Site Evaluation for Living Shoreline Projects in Delaware

Guidance and Worksheet

Delaware Living Shoreline Committee - Design and Engineering Subcommittee

April 2020

Delaware Living Shorelines Committee

Acknowledgments

This document was produced by the Delaware Living Shorelines Committee, while the text and information in this document was compiled by the Design and Engineering Sub-Committee. The sub-committee consists of a diverse group of professionals from the public and private sectors of restoration.

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DELAWARE LIVING SHORELINES COMMITTEE

https://www.delawarelivingshorelines.org

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List of Acronyms

USFWS	United States Fish and Wildlife Service
IPAC	USFWS Information for Planning and Consultation
SAV	Submerged Aquatic Vegetation
SAA	Statewide Activity Approval
USACE	United States Army Corps of Engineers
GIS	Geographic Information System
USGS	United States Geological Survey
VIMS	Virginia Institute of Marine Science
NOAA	National Oceanic and Atmospheric Administration
WEMo	Wave Exposure Model
MHW	Mean High Water
MLW	Mean Low Water
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
DNREC	Delaware Department of Natural Resources and Environmental Control
NWP	Nationwide Permit
BFE	Base Flood Elevation

FIRM	Flood Insurance Rate Map
FEMA	Federal Emergency Management Agency
LIMWA	Limit of Moderate Wave Action

Foreword

This guidance is intended for use by living shoreline practitioners and interested landowners considering the suitability of a site for a living shoreline project.

The term "living shoreline" describes an array of shoreline management techniques that rely on natural or nature-based features, to achieve a specific goal. Because of the broad definition and the flexibility of many techniques, it is safe to say there are a myriad of sites in Delaware suitable for living shorelines. The question of site suitability is a question of success or failure of a living shoreline; success or failure is rooted in how one defines the project goals. Set specific goals for the project early in the site evaluation process. If a goal is to create a wetland buffer to mitigate sediment runoff into a bay, the site evaluation described herein should be performed through a different lens than if the goal is to create a vegetated berm capable of protecting infrastructure from extreme storm events.

Not all living shoreline techniques are suitable for all project sites, but there is a good chance one will be able to implement a subset of these techniques on most shoreline projects. There are, however, some types of sites that present challenges that make living shoreline construction infeasible. For example, sites with exposure to extremely high wave energy such as the Atlantic Ocean coastline, are not good candidates for living shoreline techniques. Sites with high, steep embankments are also generally not viable because of the expansive areas required for regrading and substantial challenges in constructability. A living shoreline technique may be impossible to construct due to surrounding land use obstructing access, or high implementation costs. Some living shoreline project elements require regular monitoring and maintenance, so property owners should be made aware of these requirements during the site evaluation phase in order to understand the level of effort required for a successful project.

The following guidance is intended to help guide the user through a site evaluation to assess the viability of a particular site for living shoreline construction using the included worksheet in Appendix A – Site Evaluation Worksheet. The numbering on the worksheet corresponds with section numbering in the guidance to facilitate the use of this document as a reference. The written guidance should help identify design constraints and possible techniques. A list of living shoreline techniques can be found in Appendix B – Living Shoreline Techniques.

Site evaluation is one step in a continuous process that also spans concept design, engineering, construction, and monitoring. While performing a site evaluation using this guidance users may find that as certain living shoreline techniques are eliminated from the list of available options at a project site, a conceptual design may be easier to formulate.

Most of this document focuses on resources where users can find the data and information that are important in site evaluation and concept design. Look for "Site Evaluation Tips" boxes for additional insight on how parameters affect site suitability, including several important parameters that have the potential to disqualify particular living shoreline techniques.

> **Site Evaluation Tip boxes like this one contain important information to help you understand how various parameters affect site suitability of living shorelines.**

There are many resources that are referenced repeatedly in this guidance and others that have inspired its creation. The following resources from nearby states could be consulted by the Delaware reader for additional information on living shoreline techniques and design:

Hardaway Jr., C. & Byrne, R., 1999. *Shoreline Management in Chesapeake Bay*, Gloucester Point, VA: Special Report in Applied Marine Science and Ocean Engineering Number 356, Virginia Institute of Marine Science.

