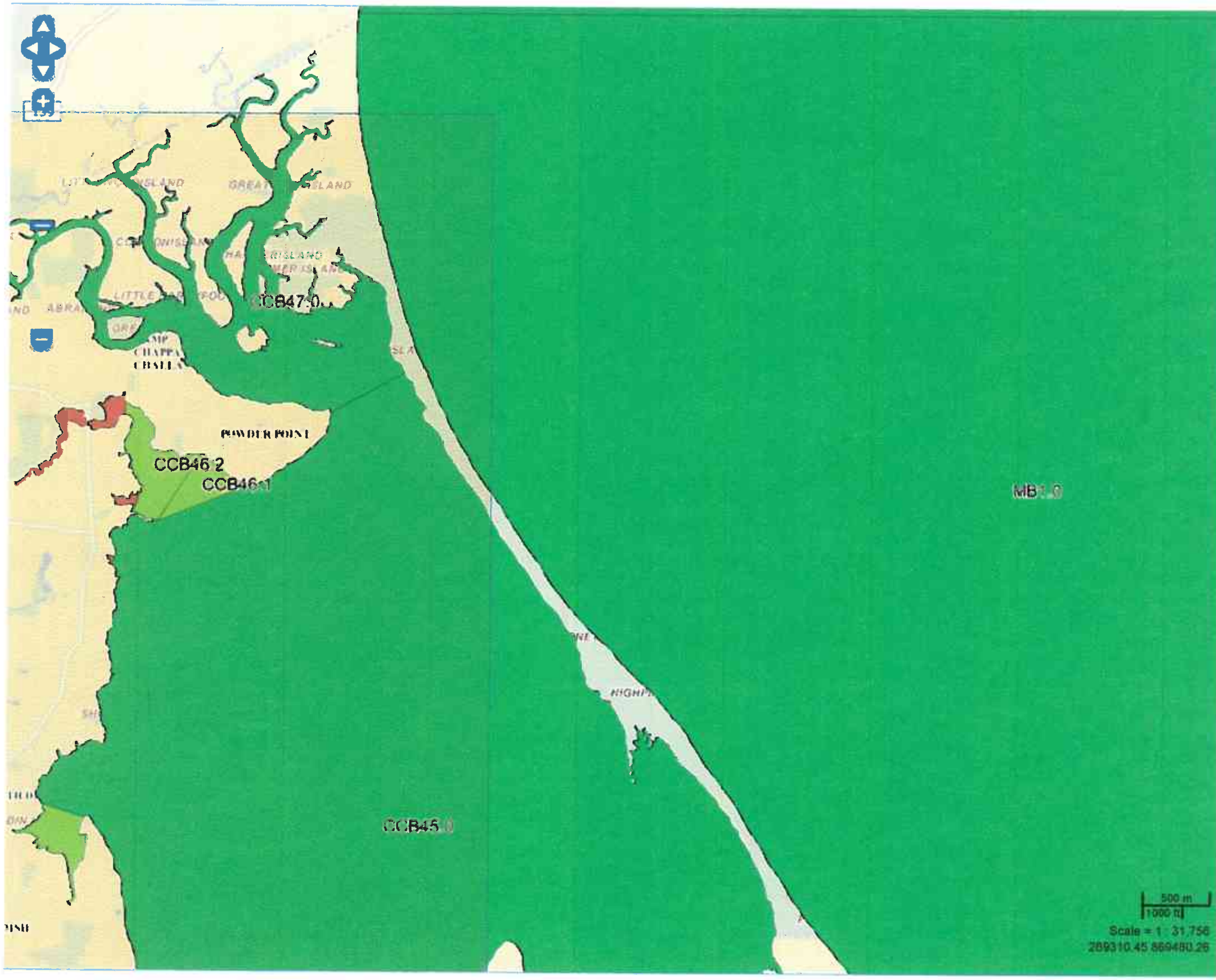
- Eelgrass
- Ruppia

DEP Seagrass Year Mapped

- 2001 Only
- 1995 and 2001


Zoom to a scale
Identify
duxbury
Clear location
Export data
Help
LITTLEWOODISLAND
GREATWOODISLAND
COMMONISLAND
POWDER POINT
HIGH PINE LEDGE
BEACH
Scale = 1: 31,756
279902.07 868791.14
500 m
1000 ft
Measure
0 m
Permalink
Scale settings
Map units
Basemaps
Available data layers
Select / search data layers
State Facilities
MassGIS Basemap
Census 1990
Census 2000
Coastal and Marine Features
Bathymetry
Barrier Beaches
Coastal Barrier Resource Units
Coastal Zone
Fish Traps 1998
Active data layers
Check all
Uncheck all
Remove all
Shellfish Suitability Areas
Shellfish Growing Areas
Barrier Beaches
DEP Eelgrass for Selected Embayments
DEP Seagrass Year Mapped
DEP Seagrass 2001 Mapping
DEP Seagrass 1995 Mapping
NHESP Priority Habitats of Rare Species
NHESP Estimated Habitats of Rare Wildlife
Areas of Critical Environmental Concern ACECs
MassGIS Basemap
Active data legends
Shellfish Suitability Areas
AMERICAN OYSTER
BAY SCALLOP
BLUE MUSSEL
EUROPEAN OYSTER
OCEAN QUAHOG

Zoom to a scale | Identify | duxbury | Clear location | Export data | Help



Measure | 0 m | Permalink | Scale settings | Map units | Basemaps

Available data layers

Select / search data layers

- State Facilities
- MassGIS Basemap
- Census 1990
- Census 2000
- Coastal and Marine Features
  - Bathymetry
  - Barrier Beaches
  - Coastal Barrier Resource Units
  - Coastal Zone
  - Fish Traps 1998

Active data layers

Check all | Uncheck all | Remove all

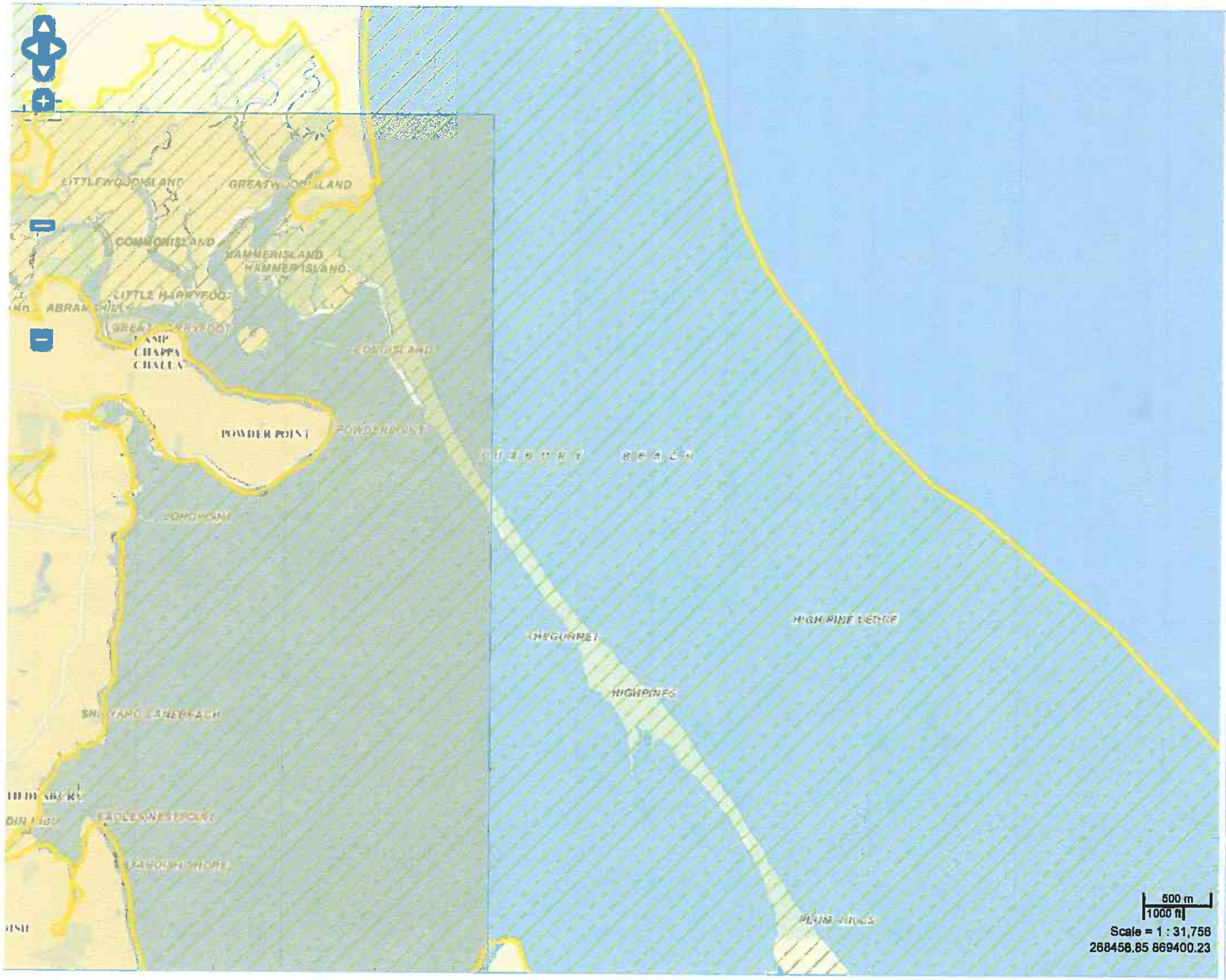
- [x] Shellfish Growing Areas
- [ ] Barrier Beaches
- [ ] DEP Eelgrass for Selected Embayments
- [ ] DEP Seagrass Year Mapped
- [ ] DEP Seagrass 2001 Mapping
- [ ] DEP Seagrass 1995 Mapping
- [ ] NHESP Priority Habitats of Rare Species
- [ ] NHESP Estimated Habitats of Rare Wildlife
- [ ] Areas of Critical Environmental Concern ACECs
- [x] MassGIS Basemap

Active data legends

Shellfish Growing Areas

- APPROVED
- CONDITIONALLY APPROVED
- CONDITIONALLY RESTRICTED
- MANAGEMENT CLOSURE

Zoom to a scale | Identify | duxbury | Clear location | Export data | Help



Measure | 0 m

Permalink | Scale settings | Map units | Basemaps

Available data layers

Select / search data layers

- **State Facilities**
- **MassGIS Basemap**
- **Census 1990**
- **Census 2000**
- **Coastal and Marine Features**
- Conservation / Recreation
  - Areas of Critical Environmental Concern ACEC:
    - Areas of Critical Environmental Concern ACI
    - Areas of Critical Environmental Concern ACI
  - Community Preservation Act

Active data layers

Check all | Uncheck all | Remove all

- [x] NHESP Priority Habitats of Rare Species
- [x] NHESP Estimated Habitats of Rare Wildlife
- [ ] Areas of Critical Environmental Concern ACECs
- [x] MassGIS Basemap

Active data legends

NHESP Priority Habitats of Rare Species

NHESP Estimated Habitats of Rare Wildlife

MassGIS Basemap

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

MassWildlife

Wayne F. MacCallum, *Director*

February 21, 2011

Alyssa Richard
Bourne Consulting Engineering
3 Bent Street
Franklin MA 02038

RE: Project Location: Duxbury Beach
Town: DUXBURY
NHESP Tracking No.: 11-29238

To Whom It May Concern:

Thank you for contacting the Natural Heritage and Endangered Species Program ("NHESP") of the MA Division of Fisheries & Wildlife for information regarding state-listed rare species in the vicinity of the above referenced site. Based on the information provided, this project site, or a portion thereof, is located within *Priority Habitat 1172* (PH 1172) and *Estimated Habitat 972* (EH 972) as indicated in the *Massachusetts Natural Heritage Atlas* (13th Edition). Our database indicates that the following state-listed rare species have been found in the vicinity of the site:

Scientific name	Common Name	Taxonomic Group	State Status
Charadrius melodus	Piping Plover	Bird	Threatened
Sterna dougallii	Roseate Tern	Bird	Endangered
Sterna hirundo	Common Tern	Bird	Special Concern
Sterna paradisaea	Arctic Tern	Bird	Special Concern
Sternula antillarum	Least Tern	Bird	Special Concern

The species listed above are protected under the Massachusetts Endangered Species Act (MESA) (M.G.L. c. 131A) and its implementing regulations (321 CMR 10.00). State-listed wildlife are also protected under the state's Wetlands Protection Act (WPA) (M.G.L. c. 131, s. 40) and its implementing regulations (310 CMR 10.00). Fact sheets for most state-listed rare species can be found on our website (www.nhesp.org).

Please note that projects and activities located within Priority and/or Estimated Habitat **must** be reviewed by the NHESP for compliance with the state-listed rare species protection provisions of MESA (321 CMR 10.00) and/or the WPA (310 CMR 10.00).

Wetlands Protection Act (WPA)

If the project site is within Estimated Habitat and a Notice of Intent (NOI) is required, then a copy of the NOI must be submitted to the NHESP so that it is received at the same time as the local conservation commission. If the NHESP determines that the proposed project will adversely affect the actual Resource Area habitat of state-protected wildlife, then the proposed project may not be permitted (310 CMR 10.37, 10.58(4)(b) & 10.59). In such a case, the project proponent may request a consultation with the NHESP to discuss potential project design modifications that would avoid adverse effects to rare wildlife habitat.

A streamlined joint MESA/WPA review process is available. When filing a Notice of Intent (NOI), the applicant may file concurrently under the MESA on the same NOI form and qualify for a 30-day streamlined joint review. For a copy of the NOI form, please visit the MA Department of Environmental Protection's website: http://www.mass.gov/dep/water/approvals/wpaform3.doc.

MA Endangered Species Act (MESA)

If the proposed project is located within Priority Habitat and is not exempt from review (see 321 CMR 10.14), then project plans, a fee, and other required materials must be sent to NHESP Regulatory Review to determine whether a probable "take" under the MA Endangered Species Act would occur (321 CMR 10.18). Please note that all proposed and anticipated development must be disclosed, as MESA does not allow project segmentation (321 CMR 10.16). For a MESA filing checklist and additional information please see our website: www.nhesp.org ("Regulatory Review" tab).

We recommend that rare species habitat concerns be addressed during the project design phase prior to submission of a formal MESA filing, as avoidance and minimization of impacts to rare species and their habitats is likely to expedite endangered species regulatory review.

This evaluation is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. If you have any questions regarding this letter please contact Amy Coman, Endangered Species Review Assistant, at (508) 389-6364.

