Tyndall Air Force Base Pilot Project, Living Shoreline: 60% Basis of Design Report

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Acronyms and Abbreviations

AFB	Air Force Base
BASH	Bird/Wildlife Aircraft Strike Hazard
BOD	Basis of Design
CRIP	Coastal Resilience Implementation Plan
EWL	extreme water level
FWC	Florida Fish and Wildlife Conservation Commission
Hm0	significant wave height
LMJ	Larry M. Jacobs & Associates, Inc.
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
N/A	not applicable
NAVD 88	North American Datum of 1988
NBS	nature-based solutions
NOAA	National Oceanic and Atmospheric Administration
RP	return period
s	second(s)
SACS	South Atlantic Coastal Study
SAV	submerged aquatic vegetation
SEARCH	SEARCH, Inc.
SLR	sea level rise
TNC	The Nature Conservancy
T_p	peak period
UF	University of Florida
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force

1. Introduction

Tyndall Air Force Base (AFB) in Florida's panhandle is strategic for military preparedness and includes important natural coastal features on and adjacent to the Base. Tyndall AFB was severely damaged by Hurricane Michael in 2018. The Department of Defense is committed to rebuilding Tyndall AFB to make it more resilient to future storms and sea level rise (SLR). The first stages of planning for Tyndall AFB's reconstruction revealed that nature-based solutions (NBS) can play a significant role in making Tyndall AFB more resilient while also providing important ecosystem services.

In March 2022, The Nature Conservancy (TNC), along with Jacobs, the University of Florida (UF), and the Naval Research Laboratory entered into an agreement with the National Fish and Wildlife Foundation (Grant Identification 0318.22.073433) for a $4.8 million award from the Readiness and Environmental Protection Integration 2021 Challenge. The grant award is being used to design and permit three specific NBS projects as part of Tyndall AFB's layered coastal defenses. The three nature-based design projects, shown on **Figure 1-1**, include a Living Shoreline, an Oyster Reef Breakwater, and a Submerged Shoreline Stabilization.

This Basis of Design (BOD) report focuses on the project site for the Living Shoreline, situated along the East Bay in the northwest portion of Tyndall AFB, the location is shown on **Figure 1-2**. This pilot project is proposed to restore and enhance coastal habitat to improve the overall resilience to future storms and SLR. The Living Shoreline pilot project is intended to reduce shoreline erosion and potentially promote shoreline accretion, which reduces flood risk and protects against land loss that could directly impact the area by damaging the infrastructure supporting mission-critical assets, such as the fuel depot area of Tyndall AFB, shown on **Figure 1-2**.

This BOD report describes the evaluation and basis of the preliminary (60%) design for the Living Shoreline pilot project at Tyndall AFB. The objectives of the Living Shoreline pilot project are to achieve the following:

- Reduce long-term shoreline erosion under operational conditions.
- Enhance the natural coastal habitat, such as existing seagrass and low marsh habitat.

Figure 1-1. Location of the Proposed Nature-based Resilience Projects

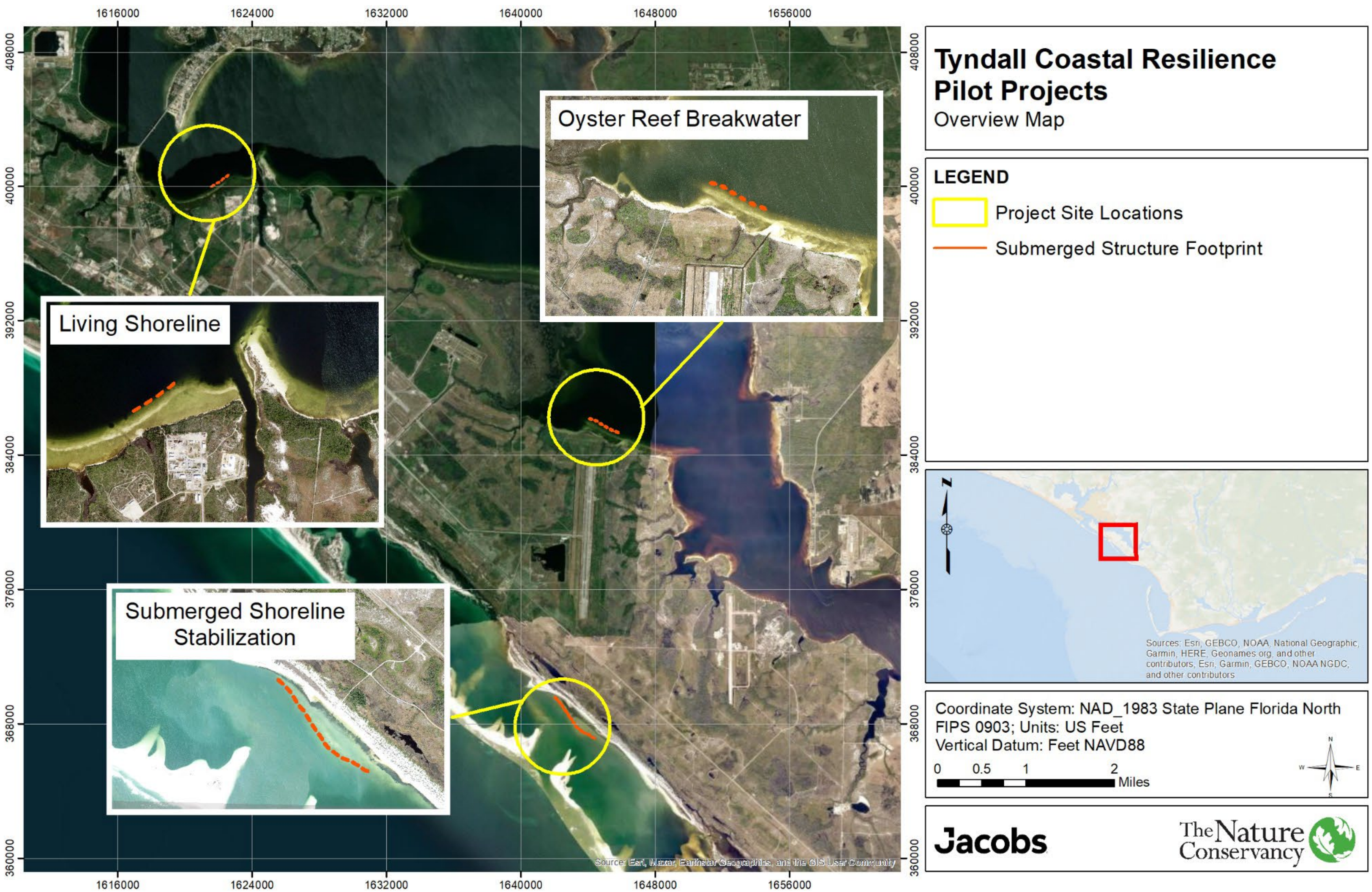


Figure 1-2. Project Location

1.1 Tyndall Air Force Base Pilot Project Design Scope of Work

The pilot projects leverage NBS to lower the risks that arise from coastal processes to improve Tyndall AFB's resilience and enhance its natural environment, which is vital to our national defense. In addition to reducing local wave hazards, NBS offer a range of co-benefits associated with natural habitats by attracting marine life. NBS are potentially less costly than hard defenses and are also self-maintaining.

These pilot projects were also considered as part of the *Coastal Resilience Implementation Plan* (CRIP) (USAF 2022). The CRIP was a U.S. Air Force (USAF)-funded project to support mission assurance for Tyndall AFB from severe weather and SLR-related coastal flood inundation. The CRIP provides a roadmap to guide coastal resilience project siting, planning, design, funding, and implementation and the associated timing of these activities based on the evolution of coastal flood risk from climate change.

The Living Shoreline pilot project was selected to demonstrate how some features could reduce the risk of wave hazards and long-term erosion. The goal was to lower both risks, which are expected to increase over time as sea levels rise, using NBS because they can be less costly than traditional coastal defenses, are self-maintaining, and offer a range of co-benefits associated with natural habitats. In addition, the pilot project is located near a mission-critical fuel depot area (**Figure 1-2**), which is a critical asset for Tyndall AFB.

The primary objective of the pilot project is to provide risk-reduction benefits to the shoreline by reducing wave heights and potential erosion that could occur in the future because of SLR.

These reductions are the result of physical and biophysical processes, underscoring the importance of the ecological components of an NBS. A secondary objective is for the solution to be adaptable in the future, allowing more material to be added to increase the structure height if desired; for example, to account for SLR or balance out excessive settlement.

1.2 Report Organization

This BOD report summarizes the 60% design analysis for the proposed Living Shoreline pilot project at Tyndall AFB. The report is structured as follows:

- **Section 2** presents an existing site overview.
- **Section 3** discusses the general site data.
- **Section 4** presents the BOD conditions.
- **Section 5** provides information regarding the design components and drawings.

A series of appendices are also provided:

- **Appendix A.** Bathymetric Survey
- **Appendix B**. Geotechnical Report
- **Appendix C**. Material Alternative Analysis
- **Appendix D**. Cost Estimates
- **Appendix E**. 60% Drawings Package
- **Appendix F**. Specifications

2. Existing Site

2.1 Site Overview

Tyndall AFB is on a peninsula along Florida's panhandle, southeast of Panama City in Bay County, Florida. It is surrounded by the waters of the Gulf of Mexico to the south, St. Andrew Bay to the west, and East Bay to the north. Tyndall AFB includes the barrier islands of Crooked Island West and East, which form St. Andrew Sound, as well as the barrier island of Shell Island, which makes up the southeastern shoreline of St. Andrew Bay.

Today, Tyndall AFB occupies the site of a former gunnery range known as Tyndall Field, which was opened in 1941. Before its construction, the site was covered with pine and palmetto trees, scrub brush, and swamps. The facility was renamed "Tyndall Air Force Base" in 1948, following the establishment of the USAF in 1947 (USAF 2020).

Tyndall AFB is subject to flooding from coastal surge propagation on both sides of the peninsula and upland rainfall runoff. If the phenomena occur simultaneously, the coastal surge may cause a hydraulic constraint on the surface drainage system of the Base, which outfalls to East Bay and St. Andrew Bay (Jacobs 2020).

Tyndall AFB and Bay County are in a very high-risk hurricane zone, where 97 tropical storms or hurricanes have been recorded within a 60-nautical-mile radius between 1851 and 2022. Hurricane Michael is the only recorded Category 5 storm recorded within this 60-mile radius (NOAA 2023a).

The longest fetch lengths at the project site within the St. Andrew Bay are northeast and northwest with lengths of 3.62 and 2.18 miles.

Based on the CRIP, Tyndall AFB will continue to experience coastal flooding through SLR and event-based storm surge through the year 2100 (USAF 2022). In preparation for these conditions, Tyndall AFB is taking measures to protect the mission and support resources around the Base's assets. This includes building or enhancing traditional gray infrastructure, such as flood walls and levees, and promoting NBS such as the Living Shoreline pilot project.

The Living Shoreline project site is along the shoreline of East Bay, approximately 1 mile southeast of the DuPont Bridge. Waves at the site will be limited to wind waves generated in the bay. The geometry of the bay limits exposure of the site to waves due to limits of the fetch over which waves can be generated, as well as shoreline features that shelter the area from waves generated within the bay, particularly the spit just east of the site at the mouth of Fred Bayou. The bayou provides some shelter from waves approaching from the northeast direction.

2.2 Site Constraints

Limiting constraints on the siting and design of components of the Living Shoreline design include the following:

- Work is limited to in-water areas. Structures are not intended to be located in upland areas above the mean high water line.
- Seagrass beds are not to be disturbed and in-water construction must be located seaward of these beds.

- During consultation after the 30% design submission the Bird/Wildlife Aircraft Strike Hazard (BASH) group raised concerns that emerged structure segments would attract birds and therefore endanger the aircraft traffic at Tyndall AFB. Only structures submerged at mean lower low water (MLLW) are to be considered. Further discussion is in Section 4.3.3.

To address the seagrass bed constraint, the structures will be sited a minimum of 25 feet seaward of the existing seagrass beds. To address BASH concerns, structures will be constructed in water depths with bottom elevations of between approximately -9 to -10 feet North American Vertical Datum of 1988 (NAVD 88) and have a crest level at MLLW.

