

Salem Living Shoreline Project- Conceptual Designs

CZM Green Infrastructure for Coastal Resilience Grant

City of Salem

May 25, 2016



Introduction

Chester Engineers participated with Salem Sound Coastwatch and Jeff Elie of the City of Salem in the criteria development for a site selection decision matrix and then participated in using the matrix to prioritize approximately ten sites down to the three sites that would be evaluated further in the Feasibility and Conceptual Design task. The Site selection process is described separately in materials submitted to CZM. As part of that process descriptive profile were developed for each of the possible candidate locations (also submitted to CZM separately). Data in the profiles were used in the site evaluation process.

As part of the site selection and conceptual design process, a number of factors were considered in the site selection and evaluation process. They included:

- Erosion rates and trends,
- Aerial photography,
- Topographic information
- Sea level rise projections
- FEMA Flood Mapping
- Nearshore geology and seafloor mapping
- Sediment and sediment transport
- Marine resources
- Current usage by the public
- Tidal Datums

Factors Entering into the Design

Erosion rates and trends

Shoreline changes maps that have been compiled in MassGIS were used to identify shoreline change in the Salem area. A map is included as Figure 1. Details of the Shoreline Mapping Project are found in Thieler et al, 2013.

The coast of Salem is generally rocky with interspersed coves and pocket beaches. The shoreline change map shows that the shoreline has generally been fairly stable of the times period on the maps (going back to the 1800's). There are numerous sections of the coast that appear to have had accretion. In reality these are areas that have been filled. They are low-lying and are shown to be more vulnerable to flooding in FEMA flood maps and inundation mapping to project potential sea level rise.

Aerial photography

To assist to the review of site, aerial photography was consulted from various sources, including MassGIS and Goggle Earth. Google Earth has historical imagery going back to about 1995. Review of

historic photographs confirmed what was seen on the shoreline change maps, that is that the coast and shoreline have been generally stable.

Topographic information

Detailed and accurate topographic information is critical in designing shoreline green infrastructure projects. To assist in the interpretation of other data e.g. inundation mapping and in the formulation of designs, detailed LIDAR mapping was downloaded and processed from MassGIS. One-foot contours referenced to NAVD88 were used in our analyses. An overview map of the Collins Cove area is included in Figure 2. Detailed topographic information is included with the conceptual design for each of the three candidate sites.

Sea level rise projections

An implicit objective in the conceptual designs is to make the specific locations more resilient to rising sea levels. While no claim can be made in regard that the designs will be resilient to a specific large elevation due to limitations in the low elevations of adjacent land areas, the objective is to make the areas more resilient. For example, studies have shown that waves traveling over marsh areas can have wave height reduced by as much as 70%.

Sea level rise projections in MA CZM document have been adopted for use in this study, Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning, Massachusetts Office of Coastal Zone Management (CZM), December 2013.

This report indicates a potential intermediate high sea level rise in the Boston area of 4 feet by the year 2100.

FEMA Flood Mapping

Flood Insurance Rate Maps (FIRMs) for Salem were consulted to help identify low areas susceptible to flooding. This was a major consideration in site selection.

Nearshore geology and seafloor mapping,

Limited information is available on the nearshore marine geology in the Salem area. One comprehensive study by USGS (Barnhardt et al, 2005) describes the general nature of the areas but does not have data in the immediate nearshore areas of our candidate sites. The general environment in Salem Sound as a nearshore basis is described as follows:

The Nahant-Gloucester study area lies in the western Gulf of Maine, where the coast and inner continental shelf are bedrock framed with numerous rocky islands and rugged headlands. Bedrock in the region consists of complexly faulted and deformed intrusive rocks that range in age from Precambrian (> 540 million years) to Paleozoic (250-540 million years) (Zen and others, 1983). Bedrock is widely exposed along the shoreline and is a primary control on the shape of the coast. Rocky headlands provide shelter for small harbors and pocket beaches. The rugged topography of the seafloor is presumably due to these same rocks cropping out offshore...

The coastal landscape has been sculpted by multiple glaciations. During the last Ice Age, glaciers reached their maximum extent south of Cape Cod about 21,000 calendar years ago. As climate warmed, the glaciers retreated northward across the study area, passing the present coast about 14,500 years ago (Kaye and Barghoorn, 1964). Numerous moraines, outwash plains, drumlins, kettle lakes, and other features record the glacial history of the region. Glacial-marine sediment was deposited contemporaneously with ice retreat, blanketing wide areas of the coast and inner shelf from northeastern Massachusetts (the "Boston blue clay" - Kaye and Barghoorn, 1964) to eastern Maine (the Presumpscot Formation - Bloom, 1963). This sediment unconformably overlies older glacial deposits and bedrock, and typically consists of well stratified sand and mud with scattered dropstones of ice-rafted material. Thick sequences of glacial-marine sediment are best preserved in bedrock valleys and deep basins in the western Gulf of Maine (Belknap and Shipp, 1991). The relatively thin glacial deposits in the Cape Ann region are discontinuous and only partly mantle the underlying bedrock (Shaler, 1889).

Nearshore Basins (NB) are areas of shallow, low-relief seafloor adjacent to the mainland and separated from offshore areas by islands and shoals. Along its landward margin, the basin sediment merges with the intertidal zone in a gradational contact. One large Nearshore Basin is recognized in the study area, located inside Salem Sound and Marblehead Harbor. It is sheltered from the open ocean by small islands and shoals. The basin is bordered by the mainland coast on its landward side and terminates against Rocky Zone, Shelf Valley, and Bay-Mouth Shoal on its seaward side. The inner-most part of the basin is the Danvers River estuary. Although exposures of bedrock and coarse-grained sediment locally occur within the basins, the generally smooth seafloor primarily consists of sandy and muddy sediment. Nearshore Basins comprise 22.4 km² or 13.1% of the mapped area (table 4.1). Water depths range from 0 to 19 m.

Sediment and Sediment Transport

As with nearshore sea floor mapping, limited information on nearshore sediments in the Salem area is available. A MA Division of Marine Fisheries report (Ford et al, 2010) describes sediments in the Salem Sound area as mostly muddy, but sandy, gravelly, and hard are also common.