Sincerely,

Thomas W. French

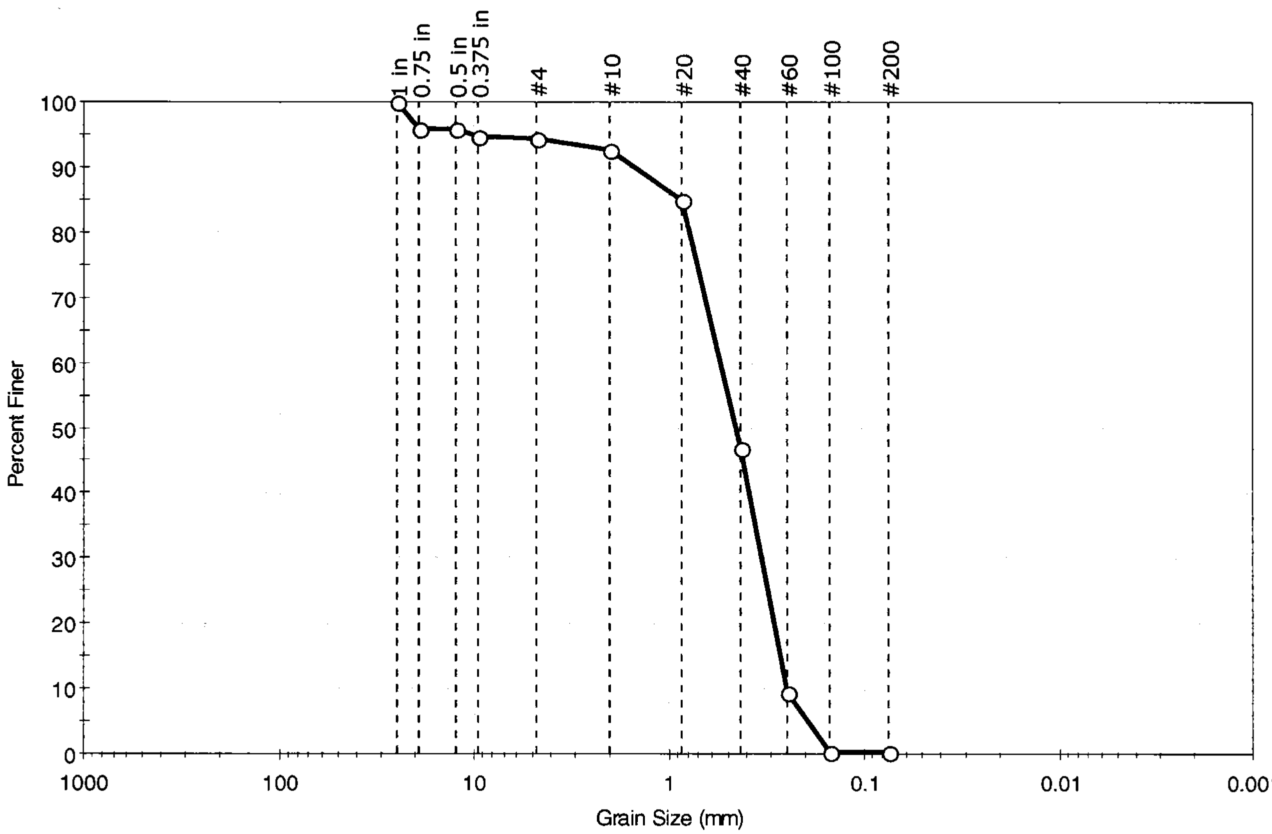
Thomas W. French, Ph.D.
Assistant Director

APPENDIX G – Beach Sample Gradation

GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.1	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205986		
Test Comment: ---			
Sample Description: Moist, light brown sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	5.8	94.0	0.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	96		
0.5 in	12.50	96		
0.375 in	9.50	95		
#4	4.75	94		
#10	2.00	93		
#20	0.85	85		
#40	0.42	47		
#60	0.25	10		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} =0.8578 mm D_{30} =0.3343 mm
D_{60} =0.5395 mm D_{15} =0.2702 mm
D_{50} =0.4495 mm D_{10} =0.2517 mm
C_u =2.143 C_c =0.823

Classification

ASTM   Poorly graded sand (SP)

AASHTO   Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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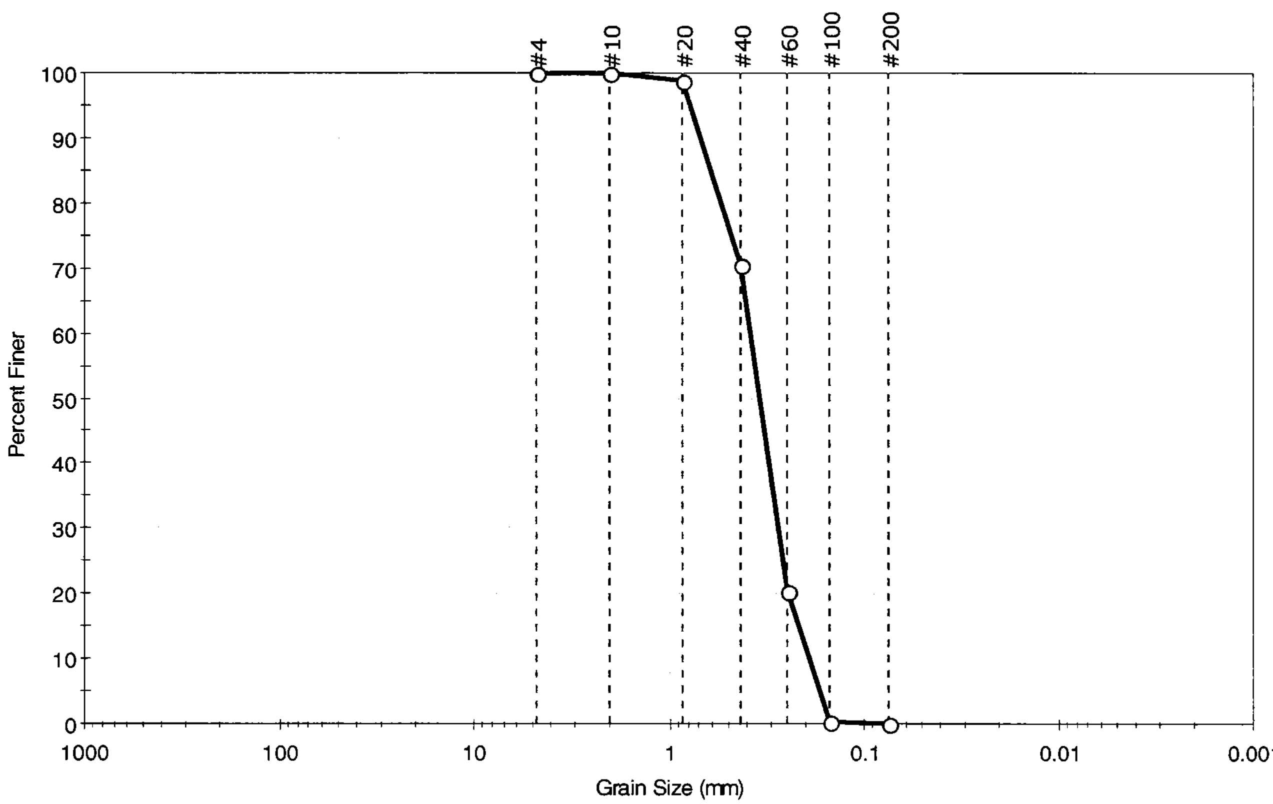
GeoTesting EXPRESS

Client:	Bourne Consulting Engineering		
Project:	Town of Duxbury Seawall Rehabilitation		
Location:	---	Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.3	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205987		
Test Comment:	---		
Sample Description:	Moist, light yellowish brown sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	99.9	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	71		
#60	0.25	20		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} =0.6060 mm	D_{30} =0.2766 mm
D_{60} =0.3798 mm	D_{15} =0.2178 mm
D_{50} =0.3417 mm	D_{10} =0.1918 mm
C_u =1.980	C_c =1.050

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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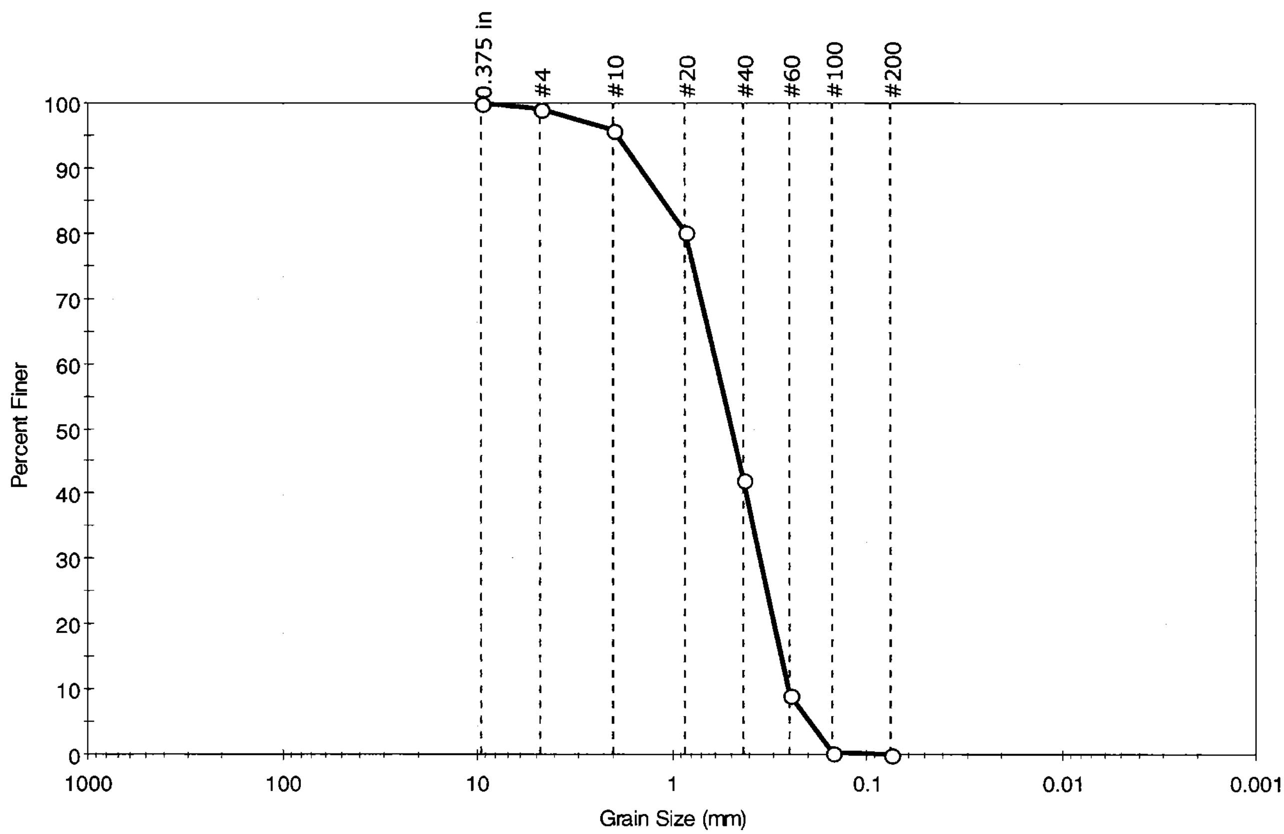
GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.4	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205988		

Test Comment: ---
Sample Description: Moist, Light brown sand
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.1	98.8	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	96		
#20	0.85	80		
#40	0.42	42		
#60	0.25	9		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} =1.0976 mm	D_{30} =0.3495 mm
D_{60} =0.5878 mm	D_{15} =0.2744 mm
D_{50} =0.4902 mm	D_{10} =0.2531 mm
C_u =2.322	C_c =0.821

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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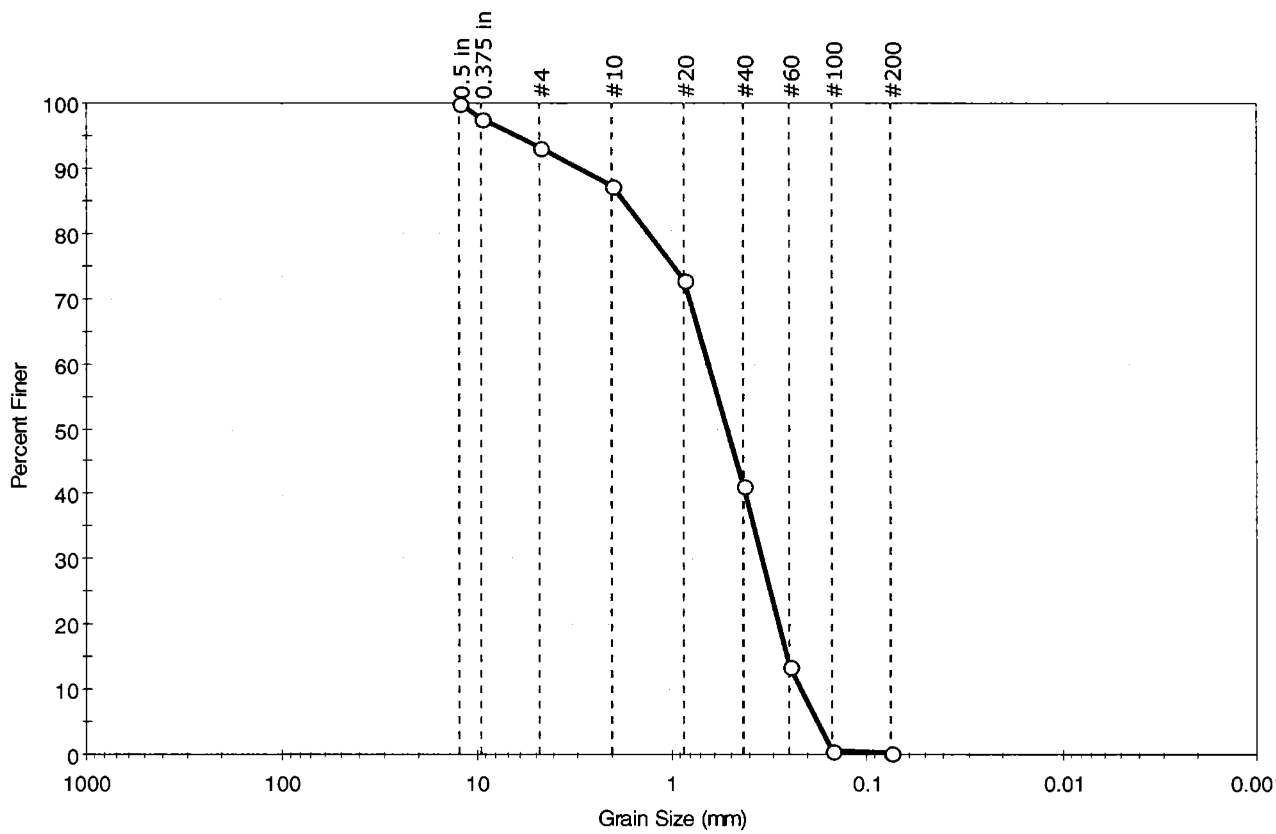
GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.6	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205989		
Test Comment: ---			
Sample Description: Moist, light yellowish brown sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	6.8	92.8	0.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	98		
#4	4.75	93		
#10	2.00	87		
#20	0.85	73		
#40	0.42	41		
#60	0.25	14		
#100	0.15	1		
#200	0.075	0		