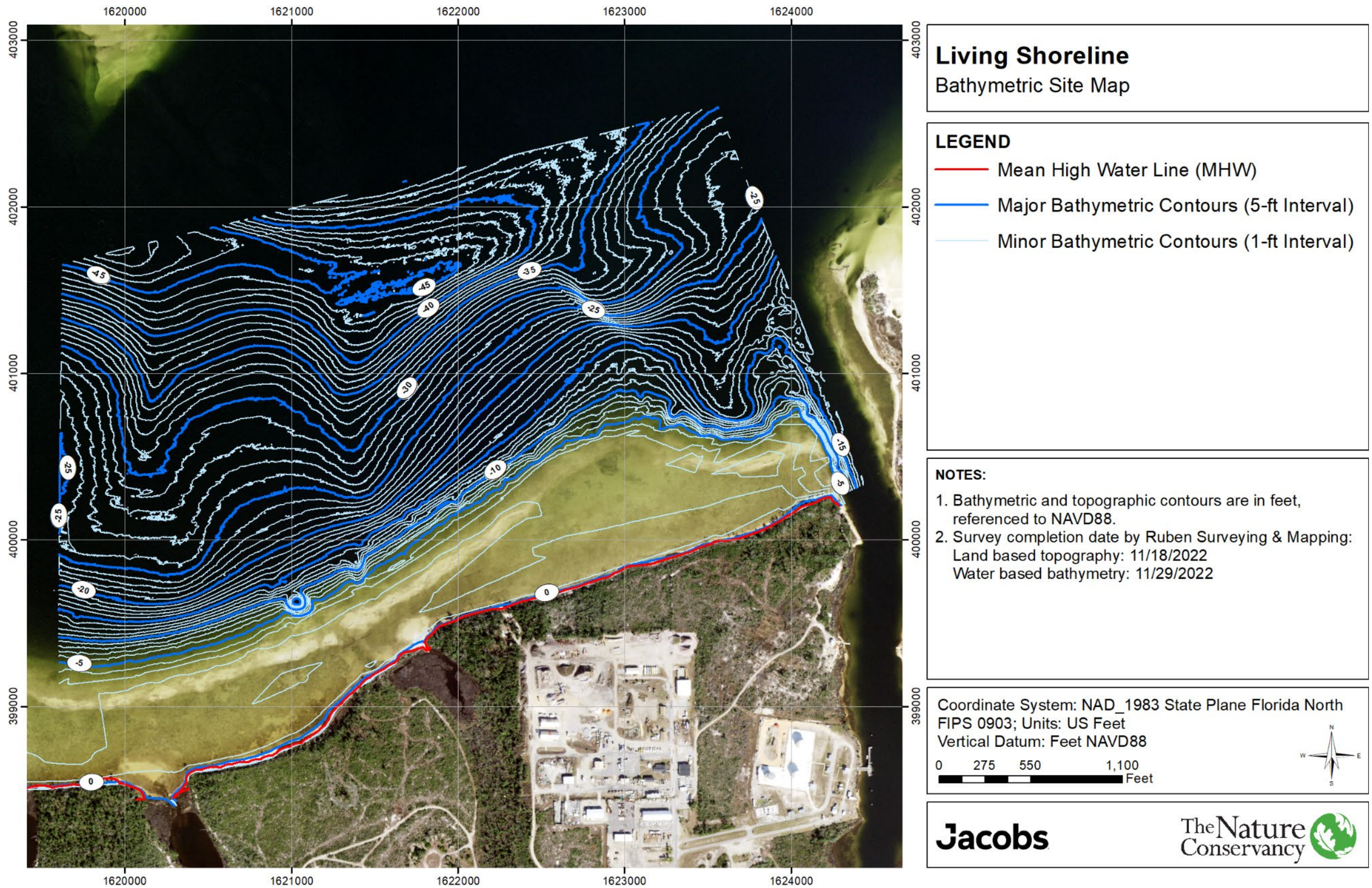
3. General Site Data

3.1 Bathymetry and Topography

Site-specific topographic and bathymetric data were collected at the Living Shoreline pilot project site in November 2022 by Ruben Surveying and Mapping, Inc. These data provide the basis for siting and development of the structures for the pilot project designs.

The data collected show that the project area is typified by shallow nearshore water depths with a gentle nearshore gradient to a water depth of approximately -2.0 to -4.0 feet NAVD 88 before dropping off into deeper water depths of the bay. **Figure 3-1** shows bathymetric contours at the Living Shoreline project site during the November 2022 survey. Mean high water at elevation 0.74 foot NAVD 88 (refer to **Section 3.3.1**) is shown on the figure for reference. The bathymetric survey is provided in **Appendix A**.

Figure 3-1. Site Bathymetry



3.2 Shoreline and Submerged Aquatic Vegetation

This section discusses existing and historic shoreline conditions and submerged aquatic vegetation (SAV) extents based on available aerial imagery, site photographs, and field data collected between May and December 2022, as documented by UF (UF 2022a).

3.2.1 Shoreline Conditions

Figure 3-2 shows a view of the shoreline along the Living Shoreline project site taken during a site visit in October 2022.

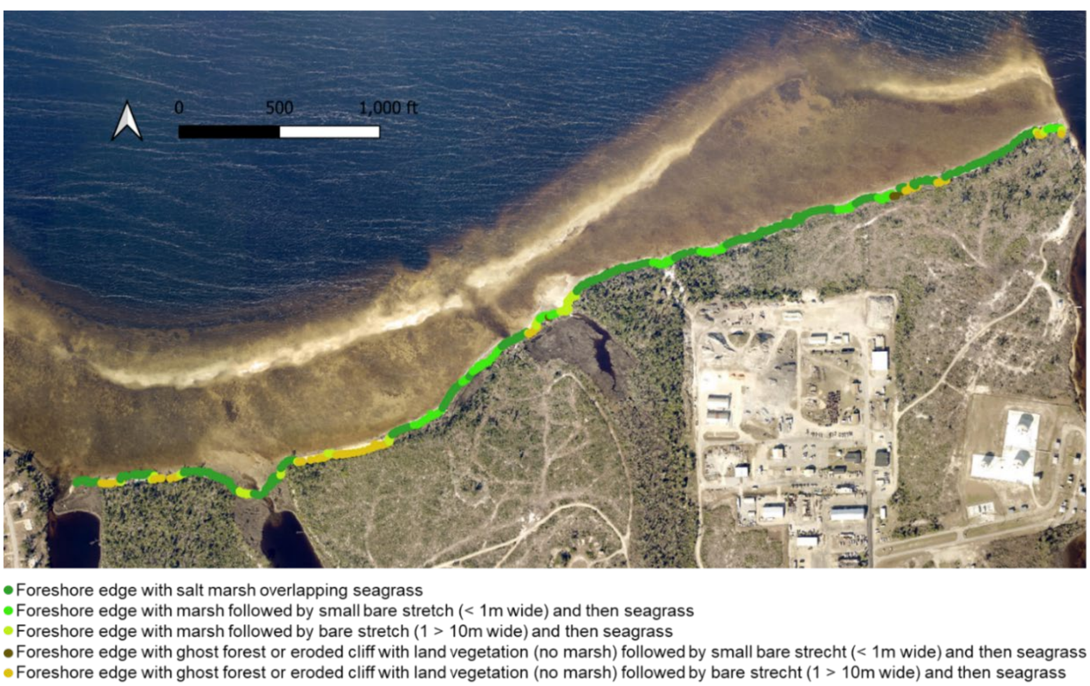
Review of aerial imagery datasets from 2007 to 2020 shows that the shoreline has not measurably retreated between 2007 and 2015. However, photograph documentation from a site visit by UF personnel in May 2022 shows isolated dead pine trees along the shoreline, some with roots extending into the water, suggesting recession has occurred over the long-term (refer to **Figure 3-3**). Future SLR may alter shoreline recession trends in part depending on future sedimentation trends.

Data on characteristics of the shoreline and saltmarsh habitats were documented by UF (UF 2022b) and are summarized on **Figure 3-4**.

Figure 3-2. Site Visit Photograph of the Project Site Shoreline, October 2022

Figure 3-3. Site Visit Photographs of Dead Trees along the Shoreline at the Project Site, May 2022

Figure 3-4. Foreshore Characterization along the Project Site Shoreline



Source: UF 2022b

3.2.2 Submerged Aquatic Vegetation

SAV, specifically seagrass, is a principal physical design constraint but also one of the main resources to be protected at the Living Shoreline project site. Therefore, import and placement of material is limited to areas beyond the seaward limits of existing seagrass footprint.

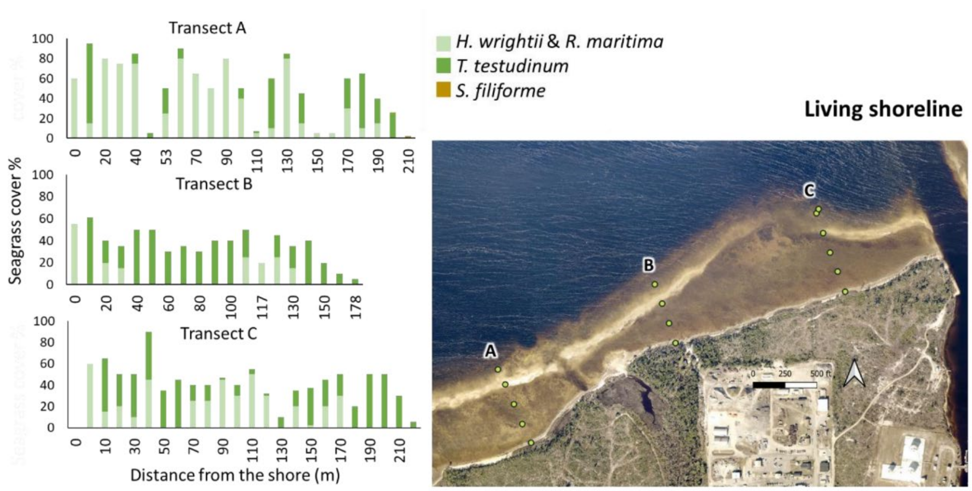
UF performed a survey to record the current extent of SAV at the project site during the peak growing season (from June 1 to September 30). The extent of the seagrass at the Living Shoreline project site during the 2022 survey is shown on **Figure 3-6** and compared with its extent in 2010 based on a mapping of seagrass habitat in Florida documented by the Florida Fish and Wildlife Conservation Commission (FWC) (2022). The data suggest that the extent of the seagrass has experienced little change between 2010 and 2022.

During the survey, UF also recorded the various existing seagrass types and their percent cover along three transects at the Living Shoreline project site. The location of the three transects is illustrated on the right side of **Figure 3-5**. On the left side of **Figure 3-5**, the percent cover is shown over the distance from the shore. The distribution in **Figure 3-5** includes seagrass types *H. wrightii* and *R. maritima*, *T. testudinum*, and *S. filiforme,* which are the most common types noted at the project site.

In the ecological surveys, UF characterized the seagrass as follows:

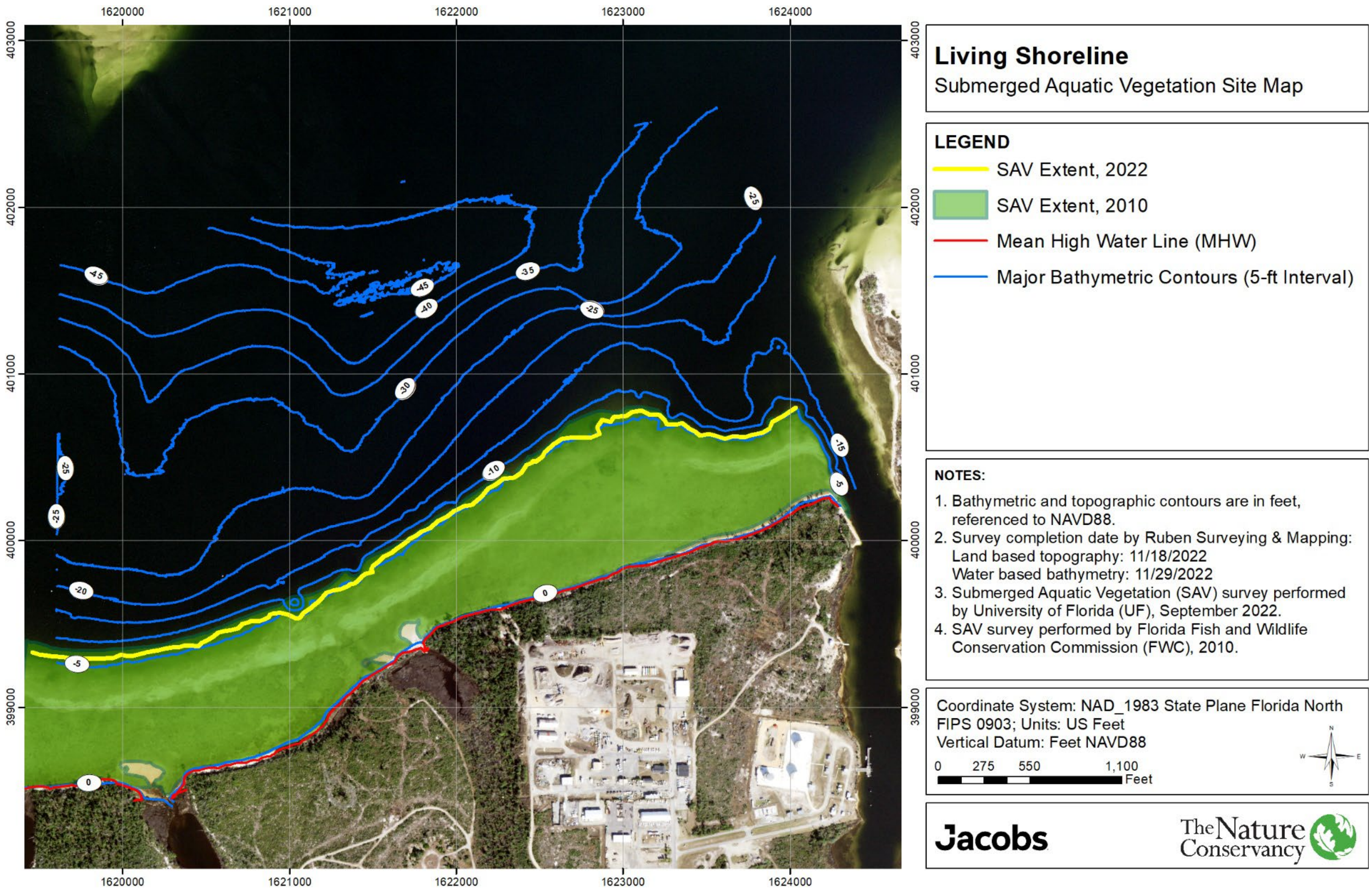
> "Seagrass cover was dominated by a mix of *H. wrightii* and *R. maritima* followed by *T. testudinum*, with overall seagrass percent covers ranging between 40 to 60% and up to 90%. A sand bar was found along the meadow parallel to the coast around 150 m from the shore. In this sand bar, seagrass densities were low (1 to 10%). Low percentage (~ 5 %) of *S. filiforme* and a patch of *H. engelmannii* (~ 2 m^2) was found when delineating the deep seagrass edge. Macroalgae cover was low (2 to 10%), mainly consisting of *Hypnea* spp., *Chondria* spp. and sporadic *Acetabularia* spp. Macroalgae cover increased in the deep edge, up to 100% cover. Overall, other organisms such as sponges were not found but few oysters were found attached to wood debris. Epihpyte load was heavy compared to the other locations. The most dominant epiphyte was an unidentified gelatinous algae or bacteria. Other components of epiphyte cover were filamentous brown algae and *Bittium spp.* (small snails). Seagrass shoot length was ~ 15 to 20 cm for *H. wrightii* with *R. maritima* and ~ 20 cm for *T. testudinum*." (UF 2022b)

Figure 3-5. Seagrass Percent Cover along the Three Survey Transects



Source: UF 2022b

Figure 3-6. Submerged Aquatic Vegetation Extent Based on UF Survey and FWC Database Extent



3.2.3 Cultural Resources Survey Impact

Jacobs subcontracted SEARCH, Inc. (SEARCH), to perform a maritime archaeological survey to identify known cultural resources in and near the project area and provide a brief historic context to help guide the planning of geotechnical investigations and siting of the project elements (SEARCH 2023). The survey was conducted on March 11 and 12, 2023.

SEARCH reported that the identified magnetic anomalies and acoustic contacts do not indicate submerged cultural resources of potential significance. Based on the data recorded during the field survey, SEARCH did not recommend additional archaeological work. If unanticipated archaeological discoveries occur during the construction phase, SEARCH recommends the cessation of work in those portions of the project site.

3.2.4 Geotechnical Conditions

Jacobs subcontracted Larry M. Jacobs & Associates, Inc. (LMJ), to perform a geotechnical investigation following the cultural resources survey at the project site. The purpose of the geotechnical investigation was to provide information to the design team for the stability of the structure and refine the preliminary design (LMJ 2023, **Appendix B**).

The borings at the site of the Living Shoreline project were conducted between May 17 and 18, 2023. The locations of the borings are highlighted on **Figure 3-7**. Boring sits B-1, B-2, and B-3 are within the project extent of the Living Shoreline.

For the Living Shoreline, the borings generally showed white, tan, and gray sand soils to the bottom of the borings at roughly 9.5 feet below the mudline at the time of drilling. At boring B-1, a layer of light gray silty sand was noted at roughly 8 to 9.5 feet below the mudline. Overall, the soils in these borings were mostly loose with some medium dense areas to the bottom of the borings, except for boring B-1, which encountered a very loose soil layer at roughly 8 to 9.5 feet below the mudline. The mudline at these locations was roughly 4 feet below the surface of the water at the time of drilling (**Appendix B**).

LMJ undertook laboratory tests to assist in soil classification and to document soil properties. The tests included grainsize analysis, hydrometer testing, wash #200 sieve tests, natural moisture content tests, organic content tests, specific gravity, and Atterberg limits tests run on selected split spoon samples. The results for conducted tests are summarized in the Geotechnical Data Report provided in **Appendix B**.

Figure 3-7. Boring Locations of Geotechnical Investigation

Source: LMJ 2023

3.3 Metocean Conditions

Hydrodynamic conditions at the site were summarized based on data and modeling results presented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). Parameters of interest for the Living Shoreline pilot project include the following:

- Water levels
- Currents
- Waves

Water levels address the existing tidal variations, potential extreme events due to storm surges, and the potential for future SLR.

Current and wave conditions are based on hydrodynamic and wave modeling. The applied models were calibrated based on collected field data. The modeling results are summarized in **Sections 3.3.2** and **3.3.3** for currents and wave conditions, more detailed information is documented in the 60% Design Modeling report (Jacobs 2023, 2024).

3.3.1 Water Levels

The following sections describe water level information, including tidal environment, extreme water levels (EWLs), SLR, and design total water levels.

3.3.1.1 Tidal Environment

The tidal datums for the project are based on the National Oceanic and Atmospheric Administration (NOAA) gauge station at Panama City (NOAA 2023b), shown on **Figure 3-8** and listed in **Table 3-1**.

Tidal datums shown in **Table 3-1** are based on the 1983 to 2001 tidal epoch and relative to the NAVD 88. The respective levels relative to NAVD 88 are considered to be relevant to the time period during which they were determined. For the purposes of design, SLR that has occurred between 1992 (the midpoint of the 1983 to 2001 tidal epoch), and the present day is considered in the design of the Living Shoreline pilot project and added to the tidal datums in **Table 3-1**.

Figure 3-8. Location of Closest National Oceanic and Atmospheric Administration Tide Station

Table 3-1. Panama City Tidal Datums Based on the Tidal Epoch of 1983 to 2001 (Station ID 8729108)

Tidal Datum	Elevation (feet NAVD 88)
Mean Higher High Water (MHHW)	0.78
Mean High Water	0.74
Mean Sea Level	0.11
Mean Low Water	-0.51
MLLW	-0.56

Source: NOAA 2023b

3.3.1.2 Extreme Water Levels

Published EWLs from the *South Atlantic Coastal Study* (SACS) were adopted to inform design the Living Shoreline pilot project (USACE 2022a). Details can be found in *Regional Hydrodynamic and Wave Transformation Modeling – 30% Design* (Jacobs 2022). In addition, EWLs were extracted at the project site of the Living Shoreline for the return periods (RPs) 10-, 25-, and 100-year. The EWL values and corresponding wave parameters are listed in **Table 3-2**.

Table 3-2. Modeling Results from the SACS Extracted at the Living Shoreline Project Site

RP (year)	SACS EWL (feet NAVD 88)	Hm0 (feet)	T_p(s)
10	4.27	2.30	3.0
25	4.92	2.62	3.1
100	6.56	3.28	3.3

Hm0 = significant wave height
s = second(s)
T_p = peak period

3.3.1.3 Sea Level Rise

Long-term SLR predictions based on U.S. Army Corps of Engineers' (USACE's) Sea Level Change Calculator (USACE 2022b) for the scenarios from NOAA et al. (2017) are illustrated on **Figure 3-9**. The spread in predictions for the scenarios shown on **Figure 3-9** illustrates the uncertainties inherent in SLR predictions. Typically, high and extreme SLR scenarios are reserved for infrastructures that are not resilient to increased SLR and/or failure could result in unacceptable risks. These more conservative estimates are not considered appropriate for the nature-based pilot projects proposed at Tyndall AFB, which have relatively short design lives, can be modified fairly easily if future SLR accelerates beyond what is assumed in the design, and where failure of the structures would pose relatively modest risks at Tyndall AFB. As a result, the intermediate-high scenario has been adopted for this study. The NOAA 2017 intermediate-high scenarios for selected years are summarized in **Table 3-3**.

SLR values in **Table 3-3** represent the SLR that occurred between 1992 (the center point of the tidal epoch used for determining the tidal datums at the site) and each of the given years. Years shown in **Table 3-3** include the following:

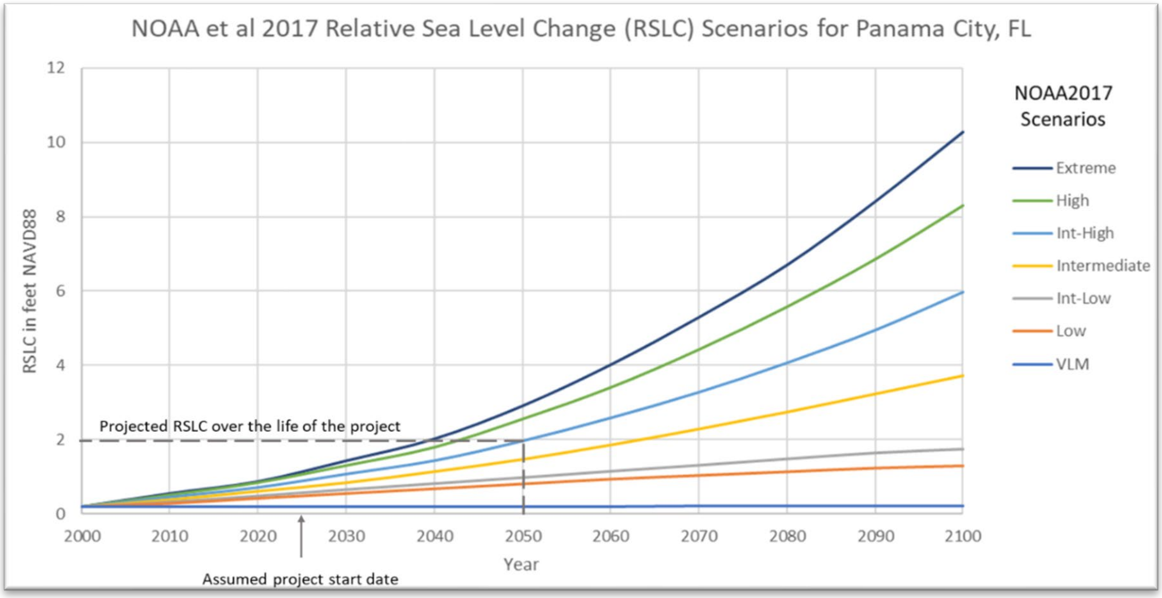
- 2018 – the year of SACS modeling
- 2025 – the year of the assumed project start
- 2050 – the year for 25-year project life of the Living Shoreline pilot project

Table 3-3. Sea Level Change for Panama City, Florida, Intermediate-high Scenario

Year	Sea Level Change (feet)
2018	0.66
2025	0.88
2050	1.96

Source: NOAA 2017

Figure 3-9. Relative Sea Level Change Scenarios for Panama City, Florida



Source: USACE 2022b

3.3.1.4 Design Total Water Levels

Appropriate SLR values to be applied depend on the scenario being addressed. The following values are used for this study:

- A SLR of 0.88 foot is applied to tidal datums shown in **Table 3-1** (based on the 1983 to 2001 tidal epoch) to obtain tidal datums at the start of the project (2025).
- A SLR of 1.96 feet is applied to tidal datums (1983 to 2001 tidal epoch) to estimate future tidal datums at the end of the 25-year project life (2050).
- EWLs at the start of the project are adjusted based on the difference in SLR at the anticipated start of the project (2025) and the SLR at the time of the SACS analysis (that is, 0.88 to 0.66 foot equals 0.22 foot).
- EWLs at the end of the project are adjusted based on the difference in SLR at the end of the project (2075) and the SLR at the time of the SACS analysis (that is, 1.96 to 0.66 foot equals 1.3 feet).

The design water elevations considered for the design are summarized in **Table 3-4**.