Hardaway Jr., C., Milligan, D. & Duhring, K., 2010. *Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments*, Gloucester Point, VA: Virginia Institute of Marine Science, College of William and Mary.

Miller, J., Rella, A., Williams, A. & Sproule, E., 2016. *Living Shorelines Engineering Guidelines*, Hoboken, NJ: Stevens Institute of Technology, prepared for New Jersey Department of Environmental Protection.

New York Department of Environmental Conservation, 2017. *Living Shoreline Techniques in the Marine District of New York State*, Albany, NY.

There are additional resources that can aid the design of a Delaware Living Shoreline. These include:

NOAA's Office of Habitat Conservation (12/11/2019). "NOAA Habitat Blueprint." https://www.habitatblueprint.noaa.gov/living-shorelines/. 12/11/2019.

New York City Department of Parks & Recreation (NYC Parks), 2018. *Salt Marsh Restoration in NYC: Assessment of Condition and Recommendations for Future Design and Monitoring*.

NOAA's Office of Fisheries (02/06/2020) "NOAA Restoration Center Monitoring and Evaluation Guiding Principles." https://www.fisheries.noaa.gov/national/habitat-conservation/monitoring-and-evaluation-restoration-projects . 02/06/2020

U.S. Army Corps of Engineers (2002). *Coastal Engineering Manual (EM 1110-2-1100)*. https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/

If after evaluating the project site, you decide to move forward with installing a living shoreline, consultation with regulatory agencies involved is advised. Acquiring the appropriate permits on both the federal and state level is an essential step before installing the living shoreline. There are often expedited permitting processes in place for using living shoreline techniques.

Contact the appropriate agency for more information:

U.S. Army Corps of Engineers
Regulator of the Day: 215-656-6728

DNREC, Wetlands & Subaqueous Lands Section
Scientist of the Day: 302-739-9943

DNREC, Delaware Coastal Management Program
Questions: 302-739-9283

Introduction

When evaluating a property for the use of living shoreline techniques many factors should be assessed. The goal of this document is to assist shoreline professionals and landowners to collect information that will help in the design of a successful living shoreline project. This document has separated the site evaluation process into 2 parts: pre-site visit which consists of a desktop analysis and a field site visit which facilitates observation of parameters that can only be collected on site as well as verification of the desktop analysis. The desktop analysis consists of 13 parameters that can be completed online or through written sources while the site visit consists of 6 additional parameters and verification of desktop parameters found in Figure 1.

Desktop Analysis		Site Visit
1. Shoreline Problem	8. Fetch	14. Site Boundaries
2. Property Owner Goals	9. Wind	15. Land Use/Land Cover
3. Site Dimensions	10. Wave Climate	16. Geology
4. Body of Water	11. Tide Information	17. Ecology
5. Shoreline Dimension	12. FEMA	18. Site Sketches
6. Shoreline Change Rate	13. Notes	19. Notes
7. Geomorphology		

Table 1. Summary of parameters that you will access through desktop analysis and site visit.

Part 1: Pre-Site Visit Desktop Analysis Parameters

Pre-site visit characterization using existing datasets during the desktop analysis process described below will be useful to prepare and answer many questions before your field observations. Pre-site visit parameters will start your guidance with some big picture ideas and brings up questions or concerns that your site visit will help answer. The combination of the pre-site visit parameters and site visit parameters will give you a well-rounded knowledge of the site to then use to make your recommendations to your client.

1. Shoreline Problem

A living shoreline is a method of shoreline augmentation that:

- offers resilience to shorelines from acute wave, wake, or storm surge energies; chronic tidal or other flows; and/or sea level change;

- utilizes natural materials, sometimes in combination with structural components; and
- sustains, enhances, and/or restores ecological functions and connections between uplands and aquatic areas.