Coefficients

D_{85} =1.7412 mm	D_{30} =0.3425 mm
D_{60} =0.6428 mm	D_{15} =0.2563 mm
D_{50} =0.5160 mm	D_{10} =0.2160 mm
C_u =2.976	C_c =0.845

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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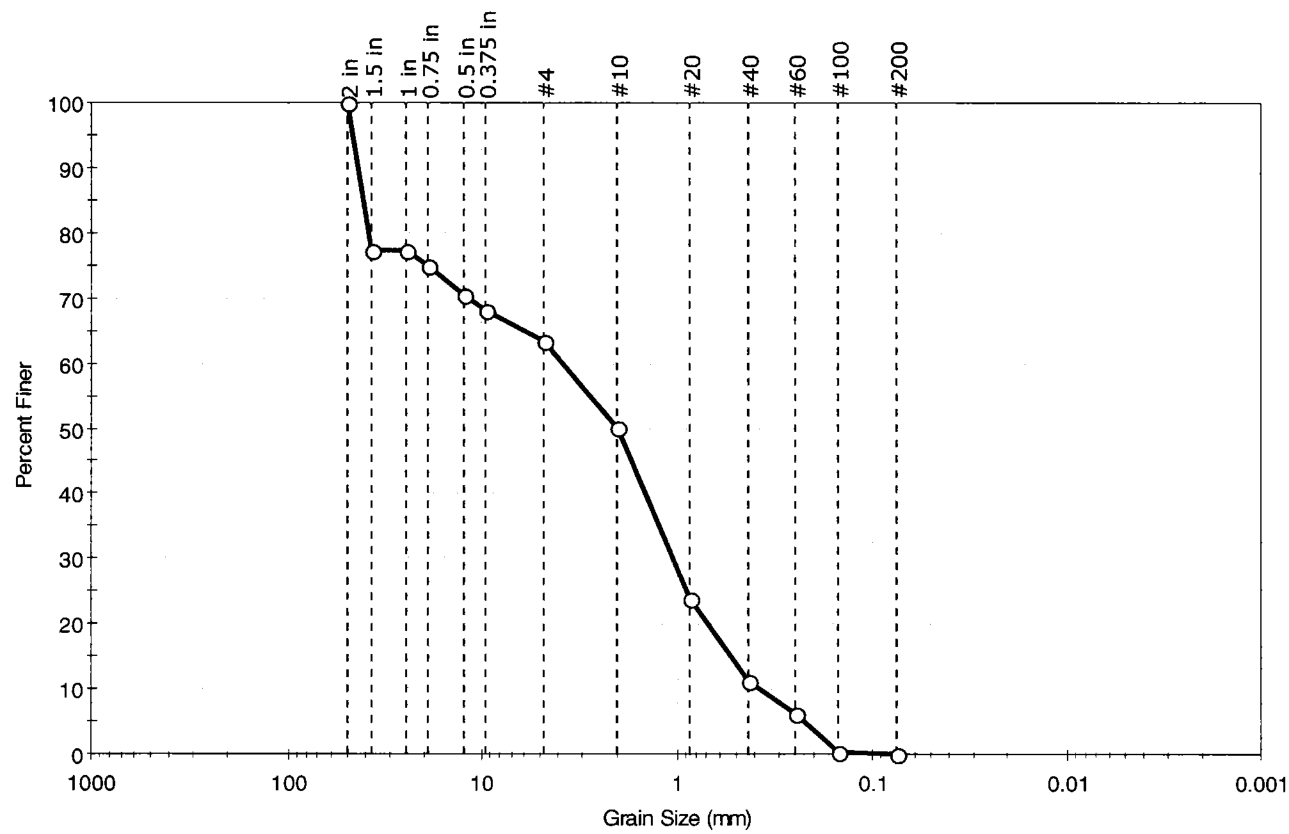
GeoTesting EXPRESS

Client:	Bourne Consulting Engineering				
Project:	Town of Duxbury Seawall Rehabilitation				
Location:	---			Project No:	GTX-10669
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	30815.7	Test Date:	04/01/11	Checked By:	jdt
Depth :	---	Test Id:	205990		
Test Comment:	---				
Sample Description:	Moist, light yellowish brown sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	36.4	63.5	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	77		
1 in	25.00	77		
0.75 in	19.00	75		
0.5 in	12.50	71		
0.375 in	9.50	68		
#4	4.75	64		
#10	2.00	50		
#20	0.85	24		
#40	0.42	11		
#60	0.25	6		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} =41.3180 mm	D_{30} =1.0406 mm
D_{60} =3.7787 mm	D_{15} =0.5242 mm
D_{50} =1.9933 mm	D_{10} =0.3743 mm
C_u =10.095	C_c =0.766

Classification

ASTM Poorly graded sand with gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

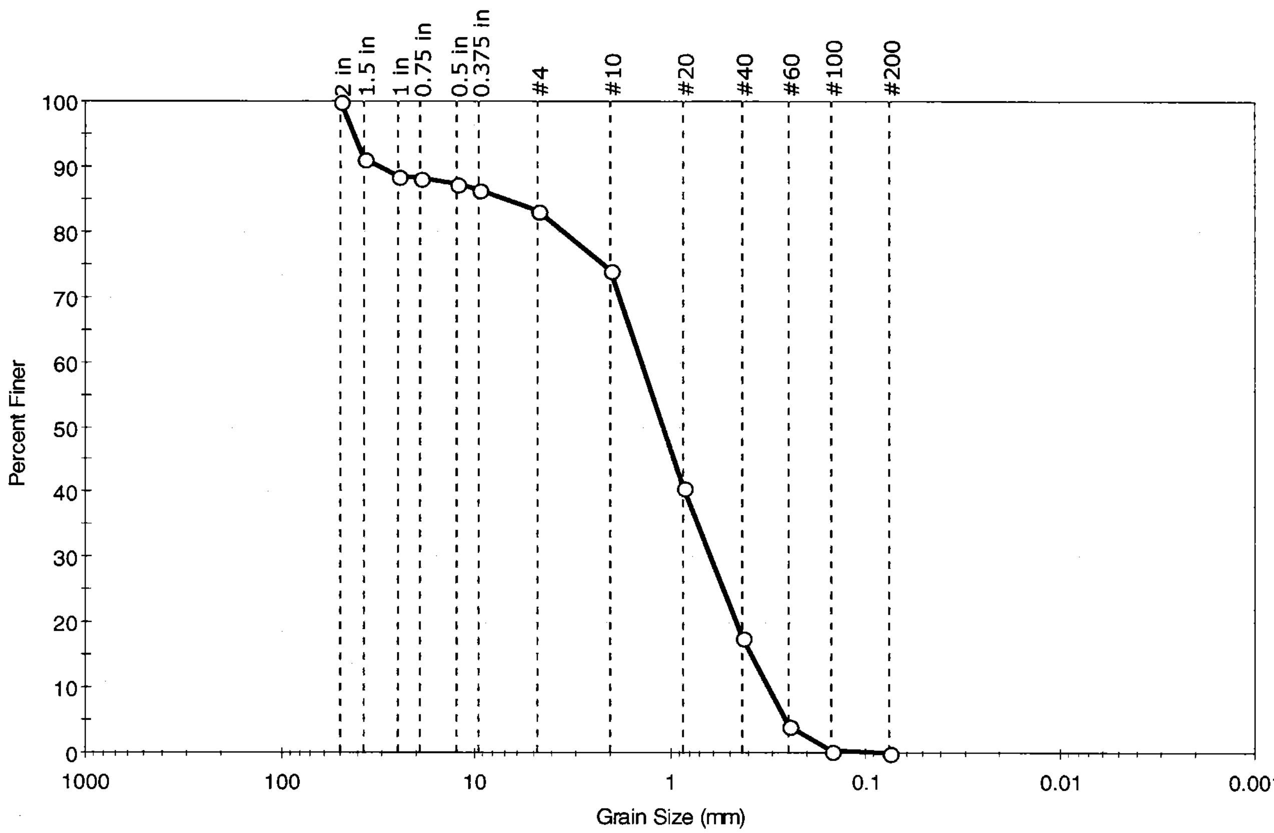
Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

GeoTesting EXPRESS

Client:	Bourne Consulting Engineering				
Project:	Town of Duxbury Seawall Rehabilitation				
Location:	---			Project No:	GTX-10669
Boring ID:	---	Sample Type:	bag	Tested By:	jbr
Sample ID:	30815.9	Test Date:	04/01/11	Checked By:	jdt
Depth :	---	Test Id:	205991		
Test Comment:	---				
Sample Description:	Moist, light yellowish brown sand with gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	16.7	83.2	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	91		
1 in	25.00	89		
0.75 in	19.00	88		
0.5 in	12.50	87		
0.375 in	9.50	87		
#4	4.75	83		
#10	2.00	74		
#20	0.85	41		
#40	0.42	18		
#60	0.25	4		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} = 6.8338 mm	D_{30} = 0.6158 mm
D_{60} = 1.3954 mm	D_{15} = 0.3828 mm
D_{50} = 1.0791 mm	D_{10} = 0.3147 mm
C_u = 4.434	C_c = 0.864

Classification

ASTM Poorly graded sand with gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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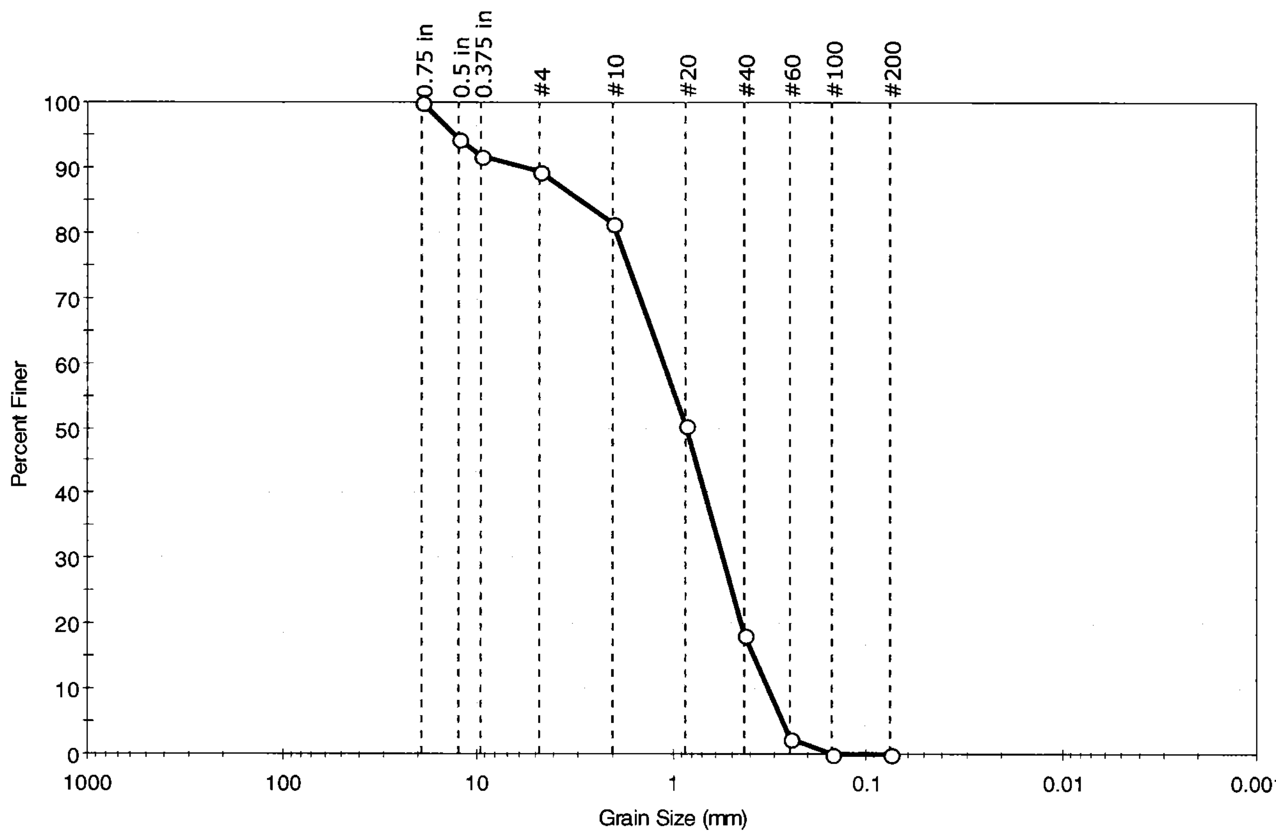
GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.11	Test Date: 04/07/11	Checked By:	jdt
Depth : ---	Test Id: 206318		
Test Comment: ---			
Sample Description: Moist, light yellowish brown sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	10.7	89.2	0.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	94		
0.375 in	9.50	92		
#4	4.75	89		
#10	2.00	81		
#20	0.85	50		
#40	0.42	18		
#60	0.25	2		
#100	0.15	0		
#200	0.075	0		

Coefficients

D_{85} =2.9484 mm D_{30} =0.5464 mm

D_{60} =1.1070 mm D_{15} =0.3795 mm

D_{50} =0.8426 mm D_{10} =0.3213 mm

C_u =3.445 C_c =0.839

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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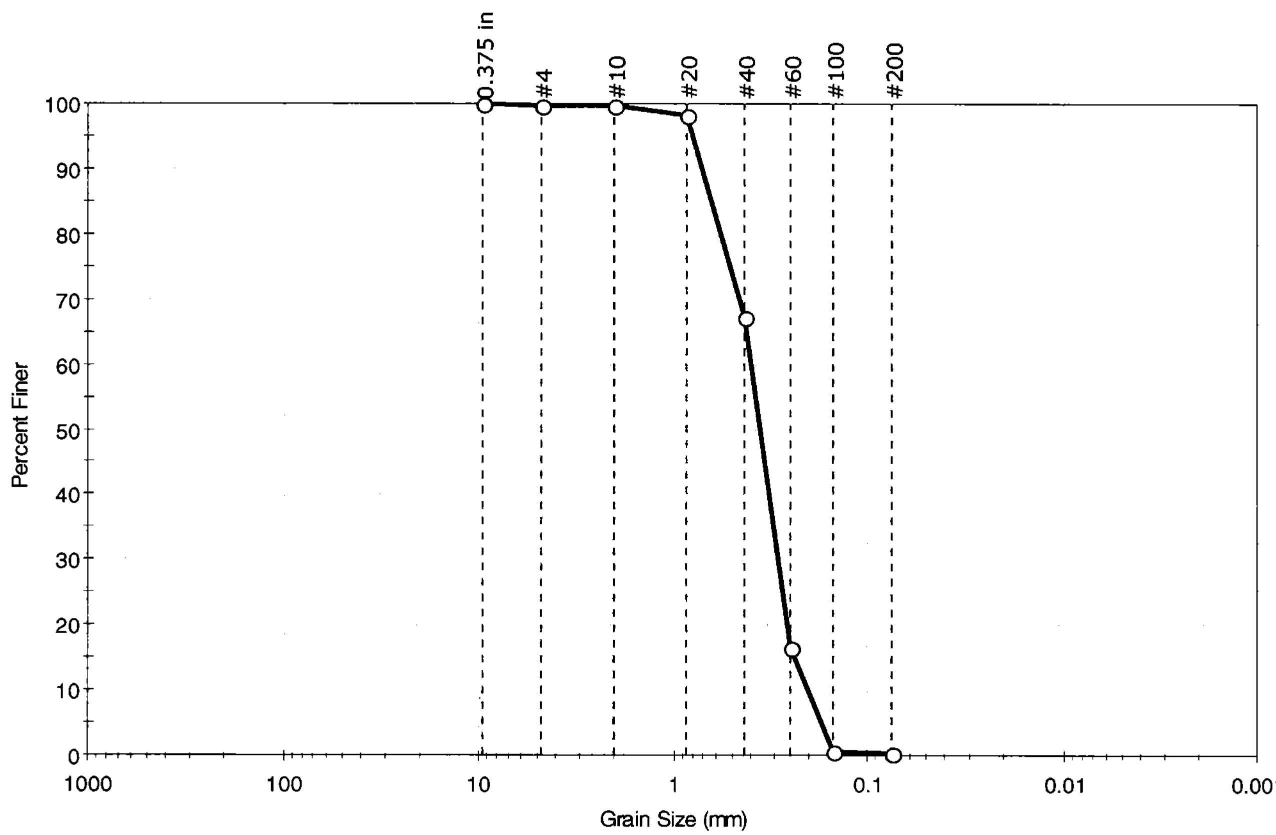
GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.12	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205993		
Test Comment: ---			
Sample Description: Moist, light brown sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.4	99.3	0.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	100		
#20	0.85	98		
#40	0.42	67		
#60	0.25	16		
#100	0.15	1		
#200	0.075	0		