Table 3-4. Design Water Levels

Year	MLLW (feet NAVD 88)	MHHW (feet NAVD 88)	Total Water Level (EWL for 1 in 25-year RP + SLR) (feet NAVD 88)
2025	0.32	1.66	5.14
2050	1.40	2.74	6.22

3.3.2 Currents

The hydrodynamic model developed during the 30% modeling efforts, which provided a basis for the preliminary assessment, was calibrated with field data during the 60% modeling stage (Jacobs 2022). The 60% model provides current conditions that were considered in the design of the Living Shoreline site, as documented in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design-Calibrated Models* (Jacobs 2023).

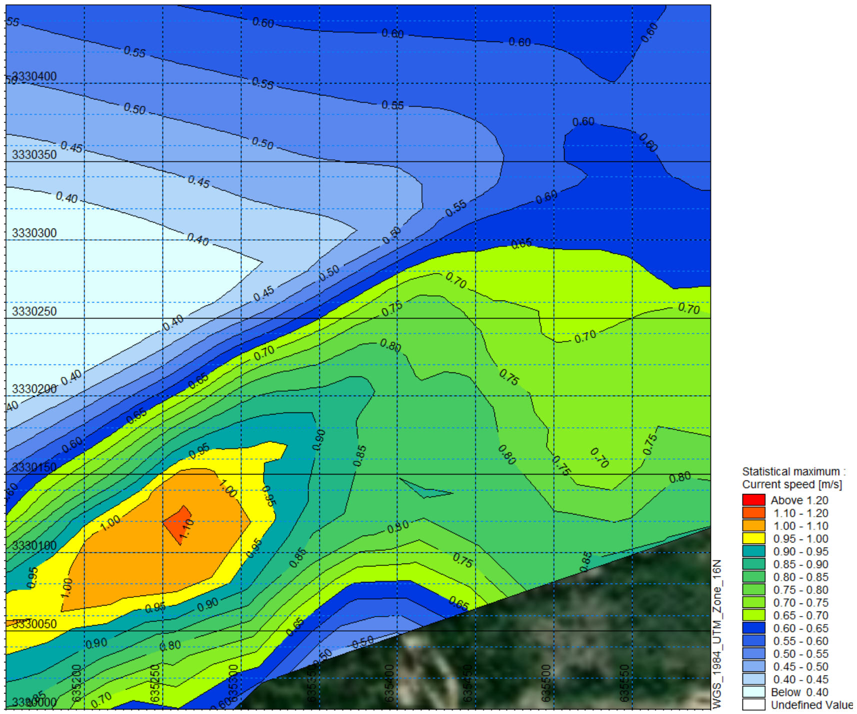
After incorporating the preferred layout, extreme and operational conditions were analyzed and are summarized in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). The modeling included scenarios under present conditions (2025), without SLR, and scenarios under future conditions (2050), including SLR.

For each case, the peak current speeds were based on an incoming storm tide. As the storm surge recedes, the flow will reverse as water drains from the bay, and circulation patterns will change. Lower current velocities are expected along the eastern end of the site due to sheltering by the spit east of Fred Bayou and higher currents expected along the western portion as flows fill in the eddy that was present during the incoming storm tide.

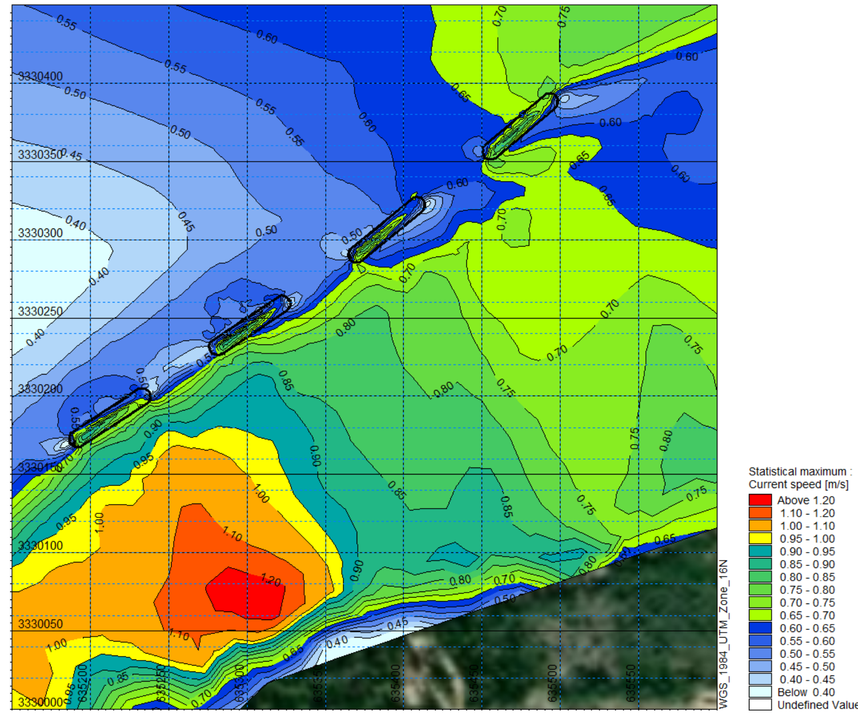
The modeling results under future conditions (2050) are shown in **Figure 3-10**, where the figure on the left represents the conditions without structures in place and the figure on the right the conditions with the preferred structural layout in place to investigate the effects of the structure on current patterns.

For the design, a peak current of 3.0 feet per second (0.9 meter per second) was conservatively considered for the scour and stability analysis of Living Shoreline. This value represented the maximum current speed near the proposed structures (**Figure 3-10**).

Figure 3-10. Maximum Current Speeds for the 25-year Extreme Event under Future (2050) Conditions without and with Structures in place



Future 2050 conditions without structures



Future 2050 conditions with structures

3.3.3 Waves

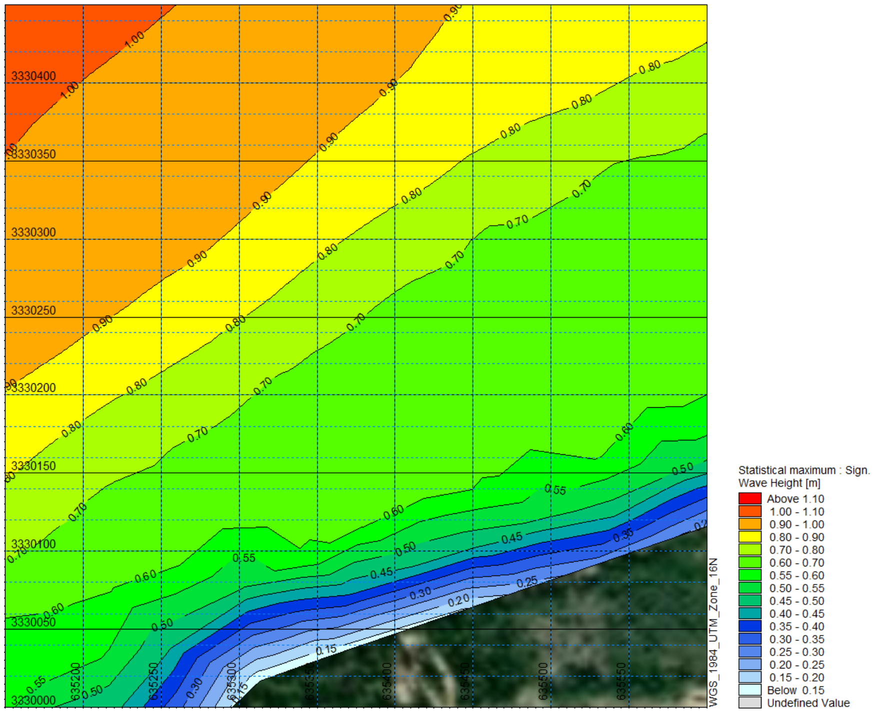
The wave transformation model developed during the 30% modeling efforts was calibrated with field data during the 60% modeling stage (Jacobs 2022). The results of the 60% wave transformation modeling are documented in *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design- Calibrated Models*, which provide insights into the wave conditions for the BOD for the Living Shoreline site (Jacobs 2023).

After incorporating the preferred layout, extreme and operational conditions were analyzed and are summarized in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024). The modeling included scenarios under present conditions (2025), without SLR, and scenarios under future conditions (2050), including SLR.

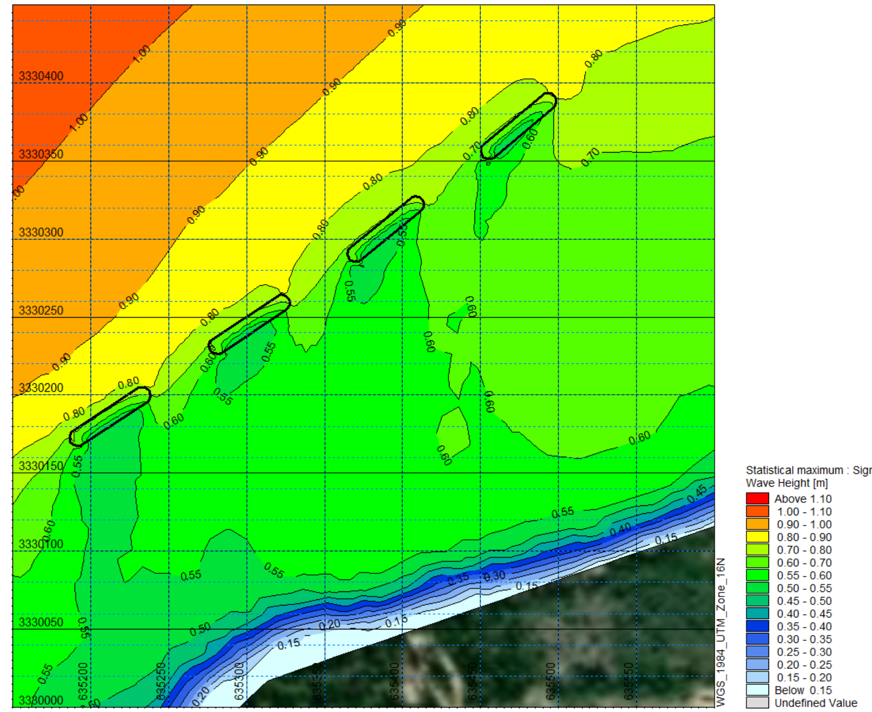
The modeling results under future conditions (2050) are shown in **Figure 3-11**, where the figure on the left represents the conditions without structures in place and the figure on the right the conditions with the preferred structural layout in place to investigate the effects of the structure on wave patterns.

For the design, a significant wave height of 2.7 feet (0.8 meter) with a peak wave period of 3.1 seconds is considered for the design of Living Shoreline. This value represents the maximum wave height near the structures for the future condition including SLR (**Figure 3-11** [right]).

Figure 3-11. Maximum Significant Wave Heights for the 25-year Extreme Event under Future (2050) Conditions without and with Structures in place



Future 2050 conditions without structures



Future 2050 conditions with structures

3.3.4 Sediment Transport

An area-wide sediment transport model was developed, which uses the results of the hydraulic and wave transformation modeling to assess the annual sedimentation rates near the project. Sediment data obtained by the geotechnical investigation were implemented in the model, and the model was calibrated by comparing with historical sedimentation. The modeling is documented in the report *Regional Hydrodynamic and Wave Transformation Modeling – 60% Design – Layout Optioneering and Sediment Transport Modeling* (Jacobs 2024).