In our shorelines surveys done for this project, (submitted separately to CZM) intertidal sediment varies greatly by location, ranging from sand, to gravel, to rock.

There appears to be relatively little longshore sediment transport along the coast in Salem. This is a function of the rocky nature of the coast, with no long stretches of coast uninterrupted by rocky headlands. Pocket beaches may have limited transport along the beach, as well as onshore-offshore transport, depending on wave conditions.

Marine Resources

A summary of marine resources in Salem Sound is found in a 1997 report by MA Division of Marine Fisheries (Chase et al, 1997). The report focuses on biological resources including shellfish, and finfish.

This report will be a resource during future permitting of the project. It is anticipated that detailed studies and surveys will be required during the permitting phase of the project.

Current usage by the public

Usage of coastal areas considered is discussed in previous sections and was a major factor in the site selection process. City interests were a major consideration into what areas might be most important for application of coastal green infrastructure.

Tidal Datums

Understanding local tides is critically important in the design of living shoreline projects such as this. In particular, marsh grasses e.g. *Spartina* species can live in a narrow tide of tide, and if incorrectly planted relative to tide, will not survive.

The following table summarizes tidal datums for Boston. Tides referenced to NAVD88 are not available for Salem, but could be established with local surveys. As can be seen below the mean range of tide is almost 9.5 feet. The mean range of tide in Salem at Station ID: 8442645 is 8.93 feet.

Tide Datums Boston		Station 8443970
		NAVD88 (feet)
Datum	Description	
MHHW	Mean Higher-High Water	4.77
MHW	Mean High Water	4.33
MTL	Mean Tide Level	-0.42
MSL	Mean Sea Level	-0.3
DTL	Mean Diurnal Tide Level	-0.37
MLW	Mean Low Water	-5.16
MLLW	Mean Lower-Low Water	-5.51
NAVD88	North American Vertical Datum of 1988	0
STND	Station Datum	-9.03
MN	Mean Range of Tide	9.49

Conceptual Design Considerations

MAPTITE

MAPTITE (Marsh Analysis and Planning Tool Incorporating Tides and Elevations) is a ZGIS add-in that was used in the initial planning stage of the project to help establish vegetation planting zones relative to tidal datums. It was developed by National Oceanic and Atmospheric Administration (NOAA) as a tool to aid in the selection of vegetation types for different restoration elevations based on a combination of a digital elevation model (DEM) derived from GPS observations, local tidal datums, and grass type information. See <https://tidesandcurrents.noaa.gov/maptite.html>.

MAPTITE was used in conjunction with our understanding of local tides and detailed topographical information derived from the LIDAR data. A GIS MAPTITE output for the Collins Cove area is included in Figure 3.

Conceptual Design Considerations

As discussed earlier, three sites were selected for development of conceptual design of living shorelines: Collins Cove, Furlong Park, and Juniper Cove. At the onset of the project several living shoreline techniques were anticipated to be considered for implementation. Selection would be based upon evaluation of site information. The green infrastructure alternatives mentioned at the project proposal stage included:

- Beach, berm, and dune building, enhancement, or restoration with compatible sediment and native vegetation
- Bioengineering with coir rolls (on coastal banks or for salt marsh restoration/creation), natural fiber blankets, and other organic, biodegradable materials combined with planting/revegetation
- Shellfish (mussel or oyster) reef creation, enhancement, or restoration
- Fringing salt marsh creation or restoration
- Natural enhancement of existing coastal structures
- A combination of alternatives.

Beach, berm, and dune building in itself was not considered appropriate for Salem given the nature of the rocky coast with limited sediment supply, and few beaches in the areas considered most vulnerable.

Shellfish (mussel or oyster) reef creation, enhancement, or restoration was considered but is not recommended for implementation at this time. Shellfish beds in Salem are closed due to contamination concerns. Creation of reefs with edible shellfish such as oysters might be a desirable technique but since oysters might be illegally harvested that might potentially be contaminated, this technique was not pursued.

Marsh augmentation with ribbed mussels was given serious consideration. Unlike the blue mussel, ribbed mussels are not commonly eaten by people. They have been used as a component of marsh

restoration projects in Delaware Bay and elsewhere. They live in low, regularly flooded marshes and mud flats. They attach themselves to marsh grass roots and other surfaces with strong, thread-like strands secreted from the byssus gland. Particles of organic nutrients are processed into inorganic matter by the ribbed mussel which is recycled back into the mud. This concentrated inorganic material helps to enrich the surrounding mud and contributes to salt marsh growth. See <http://www.edc.uri.edu/restoration/html/gallery/invert/ribbed.htm>.

Ribbed mussel production and use in marsh restoration was the topic of a CZM grant report by Martha's Vineyard Shellfish Group in 2015. As part of the current project we talked with Rick Karney of Martha's Vineyard Shellfish Group. It appears that much was learned about growing ribbed mussels but they have not been yet to produce the mussels in quantities that would be needed for a marsh restoration project. Therefore the use of ribbed mussels in conjunction with Salem project is not recommended as this time.

The living shoreline technique considered most appropriate for the three candidate sites is to fringing salt marsh creation/restoration using bioengineered techniques with coir logs, natural fiber blankets, with plantings of *Spartina patens* and *Spartina alterniflora*. In each of the three sites, existing site features were incorporated into the design (e.g. a rock sill at Collins Cove).

A literature review was conducted to help identify viable techniques and build upon previous experiences applying these techniques. Discussion was held with some experts in the field including Dr. David Bushek of Rutgers University and Dr. David Burdick of University of New Hampshire (see Acknowledgements).

Conceptual Designs

After the literature review, a basic design was created that is similar to what is known as the DELSI Tactic, after research and implementation in many locations in Delaware Bay. Figure 4 show the basic concept, (from LIVING SHORELINES IN THE DELAWARE ESTUARY, 2013).

At each location a basic design was implemented. Figure 5 shows the basic design concept. Two rows of core logs are positioned on an arcuate pattern in the area of marsh establishment (or restoration). Each arcuate section is approximately 75 feet in length. Premium coir logs of 12 foot length are recommended. There is overlap from log to log.