Coefficients

D_{85} =0.6326 mm D_{30} =0.2880 mm

D_{60} =0.3938 mm D_{15} =0.2386 mm

D_{50} =0.3548 mm D_{10} =0.2029 mm

C_u =1.941 C_c =1.038

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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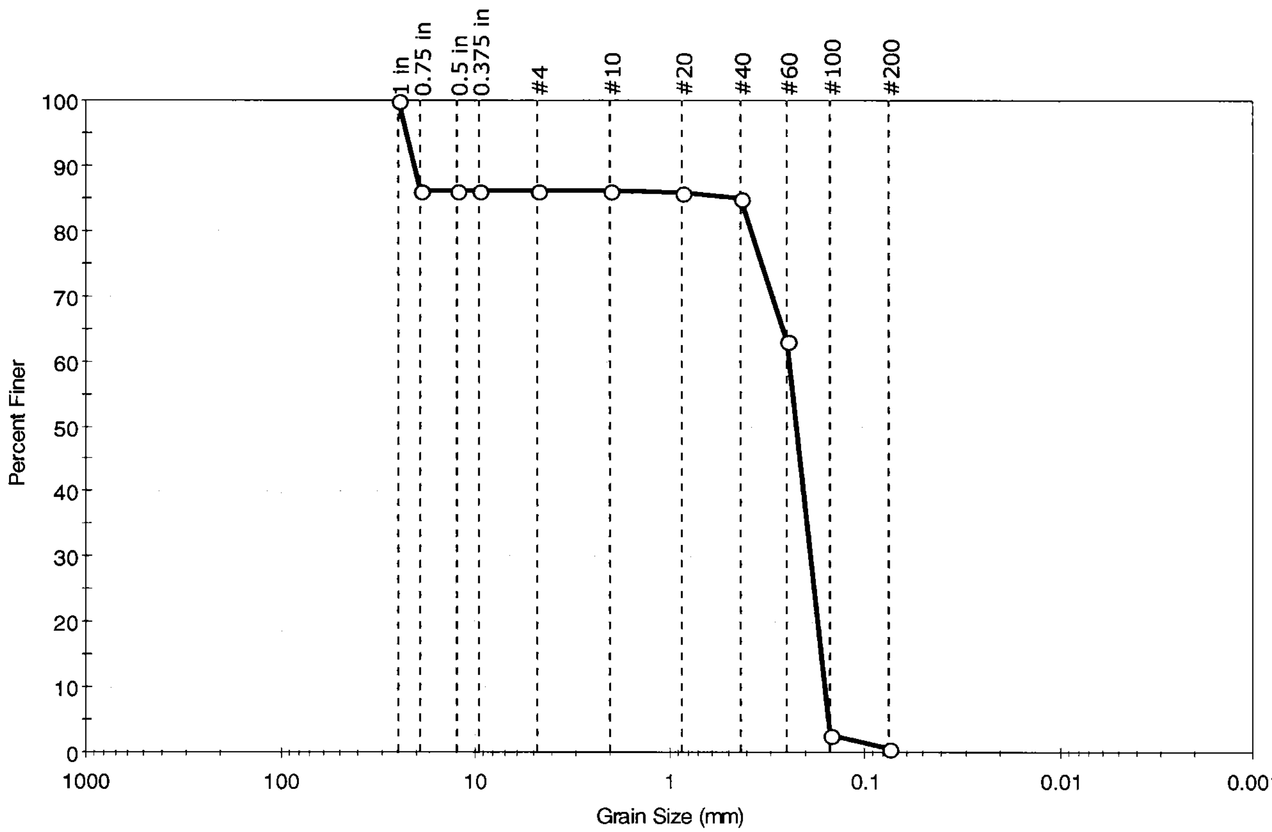
GeoTesting EXPRESS

Client: Bourne Consulting Engineering			
Project: Town of Duxbury Seawall Rehabilitation			
Location: ---		Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.13	Test Date: 04/01/11	Checked By:	jdt
Depth : ---	Test Id: 205994		
Test Comment: ---			
Sample Description: Moist, light yellowish brown sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	13.9	85.6	0.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	86		
0.5 in	12.50	86		
0.375 in	9.50	86		
#4	4.75	86		
#10	2.00	86		
#20	0.85	86		
#40	0.42	85		
#60	0.25	63		
#100	0.15	3		
#200	0.075	0		

Coefficients

D_{85} =0.4513 mm D_{30} =0.1891 mm
D_{60} =0.2434 mm D_{15} =0.1666 mm
D_{50} =0.2238 mm D_{10} =0.1598 mm
C_u =1.523 C_c =0.919

Classification

ASTM Poorly graded sand (SP)

AASHTO Fine Sand (A-3 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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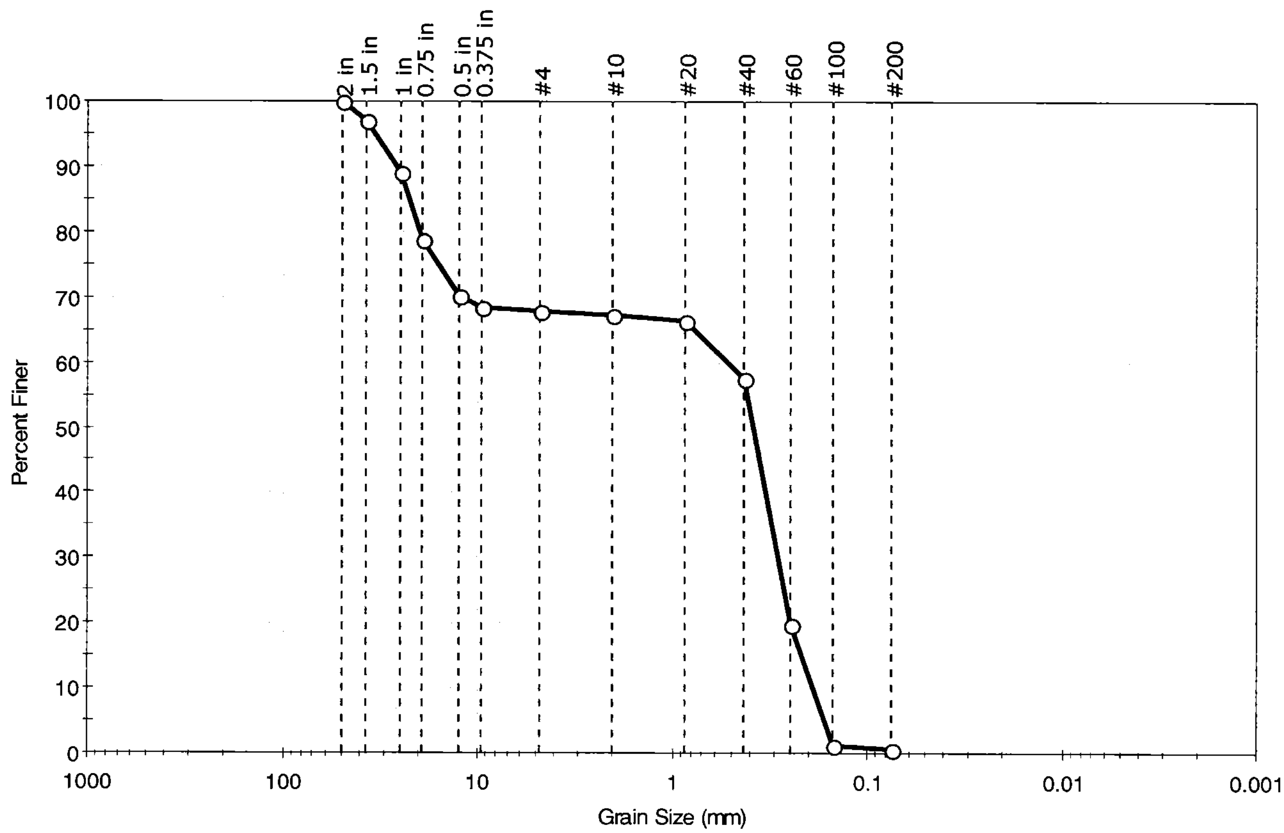
GeoTesting EXPRESS

Client:	Bourne Consulting Engineering		
Project:	Town of Duxbury Seawall Rehabilitation		
Location:	---	Project No:	GTX-10669
Boring ID: ---	Sample Type: bag	Tested By:	jbr
Sample ID:30815.14	Test Date: 03/31/11	Checked By:	jdt
Depth : ---	Test Id: 205995		
Test Comment:	---		
Sample Description:	Moist, light yellowish brown sand with gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	32.2	67.3	0.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	97		
1 in	25.00	89		
0.75 in	19.00	79		
0.5 in	12.50	70		
0.375 in	9.50	69		
#4	4.75	68		
#10	2.00	67		
#20	0.85	66		
#40	0.42	57		
#60	0.25	20		
#100	0.15	1		
#200	0.075	1		

Coefficients

D_{85} =22.4234 mm D_{30} =0.2890 mm

D_{60} =0.5203 mm D_{15} =0.2198 mm

D_{50} =0.3830 mm D_{10} =0.1916 mm

C_u =2.716 C_c =0.838

Classification

ASTM Poorly graded sand with gravel (SP)

AASHTO Fine Sand (A-3 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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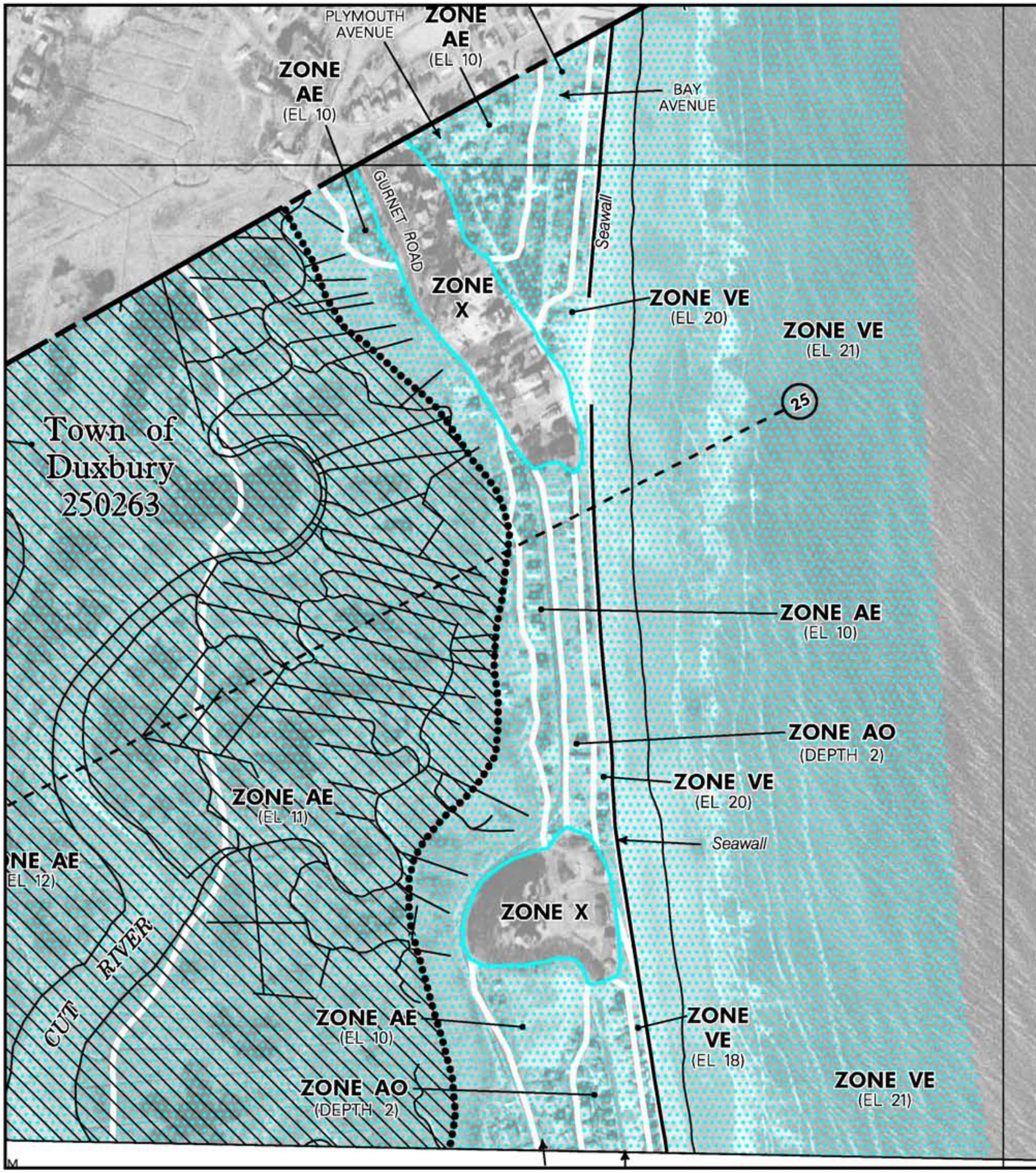
APPENDIX H – FEMA Flood Insurance Rate Map Extracts



onal Flood Insurance Program at (800) 638–6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

NATIONAL FLOOD INSURANCE PROGRAM

NFIP

PANEL 0034D

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
DUXBURY,
MASSACHUSETTS
PLYMOUTH COUNTY

PANEL 34 OF 82

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
DUXBURY, TOWN OF	250263	0034	D

–NOTE–

THIS MAP INCORPORATES APPROXIMATE BOUNDARIES OF COASTAL BARRIER RESOURCES SYSTEM UNITS AND/OR OTHERWISE PROTECTED AREAS ESTABLISHED UNDER THE COASTAL BARRIER IMPROVEMENT ACT OF 1990 (PL 101-591).