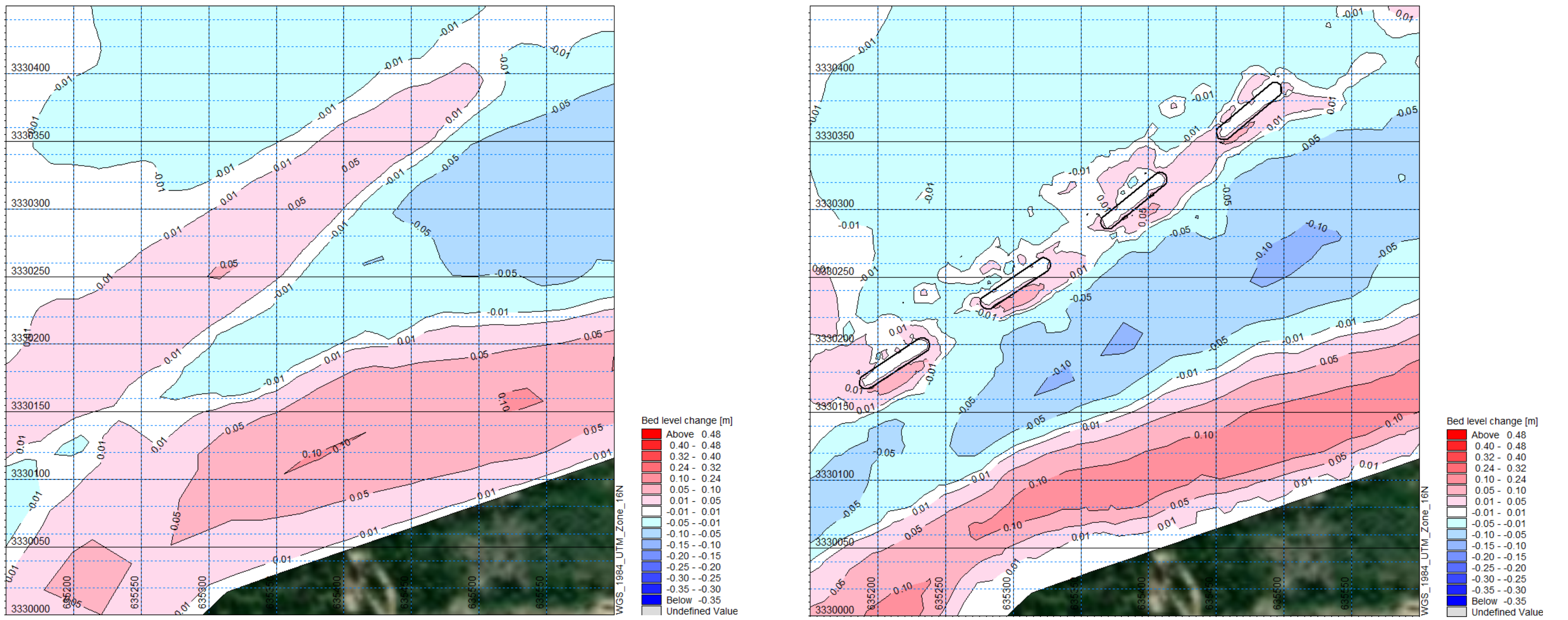
The calibrated model was used to model annual sediment transport at the site without the structures in place (baseline) and after including the preferred layouts to determine sedimentation impacts induced by the structures.

The modeling results without structures in place are shown on the left in **Figure 3-12**. The structure layout was incorporated to model the impact of the structures to the sediment transport; the results from the modeling, including the structures, are shown on the right in **Figure 3-12**.

When comparing these results, the overall changes due to the structures are minimal except for a slight increased sedimentation and erosion rates of up to plus or minus 0.05 meter. A difference plot between the preferred layout in place and without structures in place is presented in **Figure 3-13**.

With the structures in place, the model predicted an average sedimentation rate for the area behind the submerged breakwaters of 0.07 m/year. This compares with rates of sea level rise based on the NOAA 2017 intermediate-high scenario of 0.012 m/year at the start of the project and a rate of 0.015 m/year at the end of the 25-year project, suggesting that sedimentation in the area between the breakwaters and the structures could exceed the changes in sea level, reducing the water depth and reducing the potential for recession of the shoreline as a result of SLR.

Figure 3-12. Modeled Distribution of Annual Sedimentation Rate without and with Structures in place

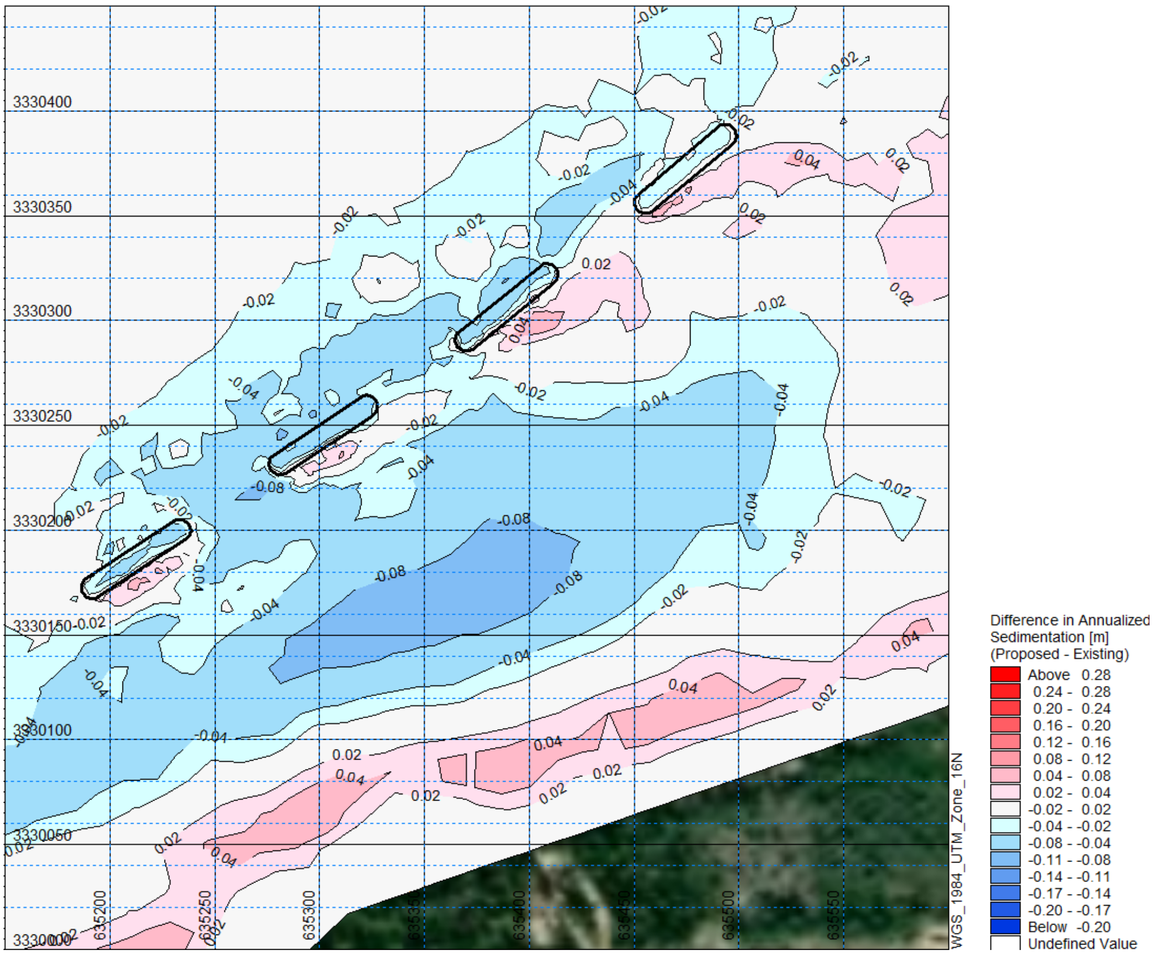


Without structures *With structures*

Note: Red color denotes sedimentation; blue denotes erosion.

Figure 3-13. Difference Plot of the Modeled Distribution of Annual Sedimentation Rate between Preferred Layout and without Structures in place

Note: Red color denotes increased sedimentation; blue denotes increased erosion relative to the existing conditions.



4. Basis of Design Conditions

The objectives of the Living Shoreline pilot project are primarily to reduce local wave hazards, reduce long-term erosion along the shoreline, and enhance seagrass and low marsh habitat. The constraints on the siting and design components are described in Section 2.1.

4.1 Design Codes and References

The following codes and references apply to the design of the Living Shoreline pilot project:

- Stability Design:
  - CIRIA, CUR, and CETMEF. 2007. CIRIA C683 – *The Rock Manual: The use of rock in hydraulic engineering (2nd edition)*.
  - U.S. Army Corps of Engineers (USACE). 2012. *Coastal Engineering Manual: Part VI Design of Coastal Project Elements* (EM 1110-2-1100).
- Geometry Calculations:
  - Environment Agency. 2010. *Guidance for outline design of nearshore detached breakwaters on sandy macro-tidal coasts*. Project Summary SC060026/R1. February.
  - U.S. Army Corps of Engineers (USACE). 2008. *Coastal Engineering Manual: Part V Coastal Project Planning and Design* (EM 1110-2-1100).

4.2 Design Life and Design Storm Conditions

A project life of 25 years, from 2025, has been selected for the Living Shoreline project. Typically, breakwater structures are designed and constructed to deliver coast and shore protection or harbor protection from wave action, and design life is defined as the length of time the structure continues to deliver such functions. However, this project's primary objectives are wave attenuation and enhancement of coastal habitat. Therefore, the design life is defined as the length of time the breakwaters are stable in place and continue providing protection from waves while also enhancing coastal habitat.

The design storm defines the conditions that the project must be able to withstand and still function over its design life. Design storms are often defined in terms of their RP, which describes, on average, the frequency that a given event could occur in any given event. The selection of the RP event for a given project should consider potential impacts and risks. For example, a 25-year RP storm has an annual exceedance probability (the probability of being exceeded in any given year) of 4% and will occur, on average, once every 25 years. However, a 25-year event could happen more than once over a 25-year span or not happen at all during that period. The probability that a 25-year event would be exceeded over a 25-year span is approximately 64%.

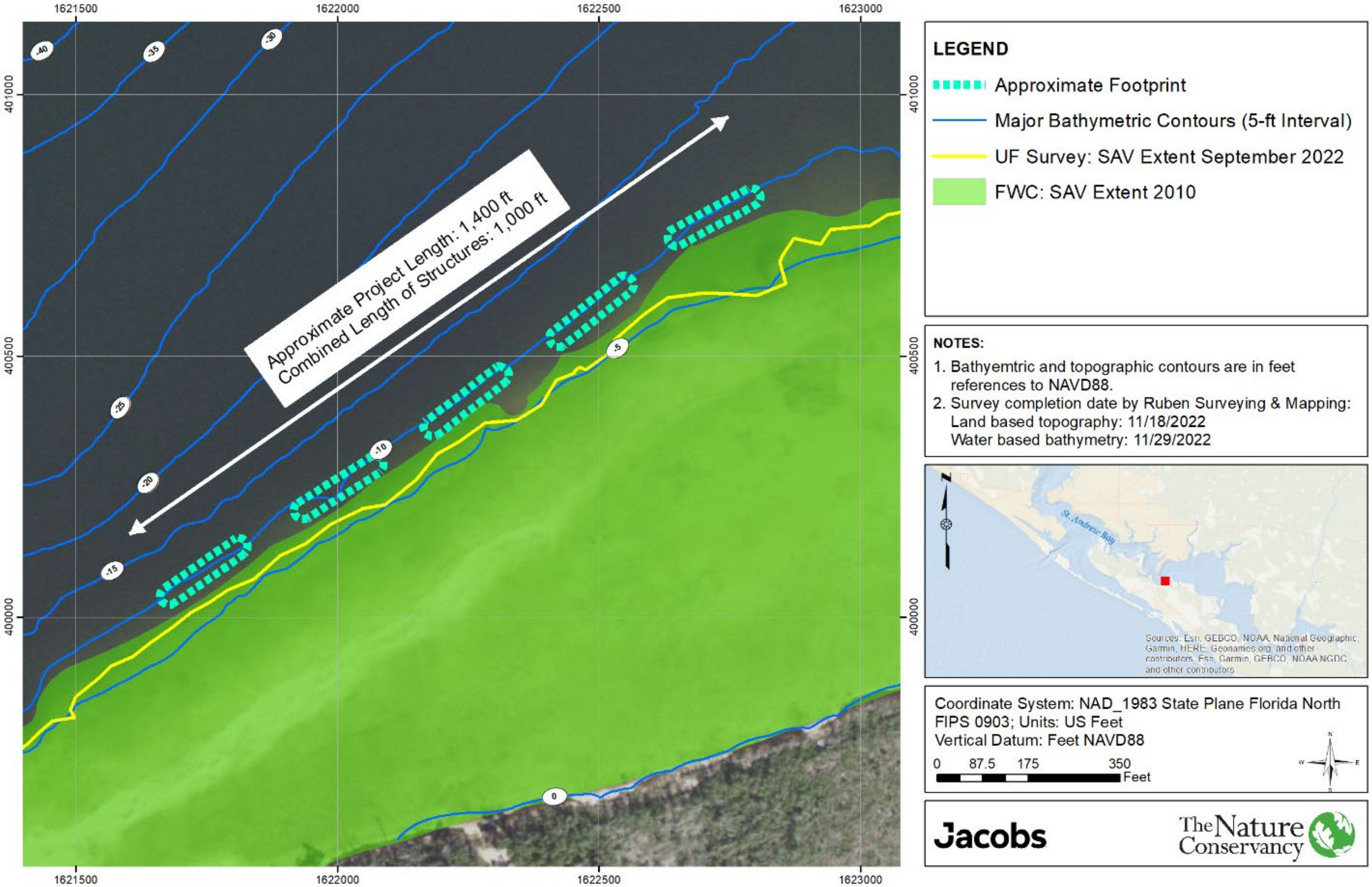
4.3 Preliminary Alternative Option Designs

During the early stages of project design, various physical characteristics of the Living Shoreline, including project footprint, cross-section, and components, were considered. This section documents the preliminary layout and the considerations that influenced the current design configuration.