Coir fiber mat may be used to provide foundation in soft substrate (if necessary) and to provide further support for new plantings of *Spartina patens* and *Spartina alterniflora*. Each species is planted at appropriate tidal elevation for optimal growth. Target range for *Spartina alterniflora* is mean sea level (MSL) to mean high water (MHW), and *Spartina patens* is targeted MSL to Mean Higher High Water (MHHW). The section in Figure 5 shows the planting zones. A mix *Spartina alterniflora* and *Spartina patens* is planted in a zone near the MHW mark. As mentioned earlier, the GIS tool MAPTITE was used to assist in establishing the planting zones.

In some locations it may be necessary to add sand to provide adequate substrate for growing the plants.

Sections are laid out to increase to size of the marsh establishment area. A small gap is left between sections to allow draining. The sections may have some preferred orientation to the shore, depending on prevalent wave direction.

Collins Cove

Conceptual designs for Collins Cove are shown in Figures 6 to 8. The approximate 700 foot section of the cove selected is parallel to Webb Street. There is some sparse marsh grass present particularly near the high tide mark. This is a low-lying area, vulnerable to flooding. There is an existing, somewhat irregular rock sill in this location. The proposed design will be implemented landward of the sill to take advantage of the wave buffering by the rocks. There is a break in the eastern portion to allow access for kayakers and others to the water.

Furlong Park

Furlong Park is another low lying area of Salem selected to consideration of implementation of a living shoreline. The conceptual design is shown in Figures 9 to 11 for this approximate 800 foot area. Furlong Park is somewhat exposed to waves with a fetch from the northeast. The design sections are slightly overlapped to allow some buffering of waves from sections to section.

The park has a shoreline bordering rock sill or low revetment. There is a single sill in the northern portion and a double sill in the southern portion. The design sections would be placed in front of the sills/revetment, due to tide elevation considerations. Figure 10 show typical sections for both areas with a single sill and with a double sill.

The extreme southern portion of the area (near the ball field) is quite low, and it may be desirable to slightly increase the height of the sill/revetment and add fill behind it as shown on Figure 10.

Juniper Cove

Juniper Cove is the third area selected for possible implementation of living shoreline as shown in Figures 12 to 15. The area is subject to flooding through an opening in the wall along Columbus Ave. There is existing marsh in this area but it does not appear to be thriving. It is partly desiccated with voids in the marsh surface. There is also a rock groin that is partially surrounded by marsh. The proposed design is intended to help expand the marsh and make the area more resilient.

The design section would be placed seaward of the existing marsh as shown in Figure 14. Due to the elevation of the marsh, the coir logs would be placed at a lower elevation than the other two areas, and would serve to provide some buffering while the marsh gets restored.

Figure 15 shows a before and after rendition of what the Juniper Cove area may look like after implementation.

Cost Estimate

The approximate materials cost for a typical design section is included in the table below.

**Salem Living Shoreline Costs, per
typical 75 foot section Source
Pinelands Nursery, NJ)**

Item	Quantity	Unit Cost	Total Cost
12" Coir Log	14	\$ 93.00	\$ 1,302.00
6.5' x 165' Coir Fiber Mat	1	\$ 248.00	\$ 248.00
2"x2"x4' Hardwood Stakes (12 per log)	168	\$ 2.25	\$ 378.00
1/8" Duckbill Earth Anchors (2 per log)	28	\$ 13.00	\$ 364.00
Spartina Alternaflora Plugs (12" O.C.)	635	\$ 0.70	\$ 444.50
Spartina Patens Plugs (18" O.C.)	236	\$ 0.70	\$ 165.20
Total			\$ 2,901.70

It is not known at this time how the project might be implemented in regard to contracting or a possible community volunteer project. It is also not known if any or all three areas are implemented, or complete designs are implemented or just portions of an area. This will obviously affect costs. Detailed cost estimate will be developed at the detailed design and construction stage.

The following are rough cost estimates for installed costs, on unit cost basis:

- Coir logs (12" diameter)—including purchase & delivery, duckbill anchors, wood stakes and labor—**\$50.00 / LF**.
- Coir Fiber Matting—all-in cost as well—**\$5.00 / SY**.
- Salt Marsh Plugs—all-in—**\$4.00 / Each**, inclusive of warranty.
- Fill Material—furnished and placed—can vary quite a bit depending on composition, quantity and access. Given the anticipated small quantities for these locations, approximately **\$80 - \$100 / CY**. If the quantity gets bigger, unit price could come down.

Permitting

Permitting would be conducted at the next project phase after a specific project is defined and designs are further developed. A number of permits are potentially applicable.

It is recommended that as project specifics are being developed that a meeting be held with CZM staff (starting with Kathryn Glenn, North Shore Regional Coordinator) to discuss permitting needs and to get guidance on the most efficient route to permitting.

The following are some of the permits and regulatory considerations potentially applicable to this project.

- Wetland Protection Act—Notice of Intent (City of Salem Conservation Commission)
- Section 401 Water Quality Certification
- Section 404 of the Clean Water Act for dredge or fill (Army Corps of Engineers)
- CZM Federal Consistency
- Chapter 91 Public Waterfront Act MA Environmental Policy Act Filing
- Massachusetts Endangered Species Act
- DMF Resource Survey (100 foot minimum from project location (sea grass, lobster, winter flounder, cod, and horseshoe crabs) NMFS Essential Fish Habitat (multiple species).

Acknowledgements

Dr. David Buskek of Rutgers University, Haskin Shellfish Research Laboratory, was very helpful in discussing design concepts. He reviewed draft conceptual designs and offered beneficial comments.

Dr. David Burdick of University of New Hampshire also reviewed the initial designs and provided helpful comments.

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Thieler, E.R., Smith, T.L., Knisel, J.M., and Sampson, D.W., 2013. Massachusetts Shoreline Change Mapping and Analysis Project, 2013 Update: U.S. Geological Survey Open-File Report 2012-1189, 42 p., <http://pubs.usgs.gov/of/2012/1189/>.