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
2502630034D

MAP REVISED
MAY 17, 2005

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

JOINS P onal Flood Insurance Program at (800) 638–6620.

N

MAP SCALE 1" = 500'

250 0 500 1000 FEET

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0042D

FIRM

FLOOD INSURANCE RATE MAP

TOWN OF
DUXBURY,
MASSACHUSETTS
PLYMOUTH COUNTY

PANEL 42 OF 82

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
DUXBURY, TOWN OF	250263	0042	D

–NOTE–
THIS MAP INCORPORATES APPROXIMATE BOUNDARIES OF COASTAL BARRIER RESOURCES SYSTEM UNITS AND/OR OTHERWISE PROTECTED AREAS ESTABLISHED UNDER THE COASTAL BARRIER IMPROVEMENT ACT OF 1990 (PL 101-591).

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
2502630042D

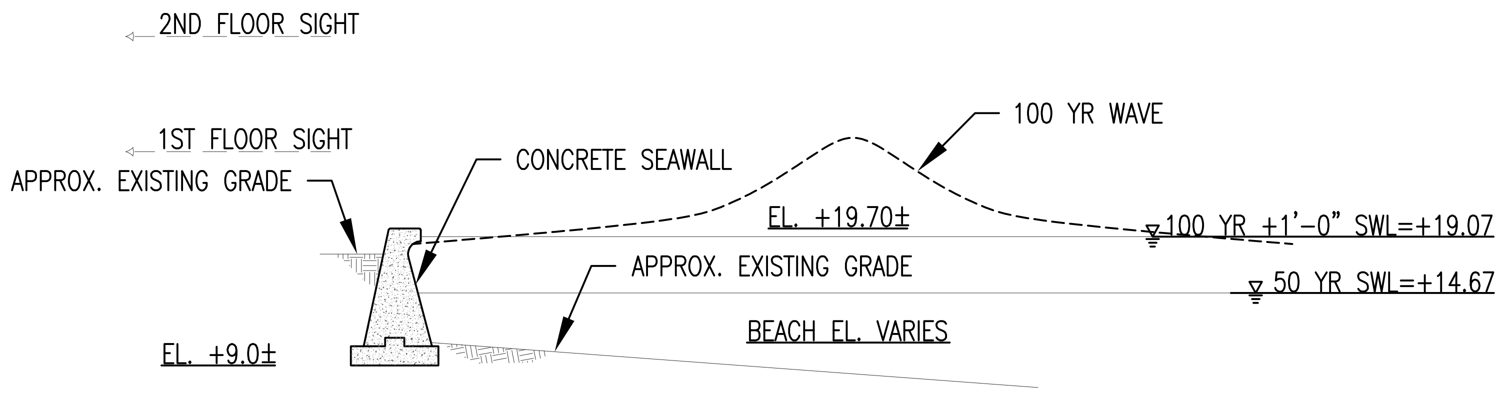
MAP REVISED
MAY 17, 2005

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

APPENDIX I – Rehabilitation Alternatives

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



NOTE:
1. BEACH CONSISTS OF SAND & STONE (<6"ø)
2. FROM SITE INVESTIGATION ON 11/11/10
   EXPOSED HEIGHT RANGES FROM 4.5' TO 11.3'
3. BEACH ELEVATION LESS THAN +11.0± FROM
   STA 104+00 TO 112+00

A/1 NO BUILD SOUTH LOW WALL (STA 100+00 TO 116+00) – ALTERNATIVE 1A

SCALE: 1"=15'

50 YR (WAVE HEIGHT=4.9 FT)
OVERTOPPING = 1.6 FT^3/S/FT

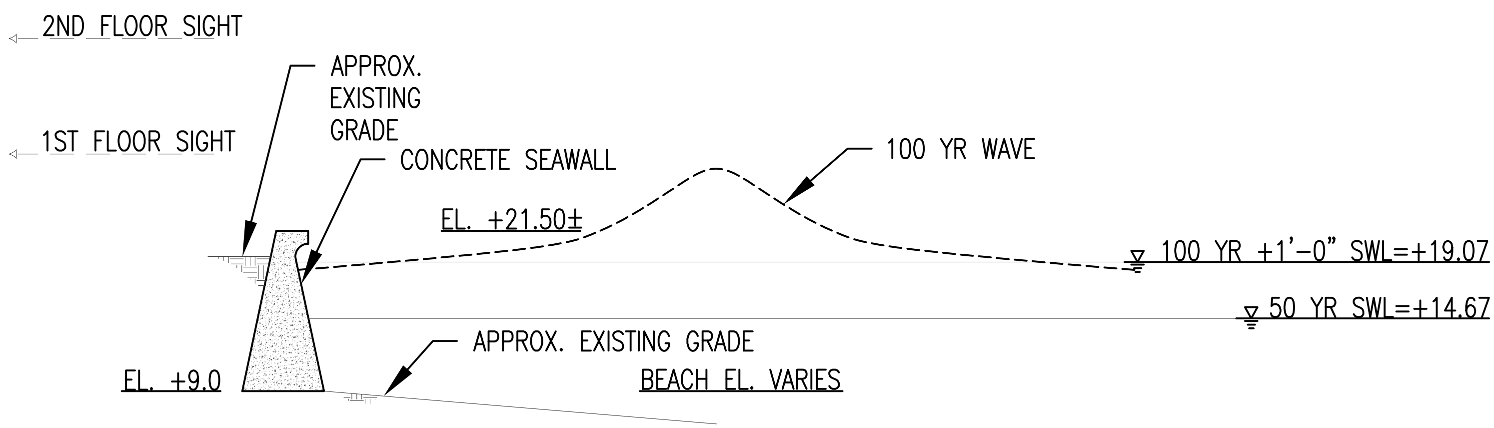
100 YR + 1'-0" (WAVE HEIGHT=8.3 FT)
OVERTOPPING = 14.7 FT^3/S/FT
COST:
$0.00

SEAWALL REHAB.
TOWN OF DUXBURY
DUXBURY, MA
JANUARY 2011

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
TEL. (508) 533-6666 FAX. (508) 533-0600

EXHIBIT 1

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



NOTE:

1. REVETMENT (½ TON–4 TON) LOCATED AT BASE OF WALL FROM STA 116+50 TO 119+50.
2. BEACH CONSISTS OF SAND & STONE (<6"ø)
3. FROM SITE INVESTIGATION ON 11/11/10 EXPOSED HEIGHT RANGES FROM 5.5' TO 11.7'
4. BEACH ELEVATION LESS THAN +11.0± FROM STA 120+00 TO 129+00

A/2 NO BUILD SOUTH HIGH WALL (STA 116+00 TO 130+00) – ALTERNATIVE #1B

SCALE: 1"=15'

50 YR (WAVE HEIGHT=4.4 FT)
OVERTOPPING = 0.71 FT^3/S/FT

100 YR +1'-0" (WAVE HEIGHT=7.9 FT)
OVERTOPPING = 9.03 FT^3/S/FT

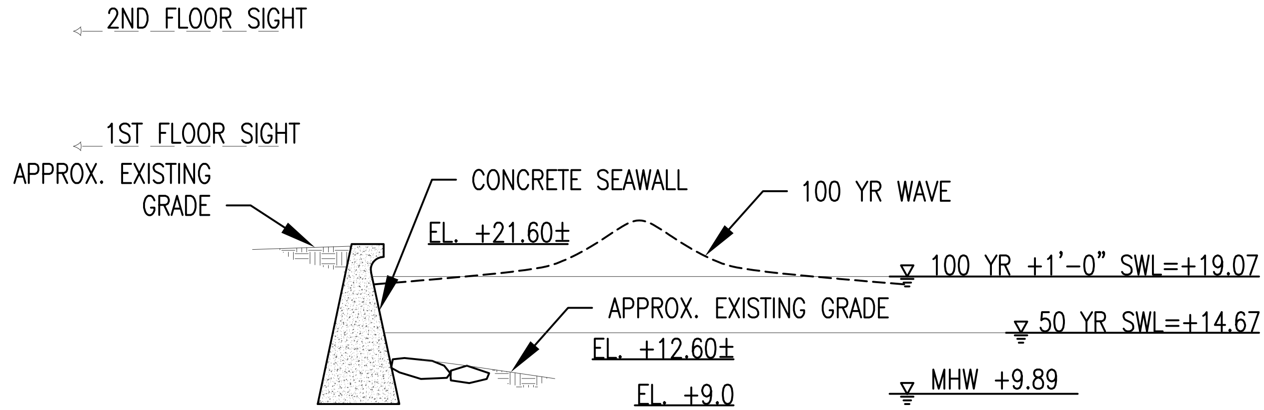
COST:
$0.00

SEAWALL REHAB.
TOWN OF DUXBURY
DUXBURY, MA
JANUARY 2011

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
TEL. (508) 533-6666 FAX. (508) 533-0600

EXHIBIT 2

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



NOTE:

1. REVETMENT (1 TON TO 7 TON) LOCATED AT BASE OF WALL FROM STA 203+50 TO 211+80.
2. BEACH CONSISTS OF SAND & STONE (<6"ø)
3. FROM SITE INVESTIGATION ON 1/11 10 EXPOSED HEIGHT RANGED FROM 6.2' TO 12.0'

NO BUILD NORTH HIGH WALL (STA 200+00 TO 211+80) – ALTERNATIVE #1C

A/3

SCALE: 1"=15'

50 YR (WAVE HEIGHT=1.6 FT)
OVERTOPPING = 0.05 FT^3/S/FT

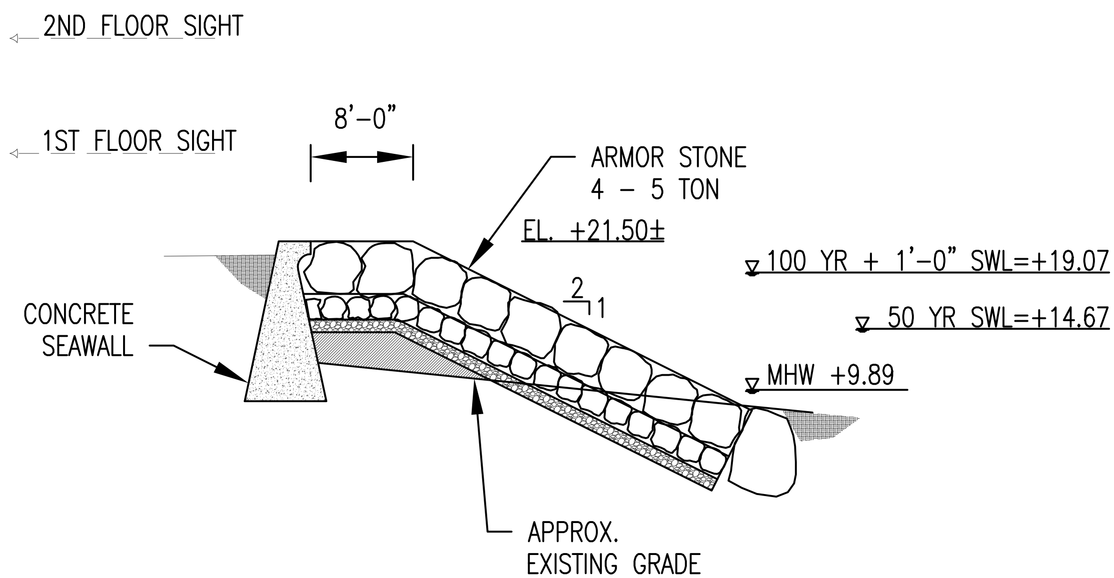
100 YR +1'-0" (WAVE HEIGHT=5.0 FT)
OVERTOPPING = 3.5 FT^3/S/FT

COST:
$0.00

SEAWALL REHAB.
TOWN OF DUXBURY
DUXBURY, MA
JANUARY 2011

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
TEL. (508) 533-6666 FAX. (508) 533-0600

EXHIBIT 3



ALTERNATIVE #2-REVETMENT TO TOP OF WALL EL.+21.5

A/4

SCALE: 1"=15'

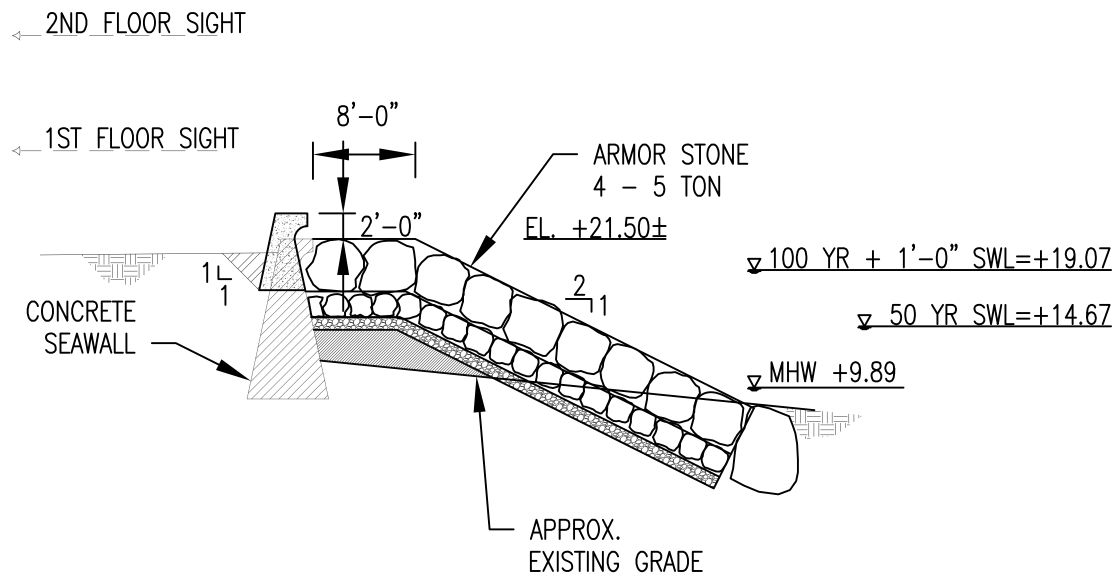
50 YR
OVERTOPPING = 0.5 FT^3/S/FT
100 YR + 1'-0"
OVERTOPPING = 10 FT^3/S/FT
COST:
$1,821/LF

SEAWALL REHAB.
TOWN OF DUXBURY
DUXBURY, MA
JANUARY 2011

BCE Bourne Consulting Engineering
3 Bent Street
Franklin, MA 02038
TEL. (508) 533-6666 FAX. (508) 533-0600

EXHIBIT 4

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A 4A ALTERNATIVE #2A-REVETMENT TO TOP OF WALL EL.+21.5, 2' CREST WALL