4.3.1 Preliminary Layout

The approximate footprint of the Living Shoreline pilot project, at the preliminary design stage, is shown on **Figure 4-1**. The total footprint was intended to cover a length of 1,000 feet (longer if gaps are included) and would be oriented parallel to the shoreline. The offshore structures were designed outside the historic extent of seagrass, based on 2010 data, and no closer than 25 feet from the seaward extent of seagrass, based on mapping performed by UF (UF 2022), to minimize negative impacts to the seagrass during construction.

Figure 4-1. Proposed Approximate Project Footprint (Preliminary Design)



4.3.2 30% Design Alternatives

Based on the initial feasibility material analysis, three alternatives were considered for the Living Shoreline pilot project, including a submerged breakwater structure, an emergent breakwater structure, and a pile-supported Reefmaker breakwater structure.

The three Living Shoreline alternatives are as follows (refer to **Appendix C** for additional detail):

- A submerged breakwater structure with its crest at the 2025 MLLW elevation (0.34 foot NAVD 88) and offshore limit at the proposed project extent (-9.5 feet NAVD 88 contour), 45-foot buffer from the 2022 SAV extent (**Figure 4-2**)
- An emergent breakwater with its crest above 2050 MHHW elevation (4 foot NAVD 88) and offshore limit at the proposed project extent (-9.5 foot NAVD 88 contour), 45-foot buffer from the 2022 SAV extent (**Figure 4-3**)
- A pile-supported Reefmaker breakwater with a crest at the 2025 MLLW elevation (0.34 foot NAVD 88) and offshore limit at the proposed project extent (-9.5 foot NAVD 88 contour), 45-foot buffer from the 2022 SAV extent (**Figure 4-4**)

These alternatives are further summarized in **Table 4-1**.

All three alternatives were designed to reduce wave energy along the shoreline, providing a potential for reduced long-term erosion and increased accretion; therefore, all three alternatives provide an added resilience level to the shoreline during extreme events.

The submerged breakwater would reduce wave energy during nonstorm periods but with reduced effectiveness for higher storm surge events and little to no effect for extreme storm surge events. However, the submerged breakwater would have a minimal visual impact and a relatively small footprint for a rubble mound structure.

The emergent breakwater was designed to reduce wave energy along the shoreline during typical conditions and extreme events (for present and future conditions), providing additional protection to the shoreline during storm events. The emergent breakwater would have the greatest visual impact of the three alternatives, the largest footprint, the greatest amount of material, and potentially raise concerns of BASH.

The Reefmaker breakwater has the smallest footprint of the three. However, as shown, similar to the submerged breakwater, it would have reduced effectiveness during higher storm surge events and little to no effect for extreme storms.

All three alternatives could be modified in the future in response to SLR; the rubble mound structures could be modified by adding more stone or armor units to the face and top of the breakwaters and the Reefmaker breakwater could be modified by stacking more disks on the piles. To allow future extension of the Reefmaker breakwater, the pile supports would need to be designed for increased wave loading on the extended structures.

Table 4-1. Design Alternatives, Cross-section Parameters

Option Number	Structure Type	Material	Crest Elevation (feet NAVD 88)	Crest Width (feet)	Slope	Footprint (square feet)	Location	Figure Number
1 (Selected)	Submerged breakwater	Limestone	0.32 (2025 MLLW)	10	1:1.5	35,300	Just offshore of 2010 SAV extent	Figure 4-2
2	Emergent breakwater	Limestone	4 (above 2050 MHHW)	10	1:1.5	47,400	Just offshore of 2010 SAV extent	Figure 4-3
3	Pile-supported Reefmaker breakwater	Reefmaker	1.66 (2025 MHHW)	4.82 (disk width)	N/A	4,820 (based on disk width)	Just offshore of 2010 SAV extent	Figure 4-4

N/A = not applicable

Figure 4-2. Submerged Rubble Mound Breakwater with a Crest Width of 10 feet and a Crest Elevation at Mean Lower Low Water 2025

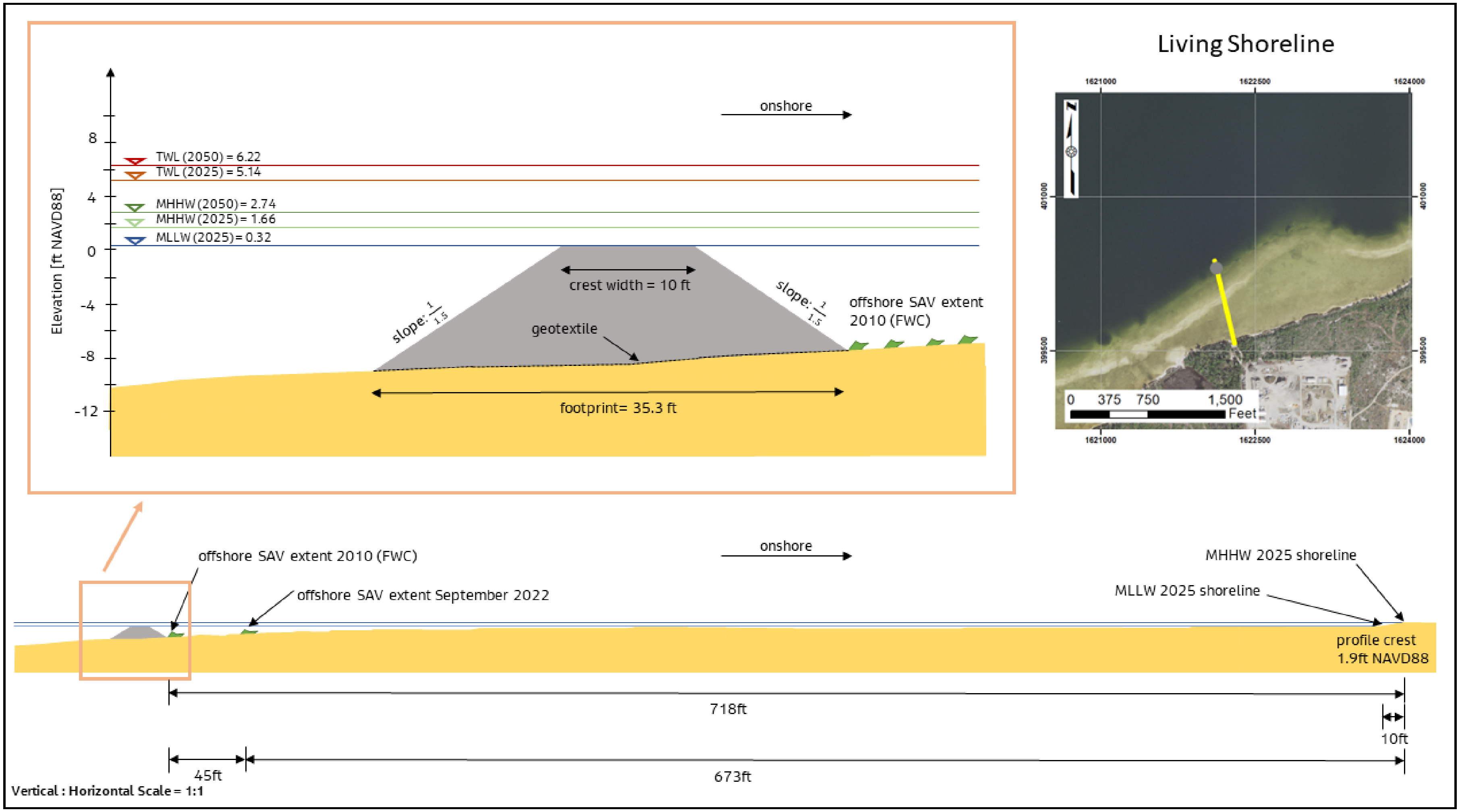


Figure 4-3. Emergent Rubble Mound Breakwater with a Crest Width of 10 feet and a Crest Elevation at 4 feet North American Datum of 1988

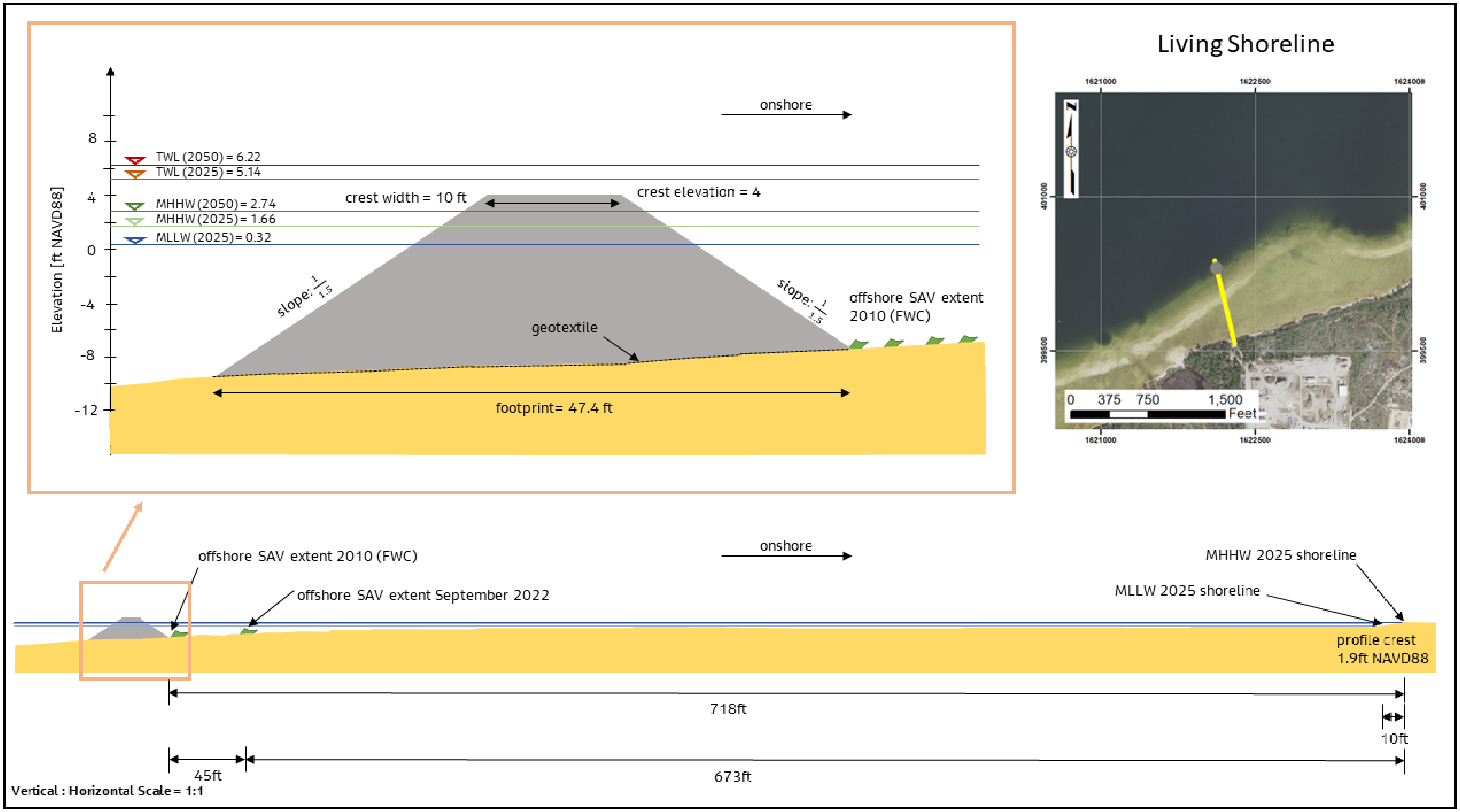
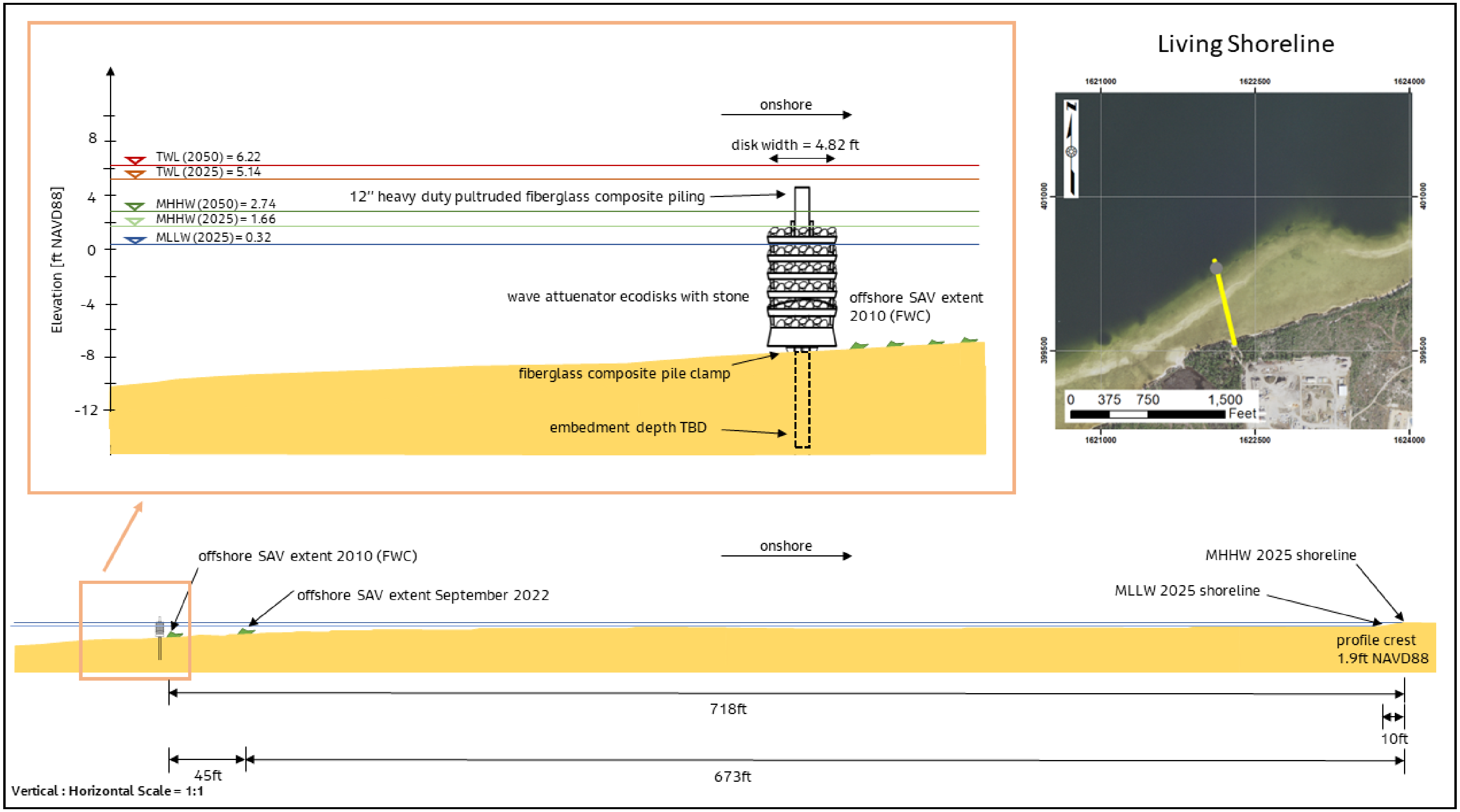