FIGURES

Figure 1: Shoreline Change Map

Figure 2: Collins Cove LiDar

Figure 3: MAPTITE Output Collins Cove Area

Figure 4: DELSI Tactic

Figure 5: Typical Living Shoreline Concept Plan

Figure 6: Collins Cove Design Layout Concept

Figure 7: Collins Cove Living Shoreline Concept Section

Figure 8: Collins Cove Typical Living Shoreline Concept Plan

Figure 9: Furlong Park Design Layout Concept

Figure 10: Furlong Park Living Shoreline Concept Sections

Figure 11: Furlong Park Typical Living Shoreline Concept Plan

Figure 12: Juniper Cove Design Layout Concept

Figure 13: Juniper Cove Living Shoreline Concept Section

Figure 14: Juniper Cove Typical Living Shoreline Concept Plan

Figure 15: Juniper Cove Living Shoreline Rendering

FIGURE 1: SHORELINE CHANGE MAP



SALEM, MA

MORIS_Shoreline Changes 1844 - 2009

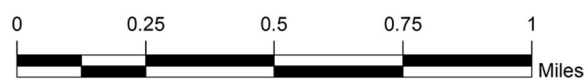


FIGURE 2: COLLINS COVE LIDAR



COLLINS COVE - SALEM, MA

Massachusetts 2013-2014 USGS Ortho Imagery

2013-2014 Sandy DEM Data LiDAR

Contours referenced to NAVD88 (feet)

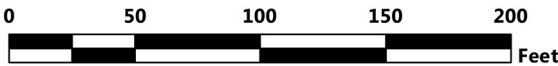


FIGURE 3: MAPTITE OUTPUT COLLINS COVE AREA



COLLINS COVE - SALEM, MA

MAPTITE Planting Zones based on 2013-2014 Sandy DEM Data
Contours referenced to NAVD88 (feet)

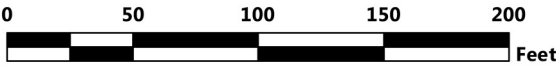


FIGURE 4: DELSI TACTIC

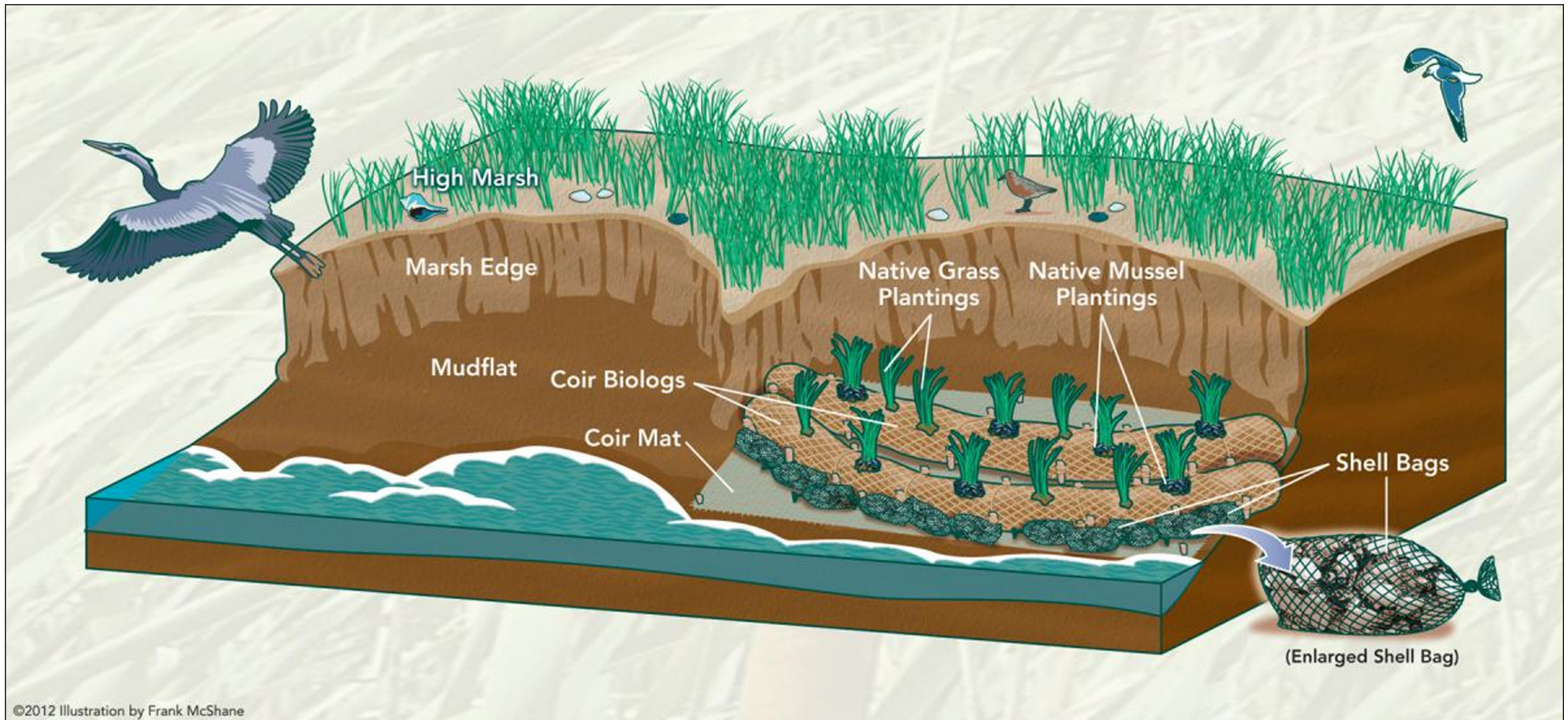
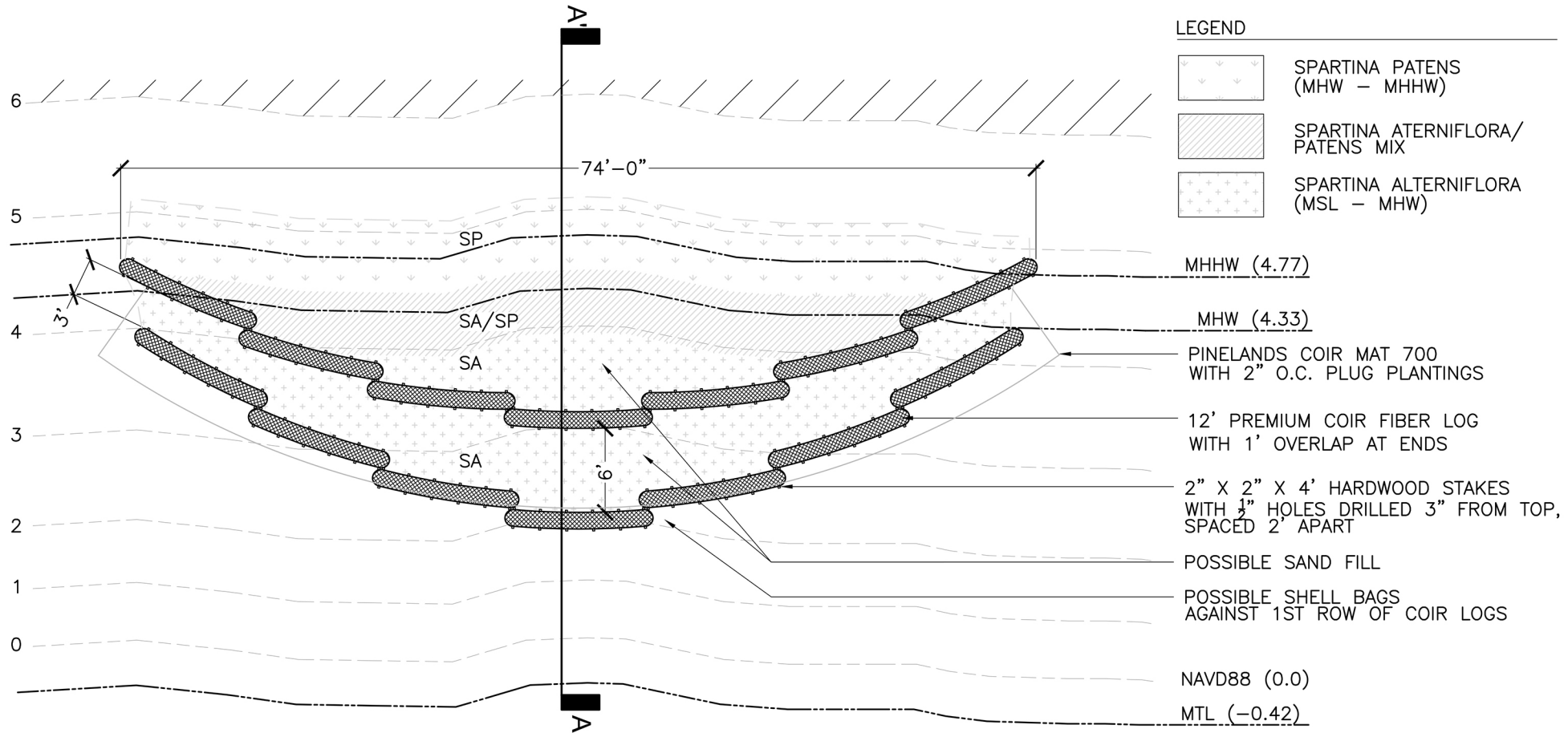