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.04 $FT^3/S/FT$

100 YR + 1'-0"
OVERTOPPING = 7.5 $FT^3/S/FT$

COST:
$2,034/LF

SEAWALL REHAB.
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DUXBURY, MA
JANUARY 2011

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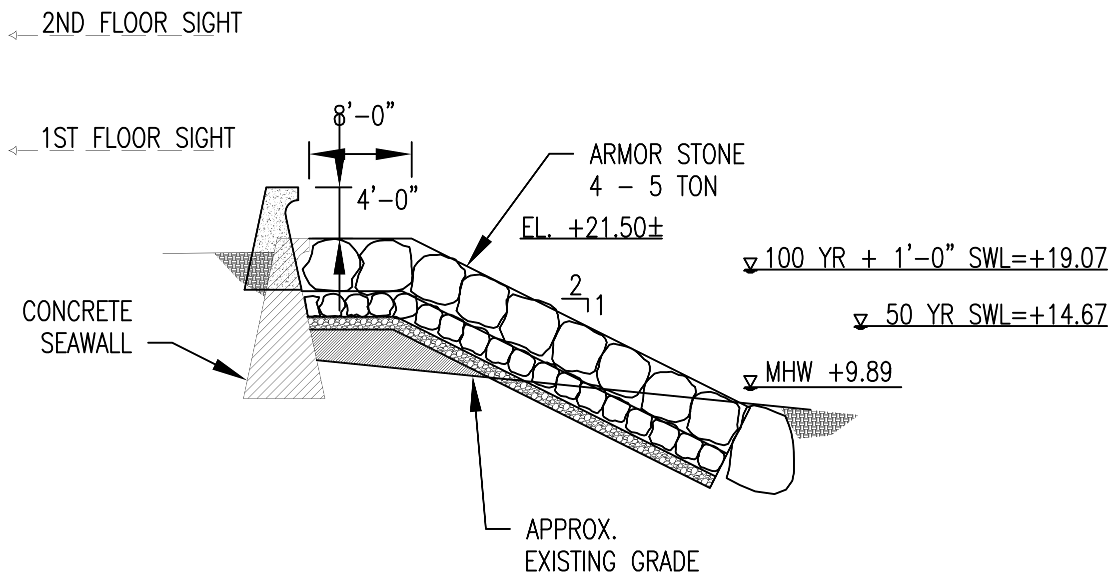
EXHIBIT 4A



A / 4B ALTERNATIVE #2B-REVETMENT TO TOP OF WALL EL.+21.5, 4' CREST WALL

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.008 $FT^3/S/FT$

100 YR + 1'-0"
OVERTOPPING = 5.3 $FT^3/S/FT$

COST:
$2,294/LF

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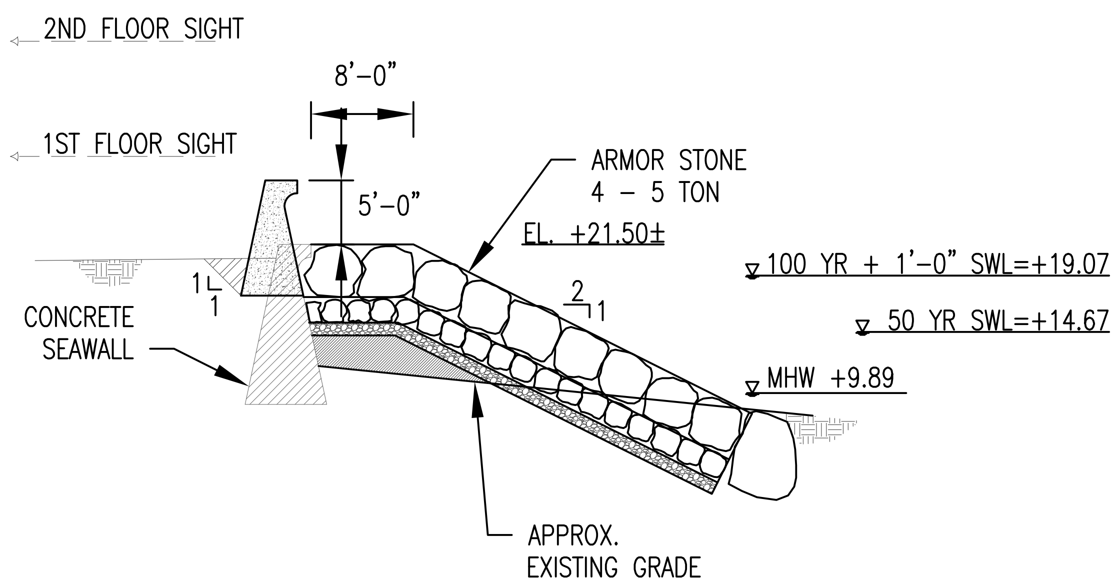
EXHIBIT 4B

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A/4C ALTERNATIVE #2C-REVETMENT TO TOP OF WALL EL.+21.5, 5' CREST WALL

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.004 $FT^3/S/FT$

100 YR + 1'-0"
OVERTOPPING = 2.6 $FT^3/S/FT$

COST:
$2,892/LF

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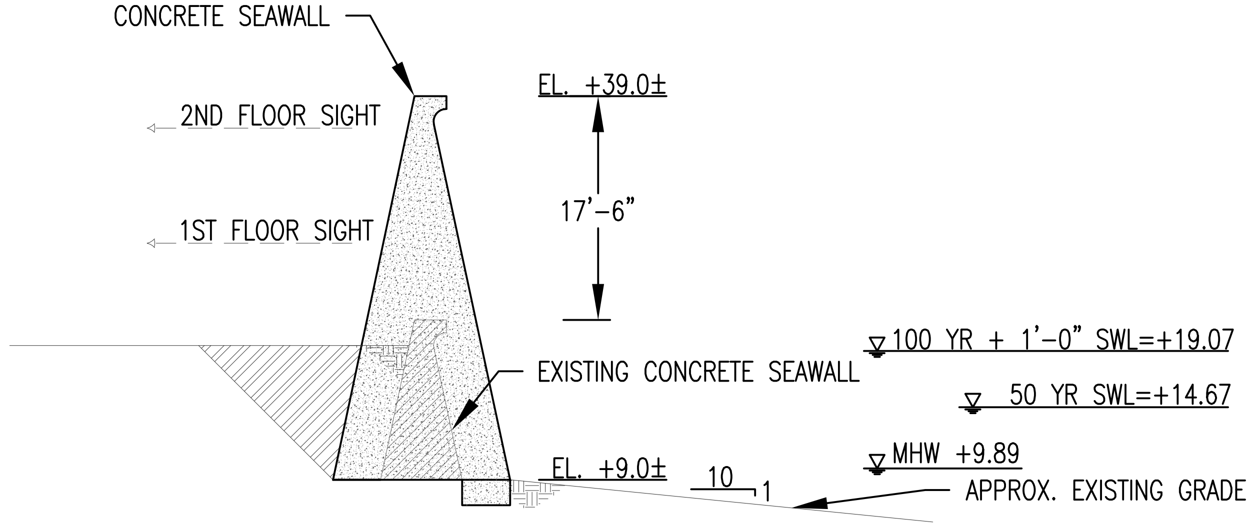
EXHIBIT 4C

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A/5 ALTERNATIVE #3-RAISE WALL TO EL. +39.0

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0003 FT^3/S/FT
100 YR + 1'-0"
OVERTOPPING = 0.09 FT^3/S/FT
COST:
$6,378/LF

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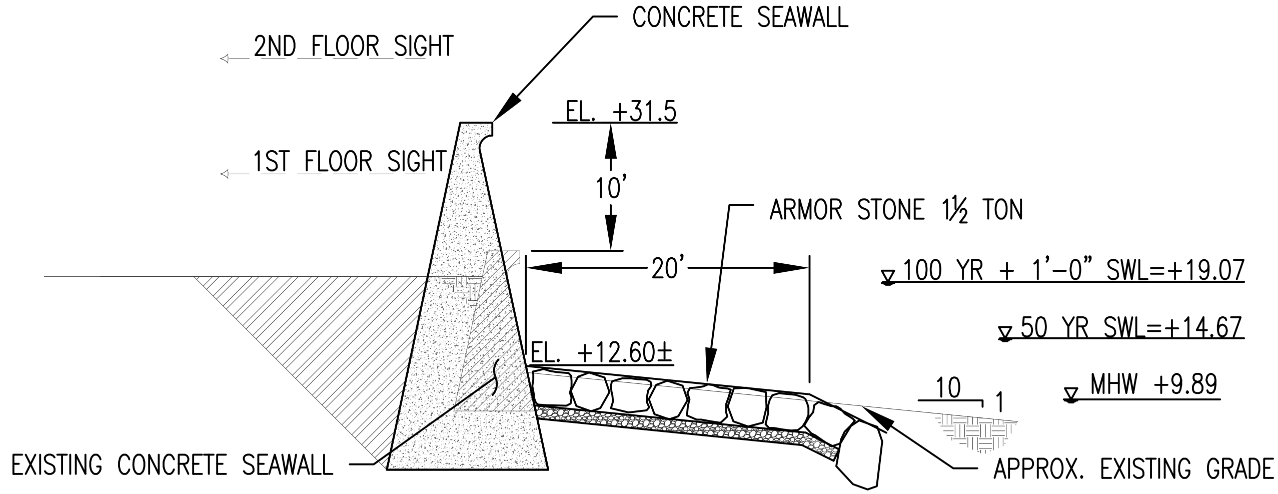
EXHIBIT 5

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A/6 ALTERNATIVE #4- RAISE WALL TO EL. +31.5, RIP RAP TOE

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0003 FT^3/S/FT
100 YR +1'-0"
OVERTOPPING = 0.19 FT^3/S/FT
COST:
$5,888/LF

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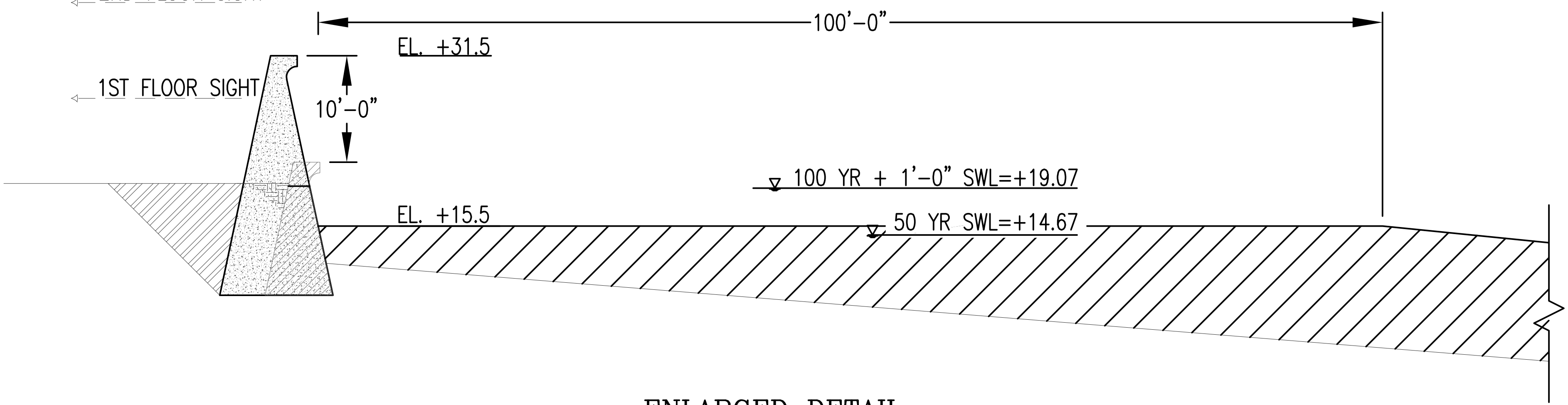
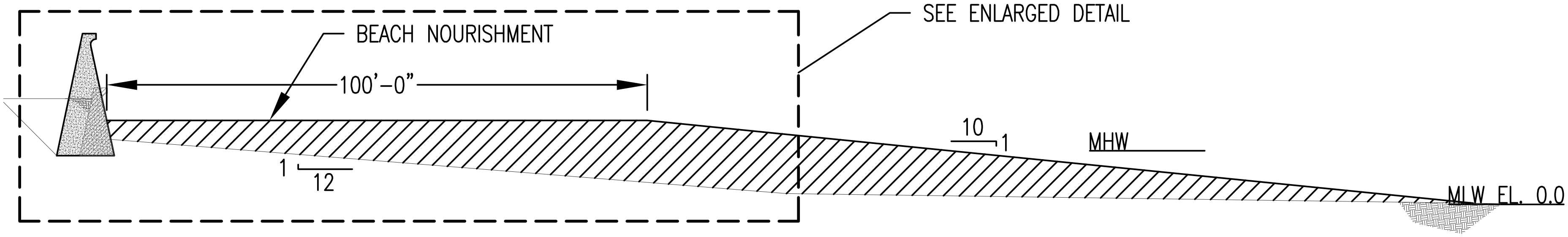
EXHIBIT 6

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



ENLARGED DETAIL

SCALE: 1"=15'



B/6A ALTERNATIVE #4A- INCREASE WALL HT. TO EL. +31.5, BEACH NOURISHMENT

SCALE: 1"=30'

50 YR
OVERTOPPING = 0.0003 FT^3/S/FT
100 YR +1'-0"
OVERTOPPING = 0.19 FT^3/S/FT
COST:
$5,868/LF

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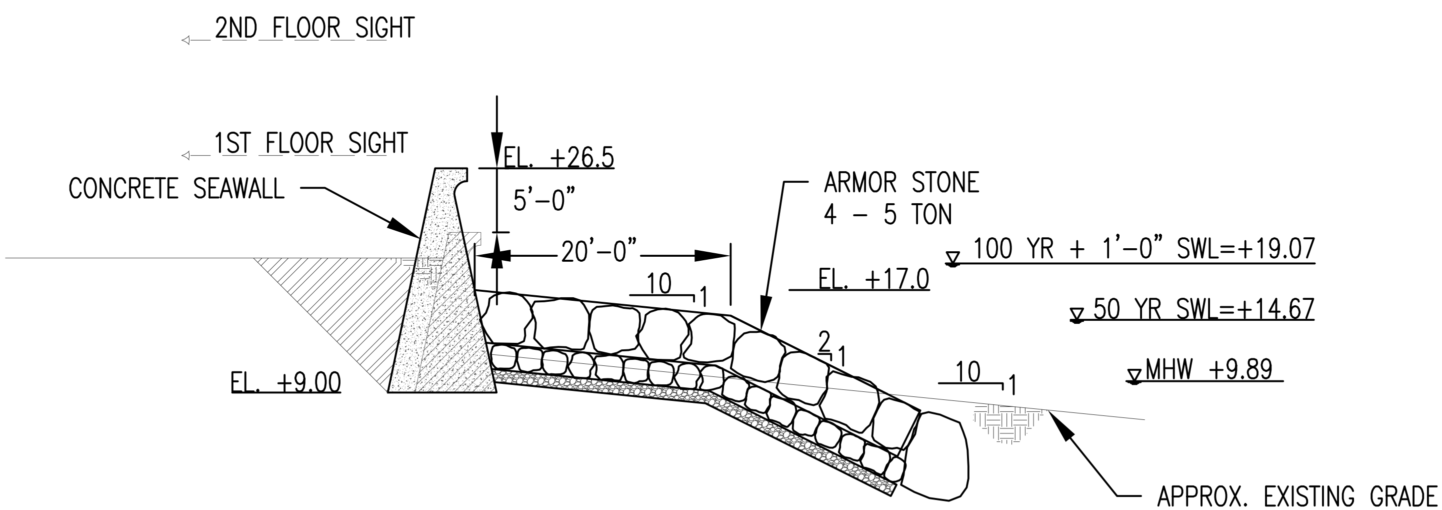
EXHIBIT 6A