Figure 4-4. Emergent Reefmaker Breakwater with Upper Disk at Mean Higher High Water 2025



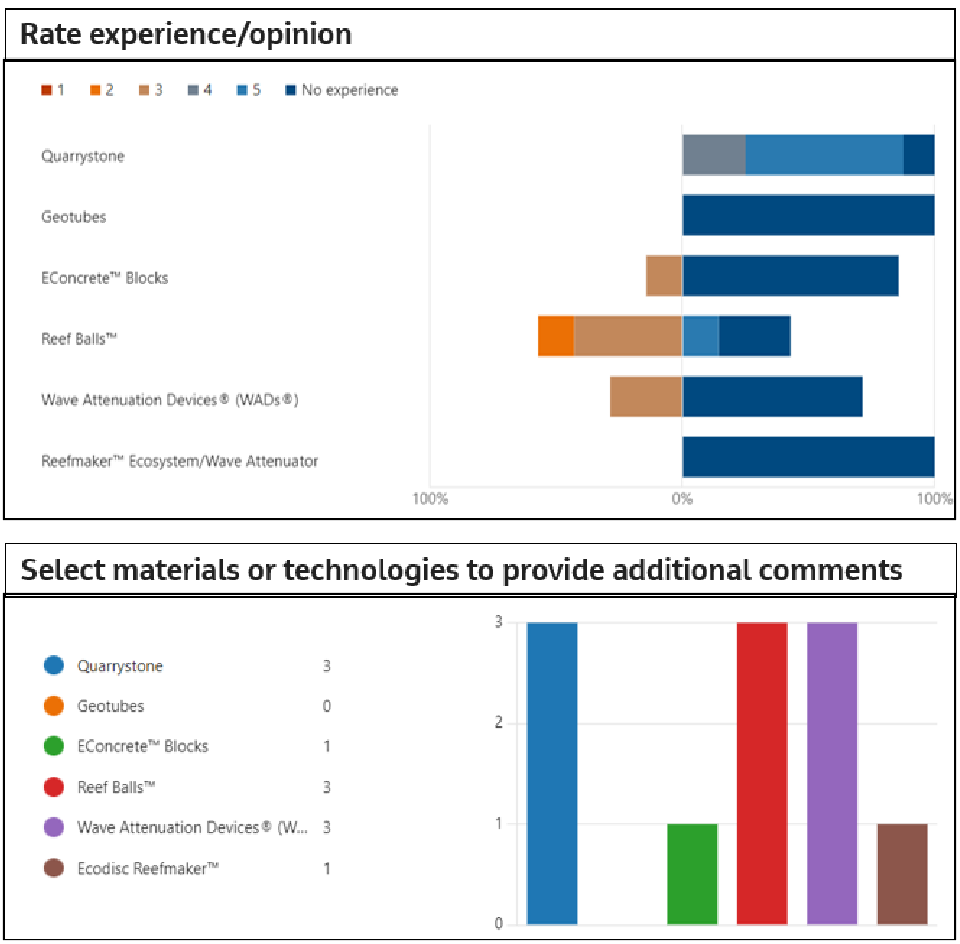
4.3.3 Stakeholder Engagement between 30% and 60% Design Phase

A series of stakeholder engagement events were held during the preliminary design phase, including the following:

- April 20, 2023, Preliminary Design Workshop
- May 4, 2023, Preliminary Design Workshop – T-CRAG
- July 6, 2023, BASH Meeting 1
- August 17, 2023, BASH Meeting 2

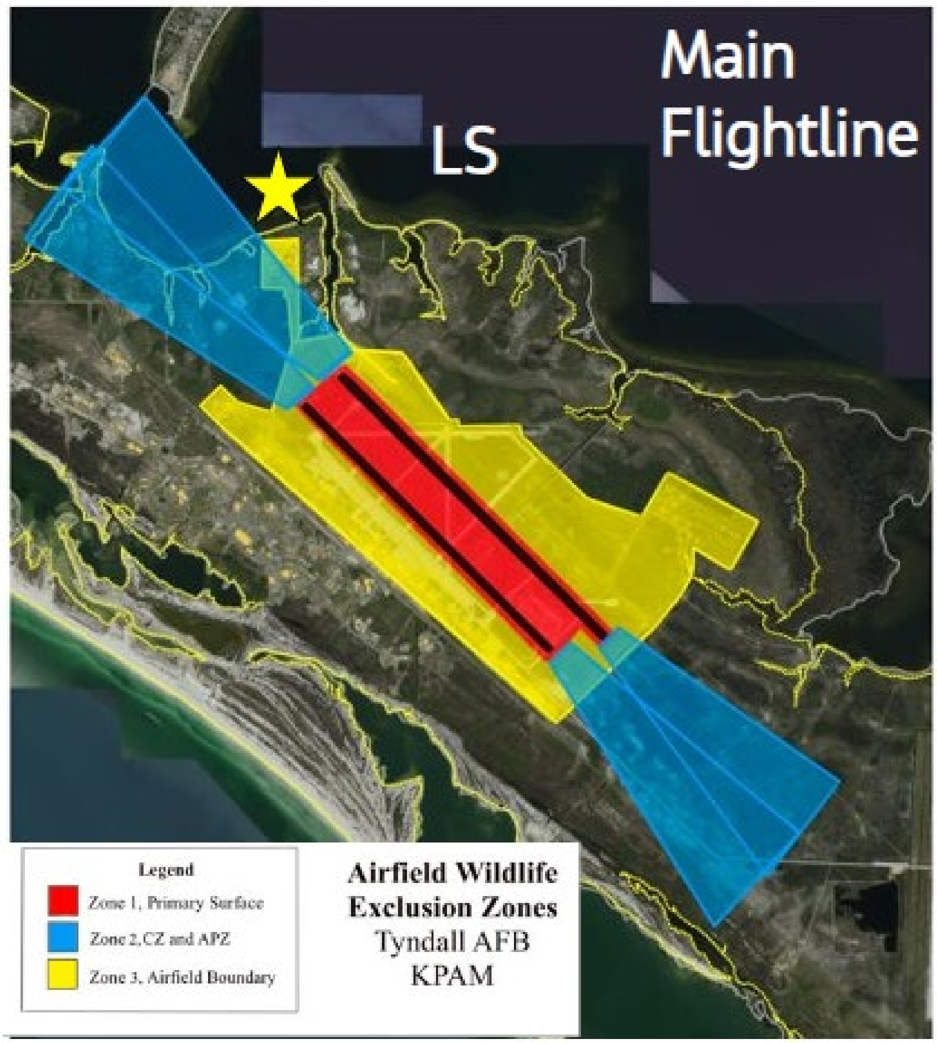
The previously discussed design alternatives were presented during a Preliminary Design Workshop held on April 20, 2023. The meeting invitation included a material alternatives analysis survey to obtain information on material preference and experiences. The results of the survey were presented during the meeting and are shown on **Figure 4-5**.

Figure 4-5. Material Alternatives Survey Summary



During the meeting, the BASH group highlighted that the project alternatives need to be further reviewed due to risks that emerged structure segments could attract birds and therefore endanger the aircraft traffic at Tyndall AFB. On July 6, 2023 (during BASH Meeting 1), a summary of wave attenuation, exposed area, and duration of exposure of the in total nine alternatives for the three pilot sites were presented. While the preference from a coastal resilience and shoreline protection viewpoint is for options that offer the highest degree of wave attention, the BASH group highlighted their preference for submerged alternatives over emergent structures. They noted that emergent structures present an increased risk of bird attraction that can endanger air traffic due to exposed area and duration of exposure. The Living Shoreline project is adjacent to airfield Wildlife Exclusion Zones as defined by BASH. The exclusion zones are shown on **Figure 4-6**.

Figure 4-6. Runway and Flightline Operational Constraints (Bird/Wildlife Aircraft Strike Hazard)



During BASH Meeting 2 on August 17, 2023, it was concluded that for the following 60% Design Optimization described in Section 4.4, only structures submerged at current MLLW are to be considered. Additional studies are not currently available that assess the potential increase in bird population or site use; therefore, the impact of emergent structures is uncertain. Consequently, emergent structures should be avoided.

4.4 Design Optimization 60%

Design optimization was undertaken with the purpose of reducing construction cost while maximizing wave attenuation benefits. The original layout presented during the preliminary phase (with an adjusted crest elevation at MLLW) was compared to two alternative layouts, summarized in **Table 4-2**. Layout Alternative 2 consisted of four reefs instead of five. The spacing between the individual segments was increased from 100 to 150 feet to decrease the number of reef segments from five to four. For layout Alternative 3, this altered layout was further changed by decreasing the crest width from 10 to 5 feet.

Table 4-2. Parameters of the Optimization Design Options

Layout Number	Number of Segments	Segment Length (feet)	Number of Gaps	Gap Length (feet)	Crest Width (feet)
1 – Original (crest adjusted to MLLW)	5	200	4	100	10
2 – Selected	4	200	3	150	10
3	4	200	3	150	5

5. Design Layout and Geometry

The following sections describe the proposed materials, layout, and location of the proposed Living Shoreline.

5.1 Materials

The current breakwater design has the following three main elements:

- The base made of geotextile and bedding stone serves as a foundational layer, providing stability and preventing soil erosion while allowing for efficient drainage. Bedding stone offers additional support and weight distribution to the breakwater structure.
- As a second element, limestone rock was selected because of its durability and natural composition. Limestone rock will form the bulk of the structure, providing wave attenuation.
- The breakwaters will be constructed of riprap using a gradation with a median rock size (Dn50) of 8 inches or greater, which is sufficient to prevent dispersal of the breakwater structure under storm conditions.