Illustration of DELSI Tactic which uses a combination of native wetland plants, natural structures, and intertidal shellfish to trap sediment and absorb waves.

FIGURE 5: TYPICAL LIVING SHORELINE CONCEPT PLAN



- NOTES:
- 1. TIDE ELEVATIONS BASED ON TIDAL DATUMS FOR BOSTON AREA, REFERENCED TO NAVD88 (FEET)
 - 2. RIBBED MUSSELS MAY BE ADDED IN CONJUNCTION WITH SPARTINA PLANTINGS

TYPICAL LIVING SHORELINE CONCEPT PLAN

SALEM, MA

FIGURE 6: COLLINS COVE DESIGN LAYOUT CONCEPT



COLLINS COVE - SALEM, MA

Design Layout Concept
Contours referenced to NAVD88 (feet)

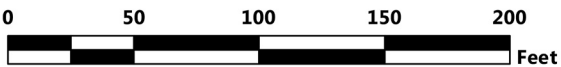
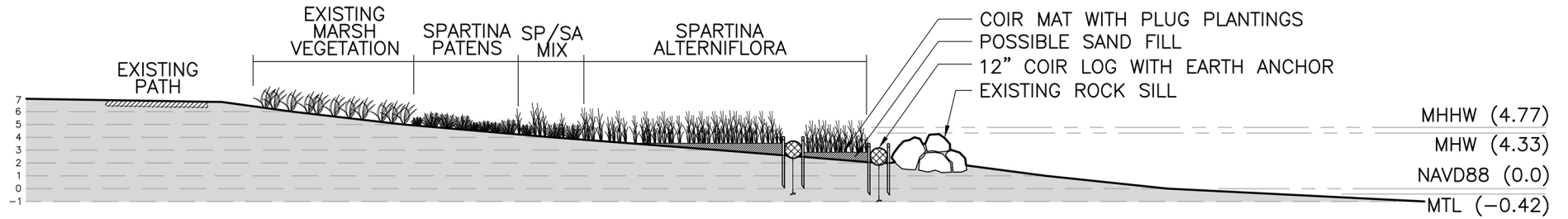