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A/7 ALTERNATIVE #5–TOP OF WALL EL. +26.5 & REVETMENT TO EL. +17.0

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0005 FT^3/S/FT

100 YR +1'-0"
OVERTOPPING = 0.05 FT^3/S/FT

COST:
$4,571/LF

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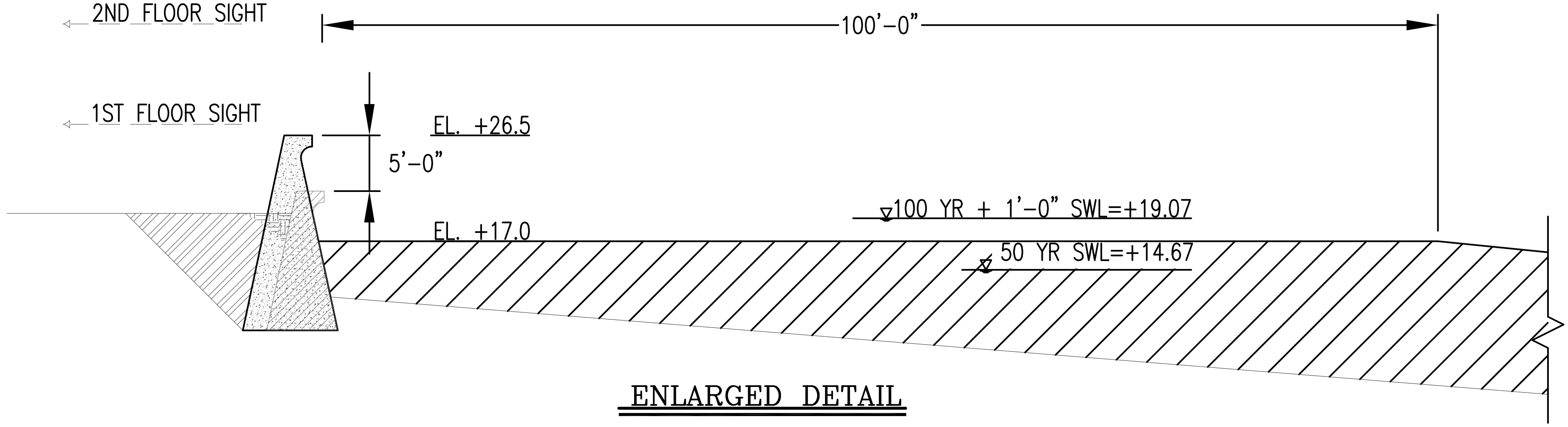
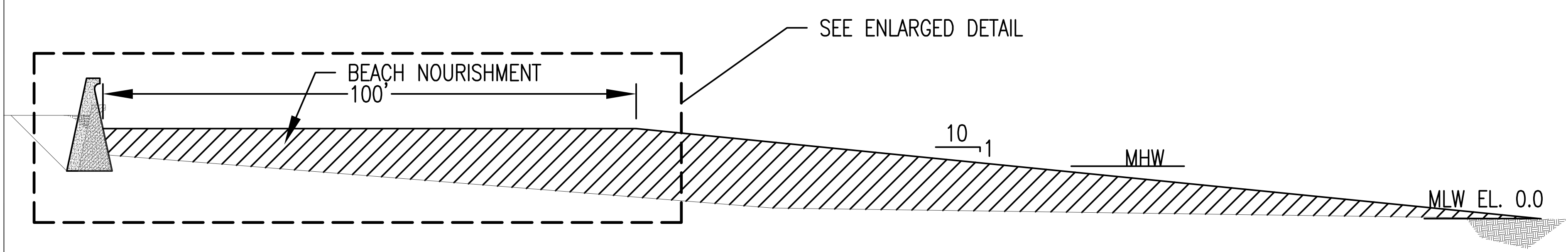
EXHIBIT 7

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



ENLARGED DETAIL

SCALE: 1"=15'



A/7A ALTERNATIVE #5A-TOP OF WALL EL. +26.5 & BEACH TO EL. +17.0

SCALE: 1"=30'

50 YR
OVERTOPPING = 0.000 $FT^3/S/FT$
100 YR +1'-0"
OVERTOPPING = 0.08 $FT^3/S/FT$
COST:
$5,015/LF

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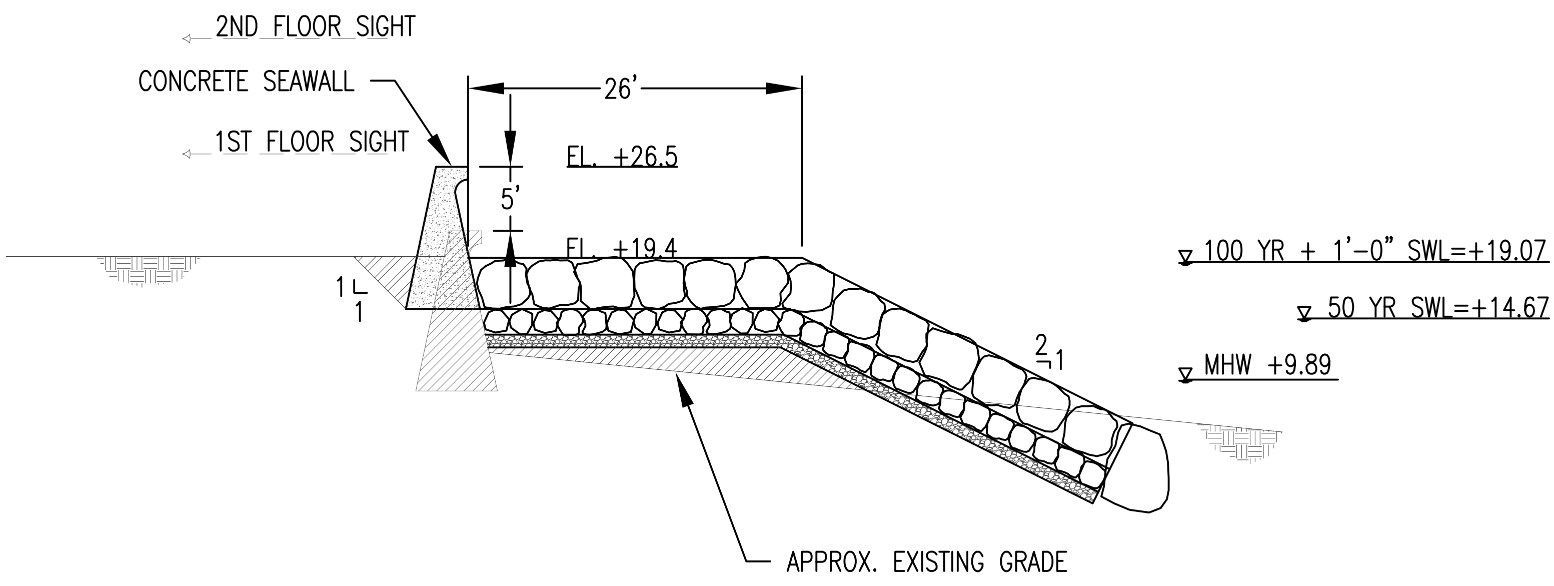
EXHIBIT 7A

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



A/8 ALTERNATIVE #6– TOP OF WALL EL. +26.5 & REVETMENT TO EL. +19.4

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.0004 FT^3/S/FT
100 YR + 1'-0"
OVERTOPPING = 0.04 FT^3/S/FT
COST:
$4,208/LF

SEAWALL REHAB.
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EXHIBIT 8

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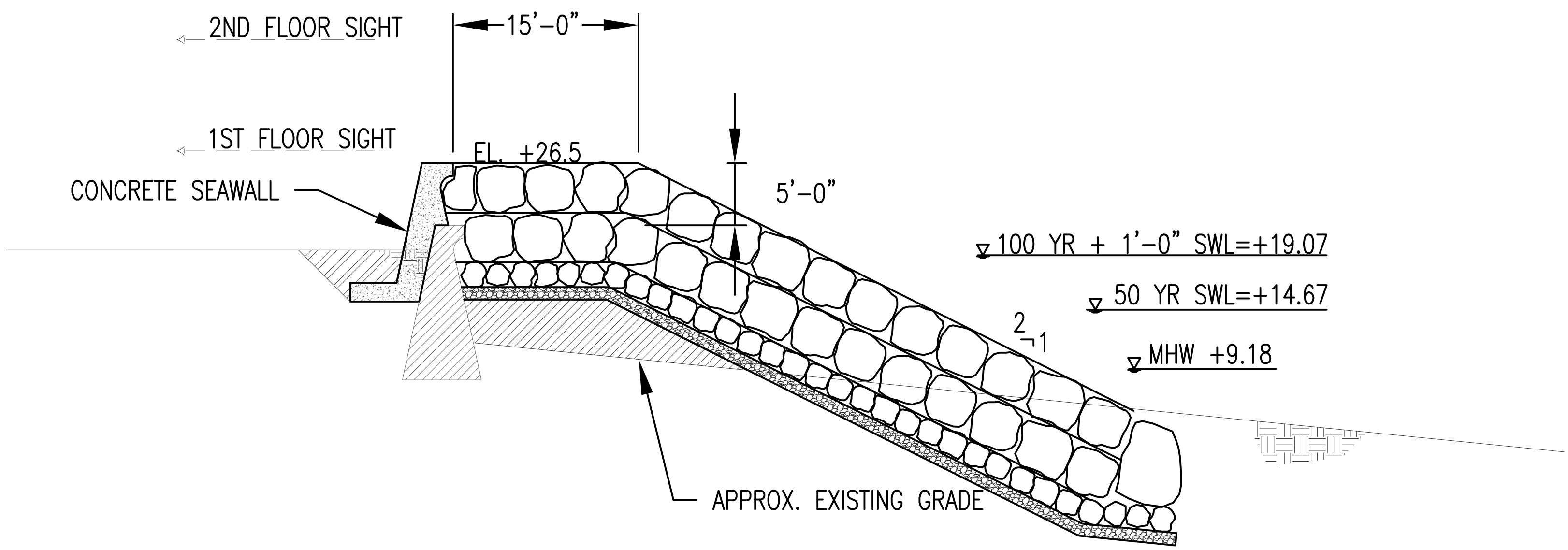

ALTERNATIVE #7-REVETMENT TO EL. +26.5

A/9

SCALE: 1"=15'

50 YR
OVERTOPPING = 0.005 FT^3/S/FT
100 YR
OVERTOPPING = 1.8 FT^3/S/FT
COST:
$5,921/LF

SEAWALL REHAB.
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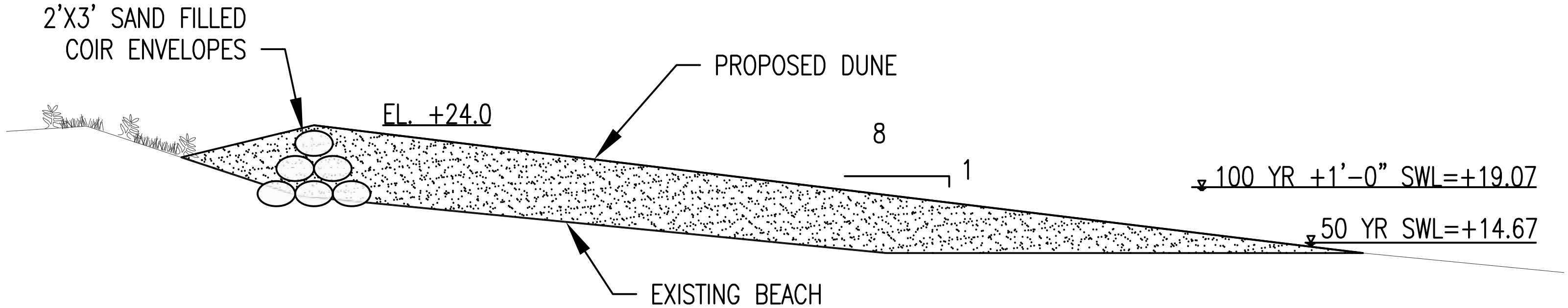
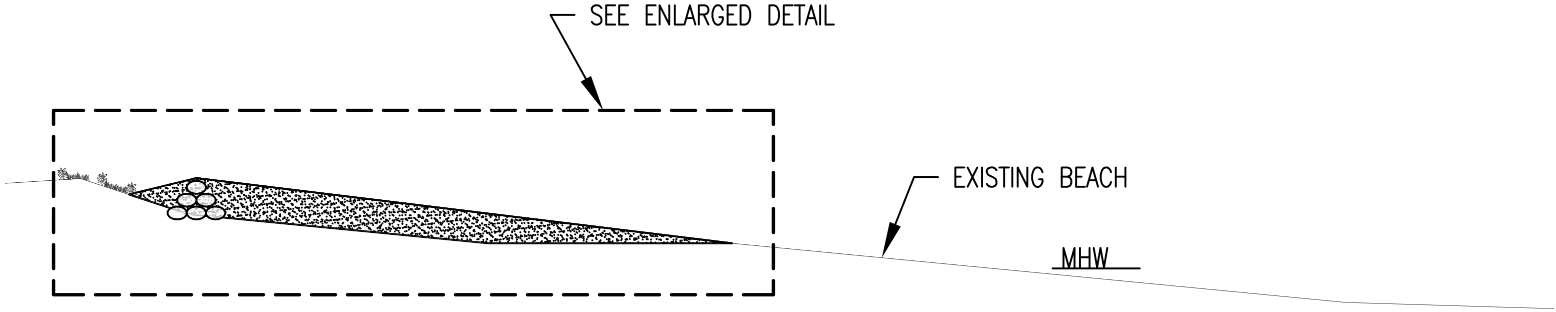
EXHIBIT 9

File: X:\30774-\30815\Report Exhibits\WALL SECTIONS.dwg



ENLARGED DETAIL

SCALE: 1"=15'



(A/10) ALTERNATIVE #8 – PROPOSED DUNE SECTION

SCALE: 1"=30'

50 YR

OVERTOPPING = 0.003 $FT^3/S/FT$

100 YR

OVERTOPPING = 0.9 $FT^3/S/FT$

COST:

$538/LF

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EXHIBIT 10

APPENDIX J – Cost Estimates

Summary of Alternatives	
Alternative	Cost per Linear foot
1	$0
2	$1,821
2A	$2,034
2B	$2,294
2C	$2,892
3	$6,378
4	$5,888
4A	$5,868
5	$3,303
5A	$5,015
6	$4,208
7	$5,921
8	$538

Alternative 2 - Raise Revetment to Ex. T.O.W. EL. +21.5 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Armor Stone (1 layer - 5 ton / 4'Φ)	150	9	TON	$110.00	$953.00	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	71	4	TON	$80.00	$329.00	
Filter layer Stone (1 layer - 12" thick)	35	2	TON	$80.00	$185.00	
Fill	28	1	CY	$30.00	$32.00	
Geotextile Filter Fabric	45	45	SF	$0.40	$18.00	
				Subtotal:	$1,517.00	
Contingency				20.00%	$304.00	
Total cost Alt 2					**$1,821.00**	per linear foot

Alternative 2A - Raise Revetment to Ex. T.O.W. EL. +21.5 MLW with 2 foot Crest wall

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	6	0	CY	$100.00	$22.22	
Armor Stone (1 layer - 5 ton / 4'Φ)	150	9	TON	$110.00	$953.00	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	71	4	TON	$80.00	$329.00	
Filter layer Stone (1 layer - 12" thick)	35	2	TON	$80.00	$185.00	
Fill	28	1	CY	$30.00	$32.00	
Geotextile Filter Fabric	45	45	SF	$0.40	$18.00	
2 foot concrete wall	8	0	CY	$600.00	$178.00	
				Subtotal:	$1,695.00	
Contingency				20.00%	$339.00	
Total cost Alt 2A					**$2,034.00**	per linear foot

Alternative 2B - Raise Revetment to Ex. T.O.W. EL. +21.5 MLW with 4 foot crest wall
All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	10	0	CY	$100.00	$37.04	
Armor Stone (1 layer - 5 ton / 4'Φ)	150	9	TON	$110.00	$953.00	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	71	4	TON	$80.00	$329.00	
Filter layer Stone (1 layer - 12" thick)	35	2	TON	$80.00	$185.00	
Fill	28	1	CY	$30.00	$32.00	
Geotextile Filter Fabric	45	45	SF	$0.40	$18.00	
4 foot concrete wall	16	1	CY	$600.00	$356.00	
				Subtotal:	$1,911.00	
Contingency				20.00%	$383.00	
Total cost Alt 2B					**$2,294.00**	per linear foot

Alternative 2C - Raise Revetment to Ex. T.O.W. EL. +21.5 MLW with 5 foot crest wall
All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	10	0	CY	$100.00	$37.04	
Armor Stone (1 layer - 5 ton / 4'Φ)	150	9	TON	$110.00	$953.00	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	71	4	TON	$80.00	$329.00	
Filter layer Stone (1 layer - 12" thick)	35	2	TON	$80.00	$185.00	
Fill	28	1	CY	$30.00	$32.00	
Geotextile Filter Fabric	45	45	SF	$0.40	$18.00	
Excavation	260	10	CY	$15.00	$144.44	
Concrete	32	1	CY	$600.00	$711.11	
Fill (Back of Seawall)	34	1	CY	$10.00	$12.59	
				Subtotal:	$2,410.00	
Contingency				20.00%	$482.00	
Total cost Alt 2C					**$2,892.00**	per linear foot

Alternative 3 - Raise T.O.W. EL. +39.0 MLW (Toe @ +9.0 MLW)
All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	49	2	CY	$100.00	$181.48	
Excavation (Backside of wall only)	106	4	CY	$15.00	$58.89	
Concrete	225	8	CY	$600.00	$5,000.00	
Fill	67	2	CY	$30.00	$74.44	
				Subtotal:	$5,315.00	
Contingency				20.00%	$1,063.00	
Total cost Alt 3					**$6,378.00**	per linear foot

Alternative 4 - Raise T.O.W. EL. +31.5 MLW & Out Shore Grade to +12.6 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	49	2	CY	$100.00	$181.48	
Excavation (Backside of wall only)	188	7	CY	$15.00	$104.44	
Excavation (Front of wall)	100	4	CY	$10.00	$37.04	
Concrete	186	7	CY	$600.00	$4,133.33	
Armor Stone (1 layer - 2 ton / 3'Φ)	88	5	TON	$110.00	$559.02	
Filter layer Stone (1 layer - 12" thick)	24	2	TON	$80.00	$126.72	
Fill Behind Wall	67	2	CY	$30.00	$74.44	
Geotextile Filter Fabric	30	30	SF	$0.40	$12.00	
				Subtotal:	$4,906.00	
Contingency				20.00%	$982.00	
Total cost Alt 4					**$5,888.00**	per linear foot

Alternative 4A - Raise T.O.W. EL. +31.5 MLW & Out Shore Grade to +15.6 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	49	2	CY	$100.00	$181.48	
Excavation (Backside of wall only)	106	4	CY	$15.00	$58.89	
Concrete	134	5	CY	$600.00	$2,977.78	
Sand Fill	1725	64	CY	$25.00	$1,597.22	
Fill Behind Wall	67	2	CY	$30.00	$74.44	
				Subtotal:	$4,890.00	
Contingency				20.00%	$978.00	
Total cost Alt 4A					**$5,868.00**	per linear foot

Alternative 5 - Raise T.O.W. EL. +26.5 MLW & Out Shore Grade to +17.0 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	
Remove & Dispose Top of Concrete Wall	18	1	CY	$100.00	$66.67	
Excavation (Backside of wall only)	32	1	CY	$15.00	$17.78	
Concrete	45	2	CY	$600.00	$1,000.00	
Armor Stone (1 layer - 5 ton / 4'Φ)	170	10	TON	$110.00	$1,079.93	
Under layer Stone (1 layer - 2' thick)	70	4	TON	$80.00	$323.40	
Filter layer Stone (1 layer - 12" thick)	33	2	TON	$80.00	$174.24	
Fill (Front of Seawall)	0	0	CY	$30.00	$0.00	
Fill (Backside of Seawall)	66	2	CY	$30.00	$73.33	
Geotextile Filter Fabric	40	40	SF	$0.40	$16.00	
				Subtotal:	$2,752.00	
Contingency				20.00%	$551.00	
Total cost Alt 5					**$3,303.00**	per linear foot

Alternative 5A - Raise T.O.W. EL. +26.5 MLW & Out Shore Grade to +17.0 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	Sub-totals
Remove & Dispose Top of Concrete Wall	49	2	CY	$100.00	$181.48	
Excavation (Backside of wall only)	89	3	CY	$15.00	$49.44	
Concrete	86	3	CY	$600.00	$1,911.11	
Sand Fill	2120	79	CY	$25.00	$1,962.96	
Fill (Backside of Seawall)	66	2	CY	$30.00	$73.33	
				Subtotal:	$4,179.00	
Contingency				20.00%	$836.00	
Total cost Alt 5A					**$5,015.00**	per linear foot

Alternative 6 - Raise T.O.W. EL. +26.5 MLW & Revetment to +19.4 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	Sub-totals
Remove & Dispose Top of Concrete Wall	18	1	CY	$100.00	$66.67	
Excavation (Backside of wall only)	32	1	CY	$15.00	$17.78	
Concrete	45	2	CY	$600.00	$1,000.00	
Armor Stone (1 layer - 5 ton / 4'Φ)	241	14	TON	$110.00	$1,530.95	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	103	6	TON	$80.00	$475.86	
Filter layer Stone (1 layer - 12" thick)	51	3	TON	$80.00	$269.28	
Fill (Front of Seawall Wall)	44	2	CY	$30.00	$48.89	
Fill (Back of Seawall)	66	2	CY	$30.00	$73.33	
Geotextile Filter Fabric	57	57	SF	$0.40	$22.80	
				Subtotal:	$3,506.00	
Contingency				20.00%	$702.00	
Total cost Alt 6					**$4,208.00**	per linear foot

Alternative 7 - Raise T.O.W. EL. +26.5 MLW & Revetment to +26.5 MLW

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	Sub-totals
Excavation	260	10	CY	$15.00	$144.44	
Concrete	32	1	CY	$600.00	$711.11	
Armor Stone (2 layers - 5 ton / 4'Φ)	502	29	TON	$110.00	$3,188.96	
Underlayer Stone (1 layer - 0.5 ton / 2'Φ)	106	6	TON	$80.00	$489.72	
Filter layer Stone (1 layer - 12" thick)	63	4	TON	$80.00	$332.64	
Fill (Front of Seawall)	71	3	CY	$10.00	$26.30	
Fill (Back of Seawall)	34	1	CY	$10.00	$12.59	
Geotextile Filter Fabric	69	69	SF	$0.40	$27.60	
				Subtotal:	$4,934.00	
Contingency				20.00%	$987.00	
Total cost Alt 7					**$5,921.00**	per linear foot

Alternative 8 - Proposed Dune

All quantities/costs are per linear foot

Item	Area	Quantity	Unit	Rate	Total	Sub-totals
Excavation & Grading	120	4	CY	$5.00	$22.22	
Sand Fill	354	13	CY	$25.00	$327.78	
Coir Envelopes	75	75	SF	$1.00	$75.00	
Coir Fill	20	1	CY	$30.00	$22.22	
				Subtotal:	$448.00	
Contingency				20.00%	$90.00	
Total cost Alt 8					**$538.00**	per linear foot

APPENDIX K – Public Meeting Notes

Bourne Consulting Engineering
3 Bent St.
Franklin, MA 02038
Phone (508) 533-6666 Fax (508) 533-0600 email: bce@bournece.com

MEETING NOTES

TO:	**Peter Buttkus** **Duxbury Town Hall** **878 Tremont Street** **Duxbury, MA 02332-4499** **Attendees**	**DATE:**	**June 4, 2012**
		BCE#	**30815**
		RE:	**Duxbury Seawall Rehab**
FROM:	**Kevin Buruchian**	**SUBJ.:**	**Town Public Meeting**

1. **Attendees:**
   - Peter Buttkus, Duxbury DPW
   - Kevin Mooney, DCR Waterways
   - Town Residents
   - Russell Titmuss, Bourne Consulting Engineering
   - Kevin Buruchian, Bourne Consulting Engineering

2. **Summary of Questions**
   - Do Costs shown in the report and presentation include costs associated with taking of land?
     - No, Costs shown are calculated costs for comparison reasons only
   - None of the options solve the problem of the 60yr old concrete wall, how is the old concrete going to be fixed? How much longer can we rely on the existing wall?
     - The old concrete is in reasonable condition for its age. Old concrete can remain as base for new wall.
     - The existing wall was designed for 50 yrs, so it has already lasted longer than normal life and is still in fair to good shape.
   - How many 100yr storms in last 20 yrs have we had, given we had 3 in the 1990's?
     - A 100 yr storm does not mean a storm which comes once in a hundred years, it is just a way of saying the probability of the storm happening. There is always the possibility of having two "100yr storms" back to back in the same month.
   - This Beach is still a barrier beach, thus we have to protect the beach correct?
     - Yes, however beach protection comes down to money and beach change over time
   - Existing rip rap that is in front of the wall now acts like a "trampoline making the waves worse". Why would more rip rap be the right design?
     - The existing rip rap is not high enough to be completely effective in protecting against wave action; it was an emergency repair to protect the wall foundation and prevent wall undermining.
     - A new design including riprap would have higher riprap to break up wave energy. Top of riprap needs to be above storm tide to be effective.
   - Existing Rip Rap in front of the north wall has already moved and broken apart. How come we are not using beach nourishment similar to southern states?
     - Southern states use "offshore mining" as a source of sand. Using dredge material can be very costly and US Army Corps of Engineers (USACE) performs dredging projects using cheapest practical alternative. Placing dredge material from Green Harbor dredging project on Duxbury Beach would cost approximately 3 times the current dredge and offshore disposal price.
     - Study looked at beach nourishment option and primary concerns are cost and how long it will last. We know beach levels rise and fall quickly and you could have storm event shortly after placing beach nourishment which removes a lot of the material and reduces wave protection.
   - What is the average distance between the high water and low water? Doesn't installing rip rap take away the beach?
     - Yes, adding riprap will reduce beach width. Each alternative is a trade off between levels of flood protection, cost of construction, and beach width after construction
   - How is the 100' of beach before the slope section of the beach nourishment options determined, do we need to go out 100'?
     - The 100' is an estimated distance. To get flood protection you need to go wide enough and high enough. The whole beach might not get 100' of beach, and the width will vary depending on the location and flood protection required.
   - Can there be some form of beach nourishment to maintain the beach width?

  - Nourishment is an expensive alternative, but does not mean it can't be done. With this site, sand would have to be trucked in which is costly and impacts roads and beach access during construction.
  - After a storm event, the beach needs time to rebuild and if a storm hits before it can rebuild you don't have the level of protection you paid for
  - The design of the protection will include various alternatives providing the level of protection which best suits the community
- Who decides the final design and which alternatives are used to protect the wall?
  - The public (the Town) and environmental agencies. The final design will depend on level of flood protection to be provided balanced against cost. Any repairs completed to the wall will require permitting and the permitting agencies will limit what can be done to impact the beach and existing environment.
- Where would the salt marsh be placed if used?
  - The salt marsh would be within the intertidal zone, and mostly in the areas where the most erosion is happening
- Why can't we just build a jetty or breakwaters like other towns have done?
  - Environmental agencies will not normally permit building of a hard structure like breakwaters or jetties, and they are very expensive to build
- Why does anything need to be done?
  - If nothing is done to protect the wall, the wall may eventually fail due to undermining.
- What is next?
  - The next step is this study we just completed and this meeting gaining the public's input.
- Is there a time frame for when something will be done?
  - There is no set time frame, everything has to start somewhere and this study and presentation is our beginning
- How will the public be notified of any future advancements on the project
  - Public meetings like this one with notice to abutters, similar to how the town was notified of this meeting
- Why can't we just build a deeper footing, since the footing is the cause of the failures?
  - Enhancing the footing would still require more land to be altered as the wall gets wider as it extends below the ground. A deeper footing also requires a deeper excavation increasing construction impacts
  - There are other alternatives, for example a steel bulkhead, but this is not recommended because it relies on the beach to keep the wall standing.
- Given the recommendations provided at the end of the report, will those be used going forward?
  - No, different alternatives will be used providing the level of protection which best suits the community
- How will notification of how the Selectmen and Town Manager feel regarding the issue be presented to the public?
  - There are various options which can be used. Could be through an open meeting or a transcriber but this has not been determined yet.
- Given the regulatory agencies involvement in the alternatives used, who will be leading the communication with them?
  - The agencies have already been invited to comment on the proposals. The Town will remain the lead contact as the project oves into design and permitting.
- What is the priority? Is there one section that needs to be done?
  - This wall is number one in the state in terms of needing to be repaired; the project can be done in steps and can be permitted in phases to help minimize the immediate cost associated with completing the project.
- Last repair done to the wall, material used for backfill was not great; water sits on backfill and does not drain. Can better material be used to help reduce flooding impacts?
  - The wall design will include ways of handling the water which does overtop the wall such as including drainage behind the wall.