5.2 Layout

The elements influencing the selected layout are described in the following sections.

5.2.1 Distance from Shore

The proposed distance from the shoreline was influenced by the following:

- The presence of SAV as a project constraint
- The desired water depth and practicality of installation from water (refer to Section 6 for additional detail)
- Estimated distance from shore within which all sediment movement is contained to aid sediment stabilization
- Locations to tie in up and downstream and the topography of the existing shoreline

Ultimately, the presence of SAV was the primary driver for the selected distance from shore.

5.2.2 Reef Length

Reef length is typically determined by selecting the desired shoreline response—no change, growth of salient, tombolo—and the distance from the shoreline where the reefs are intended to be installed. If nourishment of the shoreline is taking place, this will also inform the reef length. Typically, there is a pattern of relative erosion and growth behind the line of reefs. For this project site, the distance between the proposed reefs and the shoreline is determined by the presence of the SAV. The selected reef length is 200 feet, primarily influenced by the cost-benefit analysis and wave attenuation response during present operational conditions.

5.2.3 Reef Spacing

To prevent the structures working as one long reef with limited flushing effect, the minimum reef spacing was selected as five times the wavelength at the reef structure. The wave periods are typically very small so the wavelength is short; therefore, the minimum spacing is 100 feet. However, to balance the material costs required, a spacing of 150 feet has been adopted. The spacing and orientation of the reefs were selected to achieve the optimal level of protection of the shoreline based on design criteria and modeling results. It is best practice to construct the reefs with a shore-parallel orientation; therefore, this approach has been adopted.

5.2.4 Cross-section and Plan View

Based on the geotechnical investigation, the existing sandy soils are expected to support the weight of a geotextile with manageable settlement. A layer of bedding stone is recommended as an underlayer to serve as a separation layer to minimize migration of fines into the rock. Fines displacement would have the same effect as subgrade settlement and consolidation. Geotextile and geogrid, while providing a benefit to project construction (reduced settlement and fines migration), might not be required for the Living Shoreline project as shown by early indications. This will be revisited during the 90% design stage.

Due to the ground conditions and water depth, a toe berm is required on seaward side faces of the structure and roundheads to ensure the stability of the structure. This detail allows the rock to counteract scour at the toe without reducing the crest level or width.

The design crest level is -0.56 foot NAVD 88, which fulfills the BASH requirement for submergent structures. Slopes of 1 in 2 are recommended to limit the footprint and the associated quantity of material.

The typical breakwater plan view and cross-section is shown on **Figure 5-1** and **Figure 5-2**.

Figure 5-1. Typical Living Shoreline Plan View

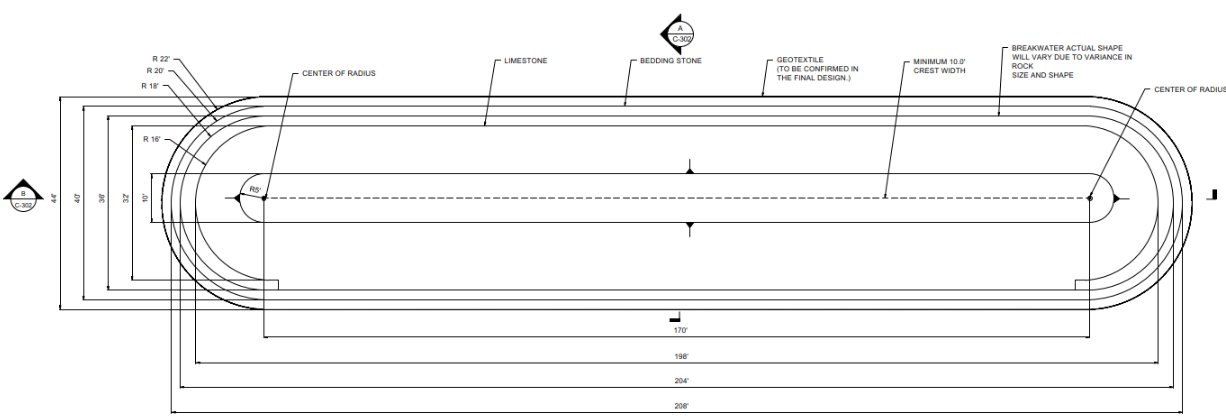
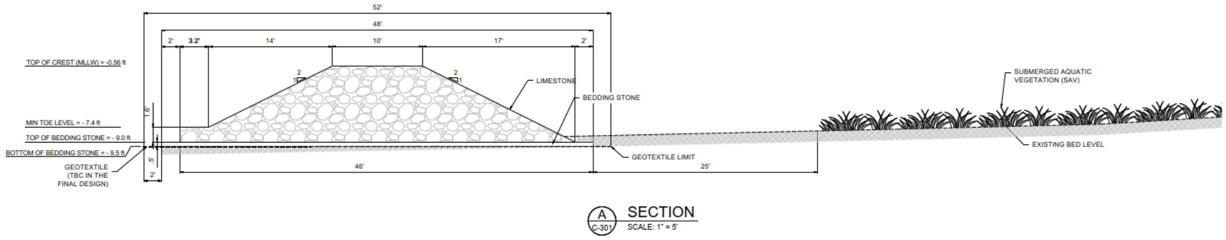
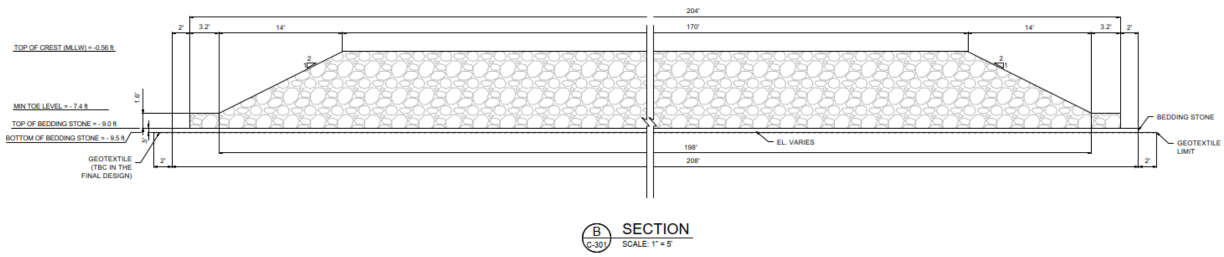


Figure 5-2. Typical Living Shoreline Structure Profile





6. Constructability

The constructability of the Living Shoreline is dependent on the depth of water, which will dictate the type of equipment capable of constructing the structures. It is proposed to build the structures using tugboats and barges to transport material to the proposed breakwater locations. A barge-mounted crane would be used to place the material. With the reefs located along the -9.5-foot contour, the minimum depth of water anticipated is approximately 9 feet (at MLLW). Barges will be positioned seaward of the reef to allow sufficient draft and avoid grounding during construction. Barges will be working in water depths of 9 feet or more depending on the tide.

The following are construction assumptions:

- Anticipated construction timeline: March 2026 to March 2027 to construct all four breakwaters.
- Assumed five rock barges (50 feet by 200 feet) for staging and one rock barge (50 feet by 200 feet) and one excavator for placement (**Figure 6-1**).
- Assume some barges would be left overnight at construction site.
- Assume two 25-foot tugboats.
- Barge and other vessel access to project site from Gulf and East Bay. Refer to drawings package (**Appendix E**) for more information.
- Anticipated working hours daytime and nighttime depending on tides.

Figure 6-1. Pensacola East Bay Construction
Photo courtesy of TNC.

The construction schedule has not been developed yet. Current assumption is that construction will occur 5 days per week, working 5- to 8-hour days. The ability to bring in the stone by barge might necessitate higher tides during the construction period. The summer months have predictably higher tides, with the winter months being subject to cold fronts with northerly winds blowing the water out of the East Bay and decreasing the depth of water. The ability to supply the site with stone, expected to be a daily task, will dictate the best construction time frame and equipment to be used.

7. Adaptive Management

Adaptive management is a process by which future monitoring information may be used to assess the performance of the Living Shoreline project. Monitoring of the project will be conducted by UF and includes metrics such as:

- Areal dimensions
- Height
- Rugosity
- Oyster density and shell height
- Density of sessile invertebrates
- Percent cover of substrate
- Water quality
- Shoreline position
- Topo-bathymetric profile
- Marsh areal extent
- Percent cover of emergent marsh vegetation
- SAV areal extent
- SAV percent cover
- Wave height and currents

Following construction and as monitoring data are evaluated, information may be used to inform future design as well as potential modification to the installed structures. Based on the design intent of the Living Shoreline, little to no future direct modifications are anticipated. The project is expected to adapt naturally over time as site conditions change. Minor deviations to the project footprint and geometry are anticipated over the design life. It should be noted, however, that some foreseen, unforeseen, and/ or extreme circumstances may substantially impact the project and modifications to the project may occur. Future potential scenarios that may require direct modifications of the Living Shoreline include the following:

- Forcing factors (i.e., hurricanes) beyond the design criteria alter the project geometry and create potential navigation hazards. Direct modifications may be performed to address any potential navigation hazards or impacts.

- Future water surface elevation changes outpace physical and biological adaptation rates and project performance is reduced. If considered worthwhile, direct modification may be conducted to reestablish successful performance relative to success criteria, i.e., adding additional materials to increase crest height (without affecting BASH requirements).

Any future direct modification to the Living Shoreline project will require coordination with Tyndall AFB as well as relevant regulatory permitting agencies.

8. Opinion on Construction Cost

A Class 2 cost estimate, as defined by the Association for the Advancement of Cost Engineering International, is provided in **Appendix D**. The estimating accuracy for 30% to 70% design level is in the range of -15% to +20%. At this level of design, a contingency of 25% is recommended and is included in the total estimate cost. The cost includes escalation.

Table 8-1 provides the low-range, estimate, and high-range cost estimated based on the 60% design. **Figure 8-1** includes additional cost estimate information.

Table 8-1. Summary Cost Estimate

Low Range (rounded) -15%	Estimate Total (rounded)	High Range (rounded) +20%
$3,255,507	$3,830,009	$4,596,010

Figure 8-1. Additional Cost Estimate Details

	On Bid Quantities	%
Direct Cost	2,089,794	54.56%
Indirect Cost	338,320	8.83%
Addons	91,227	2.38%
Bond	45,960	1.20%
Pass Through Cost	779,047	20.34%
Direct Markup	417,959	10.91%
Indirect Markup	67,664	1.77%

This estimate was prepared based on the following key assumptions:

- The estimate is based on 60% drawings prepared in May 2024.
- Crews work 5 to 8 hours per days and 5 days per week.
- Construction is assumed for 60 days.
- Riprap includes delivery, material, and installation.
- Costs are provided in 2024 U.S. dollars.

As with all estimates, it represents a snapshot in time of what is known about the project and expected to occur. The commodities and energy markets are currently extremely active. Changes in either will have dramatic effects on this estimate. Therefore, this estimate should be viewed in that light. If more than 90 days have passed, or significant changes occur in the commodity markets, this estimate should be updated and reevaluated. The estimate does include escalation to address the potential for this to occur.

9. Conclusion and Next Steps

Different preliminary alternative options were considered during the 30% design stage. During that phase, preliminary modeling results were available for the analysis. The options, which were presented during a workshop, raised questions by BASH regarding the attraction of birds by emergent structures. It was decided to only pursue options further with a crest elevation at MLLW. During the 30% design stage, field data were collected that included waves, currents, cultural resources survey, and geotechnical survey. The field data were used to calibrate the wave, hydrodynamic, and sediment transport models and inform the design. The results from the calibrated modeled were applied during the 60% design. Different layout alternatives were analyzed during the optimization. The optimization included weighing function and cost. Ultimately, a layout with four structure segments was chosen.

The next steps include the review of the 60% design package by TNC and incorporating any consequential comments before advancing to the 90% design stage and developing construction documents. Once the proposed design is chosen, Jacobs will move forward with the detailed design phase of the project. Detailed design will be completed in summer 2024.

The following initial risks were identified at this stage and are offered as an example of best practice and can be used to gauge the level of risk process that is applicable to this project. It is intended to be the start of the risk management process and should be updated regularly, as follows:

- Lack of funding for construction and long-term monitoring
- Bathymetry impacts, including potential exposure of cultural resources, from recent hurricanes
- Changes in SAV footprints near the proposed breakwaters
- Inability to secure materials from a reliable and affordable source
- Regulatory changes

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Appendix A
Bathymetric Survey

Appendix B
Geotechnical Report

Appendix C
Material Alternative Analysis

Appendix D
Cost Estimates

Appendix E
60% Drawing Package

Appendix F
Specifications