FIGURE 7: COLLINS COVE LIVING SHORELINE CONCEPT SECTION

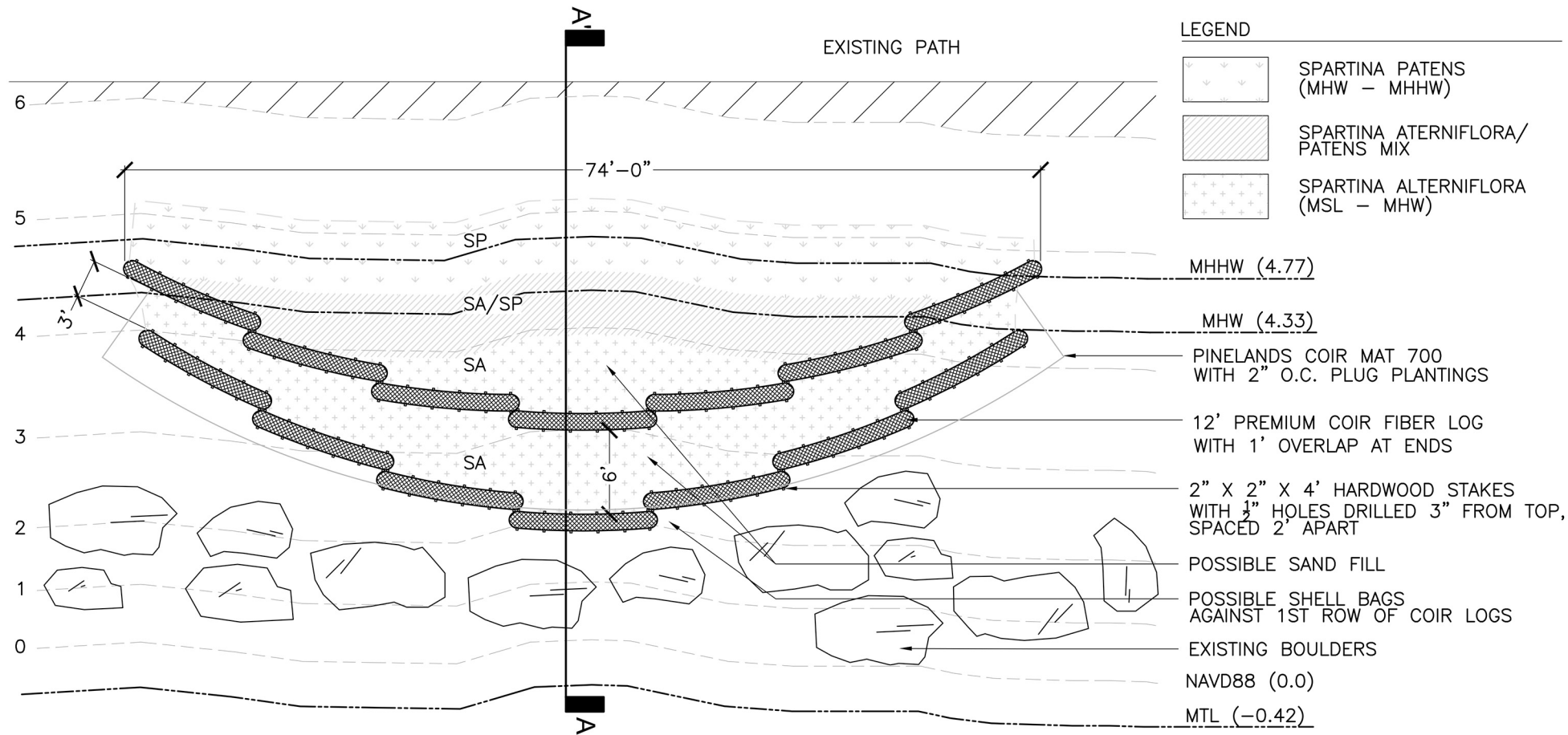


NOTE:
FUTURE CONSIDERATION MAY BE GIVEN TO
RAISING THE ELEVATION OF THE EXISTING PATH
(APPROXIMATELY 1' - 0")

COLLINS COVE LIVING SHORELINE CONCEPT SECTION

SALEM, MA

FIGURE 8: COLLINS COVE TYPICAL LIVING SHORELINE CONCEPT PLAN



TYPICAL LIVING SHORELINE CONCEPT PLAN: COLLINS COVE
SALEM, MA

FIGURE 9: FURLONG PARK DESIGN LAYOUT CONCEPT



FURLONG PARK - SALEM, MA

Design Layout Concept
Contours referenced to NAVD88 (feet)

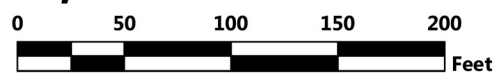
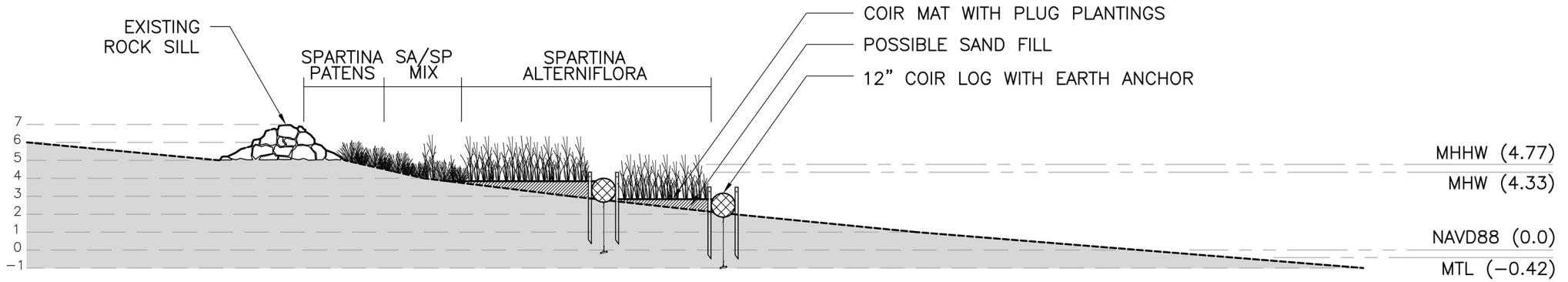
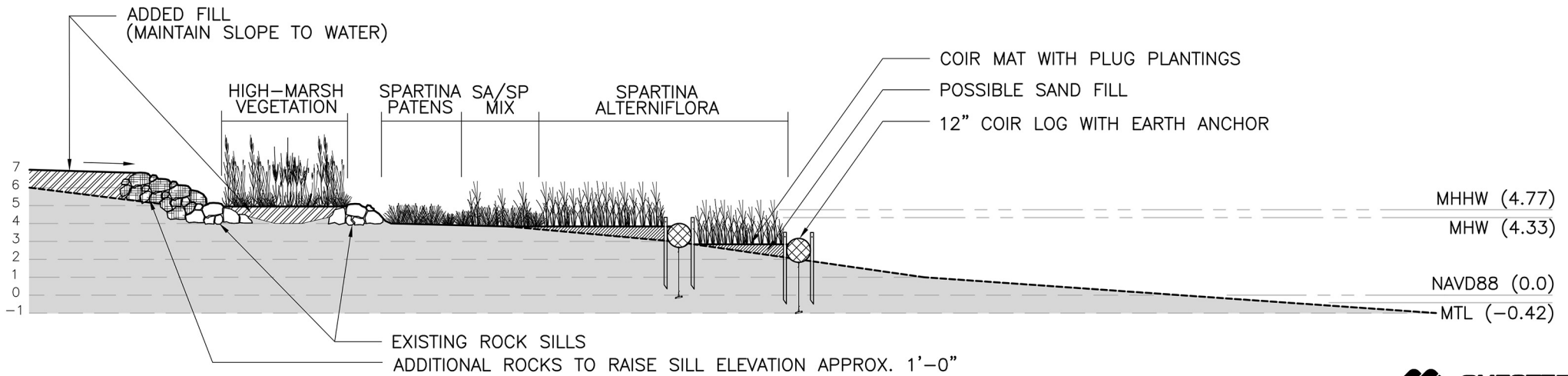


FIGURE 10: FURLONG PARK LIVING SHORELINE CONCEPT SECTIONS

SECTION A - A'



SECTION B - B'



FURLONG PARK LIVING SHORELINE CONCEPT SECTIONS

SALEM, MA

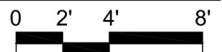
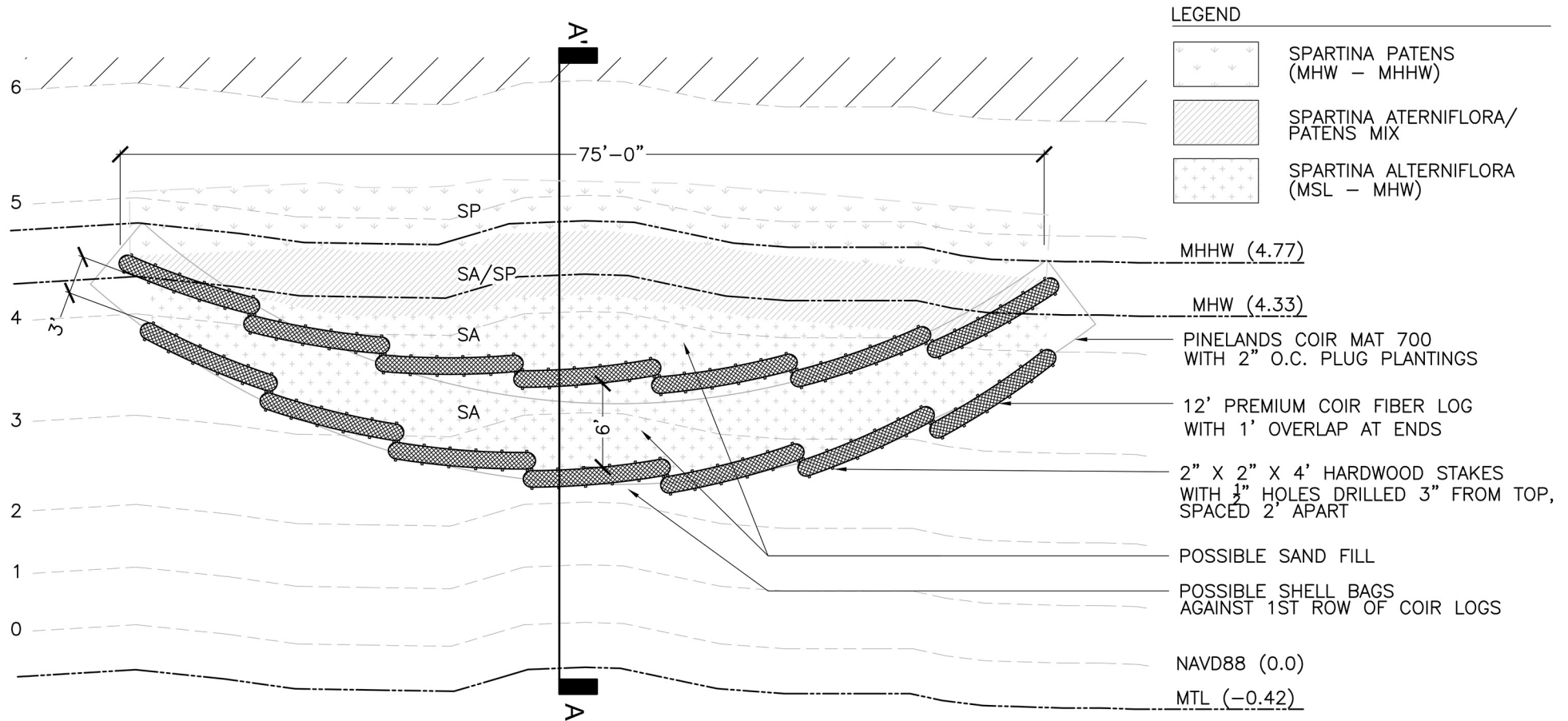


FIGURE 11: FURLONG PARK TYPICAL LIVING SHORELINE CONCEPT PLAN



NOTES:

1. TIDE ELEVATIONS BASED ON TIDAL DATUMS FOR BOSTON AREA, REFERENCED TO NAVD88 (FEET)
2. RIBBED MUSSELS MAY BE ADDED IN CONJUNCTION WITH SPARTINA PLANTINGS

TYPICAL LIVING SHORELINE CONCEPT PLAN: FURLONG PARK

SALEM, MA



FIGURE 12: JUNIPER COVE DESIGN LAYOUT CONCEPT



JUNIPER COVE - SALEM, MA

Design Layout Concept

Contours referenced to NAVD88 (feet)

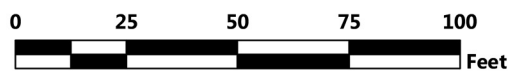
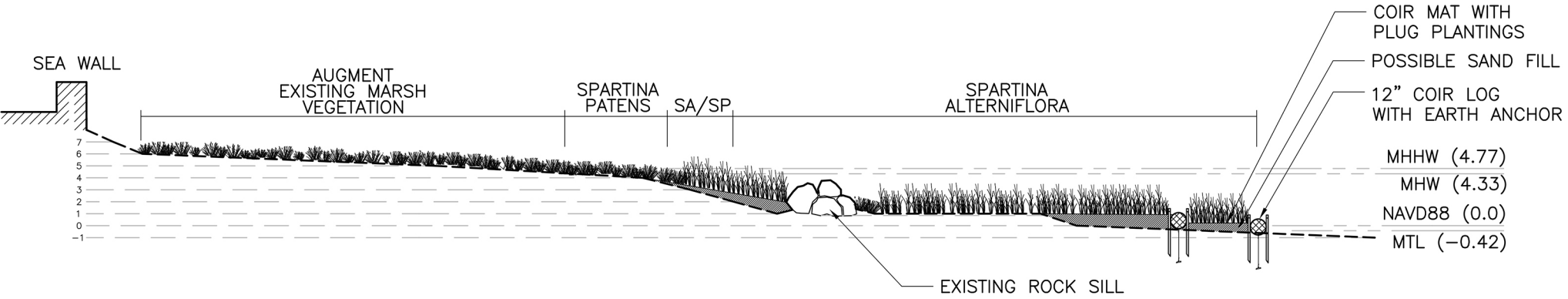


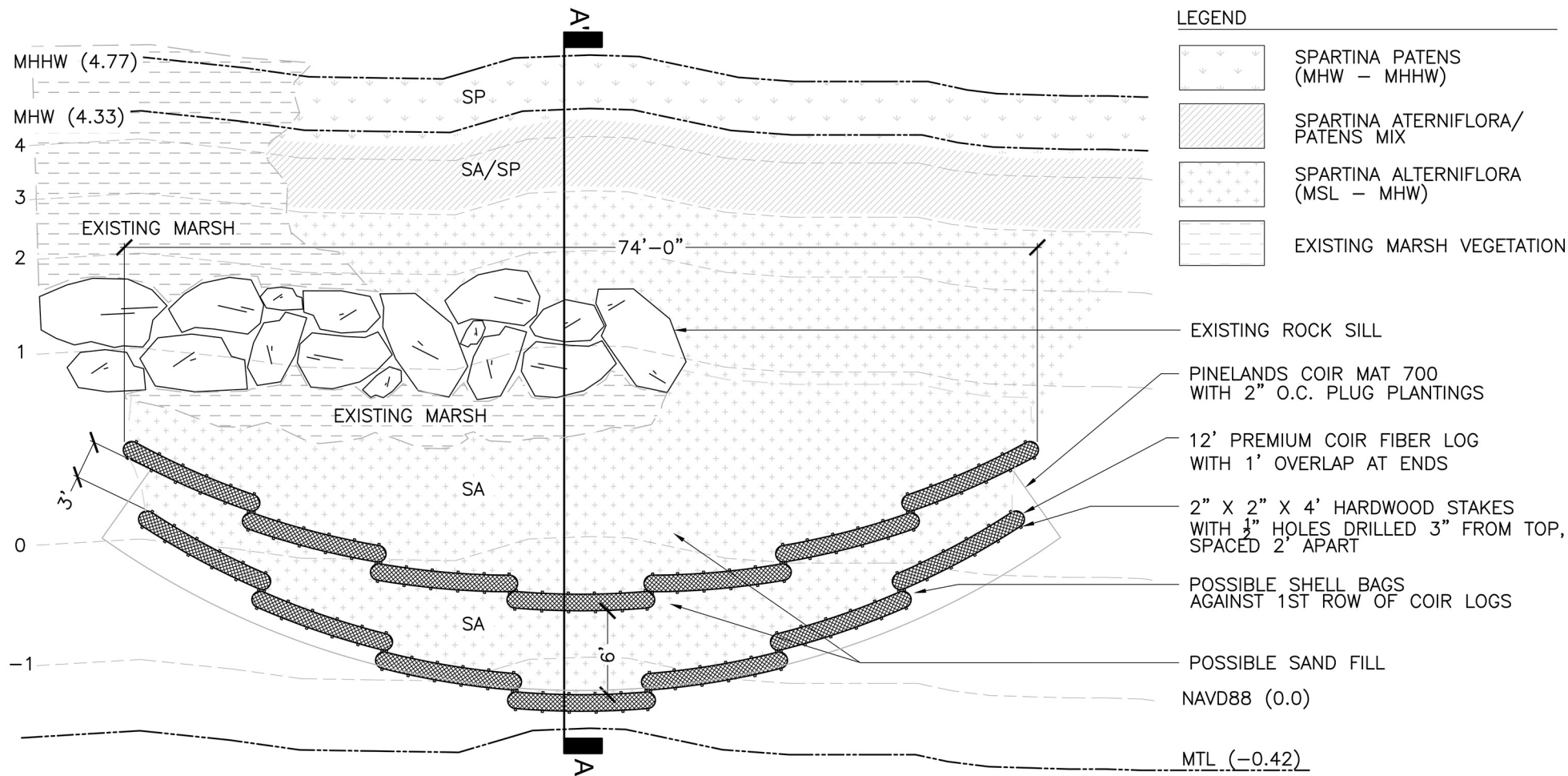
FIGURE 13: JUNIPER COVE LIVING SHORELINE CONCEPT SECTION



JUNIPER COVE LIVING SHORELINE CONCEPT SECTION

SALEM, MA

FIGURE 14: JUNIPER COVE TYPICAL LIVING SHORELINE CONCEPT PLAN



NOTES:

1. TIDE ELEVATIONS BASED ON TIDAL DATUMS FOR BOSTON AREA, REFERENCED TO NAVD88 (FEET)
2. RIBBED MUSSELS MAY BE ADDED IN CONJUNCTION WITH SPARTINA PLANTINGS

TYPICAL LIVING SHORELINE CONCEPT PLAN: JUNIPER COVE

SALEM, MA



0 4' 8' 16'

FIGURE 15: JUNIPER COVE LIVING SHORELINE RENDERING



JUNIPER COVE LIVING SHORELINE RENDERING
SALEM, MA