Most importantly, the construction of a living shoreline should solve a specific problem. When considering a living shoreline project, identifying the problem or problems at the shoreline should be the first step. The type and extent of the shoreline problem will be an important factor to consider throughout site evaluation and living shoreline design. Much of the following guidance will help to evaluate how the existing site characteristics factor into the solution to the shoreline problems.

In order to be successful, a project should be designed to solve a particular problem. Often, the problem is chronic shoreline erosion. Most solutions include techniques that dissipate water and wave energy over a wide area rather than allow all of that energy to impact the shoreline in a concentrated area.

Other issues may exist at the shoreline; including intrusion of invasive species such as common reed (*Phragmites australis*), water quality degradation due to poor circulation or unabated runoff, a desire to demolish an existing bulkhead or revetment, and many more not listed here. The problems identified during this step will lead directly into the next step where the property owner's goals are established, at least one of which will ideally include solving the identified issue. Shoreline problems and solutions may also inform the permit application process.

The Delaware Shoreline Stabilization Statewide Activity Approval (SAA) [1] expedites the permitting process for certain living shorelines built to address a particular shoreline stabilization issue; consult the SAA language to understand its usage. Similarly, some US Army Corps of Engineers (USACE) Nationwide Permits [2] expedite the permitting process for certain activities that fall under the living shoreline definition above and have various limitations. If the project does not satisfy the requirements for one of these expedited permit options, a living shoreline may still be pursued through application for individual permits from Delaware[3] and the USACE[4].

Site Evaluation Tip:

Many living shoreline projects can take advantage of an expedited permitting process.

2. Property Owner's Goals

Clearly and concisely describe the property owner's goals regarding the shoreline issues previously described. Consider prioritizing goals as primary, secondary and tertiary – as these

1 http://www.dnrec.delaware.gov/wr/Documents/Shoreline_Stabilization_SAA.pdf

2 http://www.usace.army.mil/Missions/Civil-Works/Regulatory-Program-and-Permits/Nationwide-Permits/

3 http://www.dnrec.delaware.gov/wr/Information/Permits/Pages/WetlandsandSubaqueousLandsPermittingInfo.aspx

4 http://www.usace.army.mil/Missions/Civil-Works/Regulatory-Program-and-Permits/Obtain-a-Permit/

may become important design considerations. For example, the primary goal may be to stop chronic shoreline erosion, a secondary goal may be to create habitat for juvenile fish, and a tertiary goal may be to maintain access to the water for recreation or water quality improvement. Describing and prioritizing the goals of the project early in the process puts the remainder of the Site Evaluation in context.

3. Project Site Dimensions

The dimensions of the project area are important to determine if there is enough space to construct a viable living shoreline and will inform many steps in the construction process including permitting, design, cost estimation, material purchasing, and others. Record the length of the site along the shoreline, as well as perpendicular to the shoreline (cross shore) that the project is expected to occupy. If this is not known, measure the distance between the shoreline and any permanent building or infrastructure that will constrain the viable construction area for a living shoreline project.

The most accurate form of measuring a site is a professional survey; however, a survey is not necessary to undertake for the purpose of a site evaluation. Accurate project area measurement can also be found using Geographic Information System (GIS) software such as Esri ArcMap, QGIS, and GRASS GIS, or web map applications such as Google Maps and Bing Maps. All of these applications have measurement tools that can measure complex shapes and can report measurements in an array of units of measure. The site dimension measurements can be verified during a site visit using a tape measure.

> **Site Evaluation Tip:**
>
> **Generally, sites with a large cross shore dimension provide more living shoreline potential because they can accommodate grading at gentle slopes, which is a good way to dissipate wave energy gradually.**

4. Body of Water

Name the body of water adjacent to the property. If the property is located at a confluence or sits adjacent to multiple bodies of water, this should be noted. By naming the body of water explicitly, context is provided to anyone who may review the Site Evaluation Worksheet in the future.

5. Shoreline Orientation

The shoreline orientation is the average direction the shoreline faces and is indicative of the directions from which it is subject to incoming waves. This is an important consideration in the analysis of wave climate, which is discussed below in Section 10.

To record the compass direction on desktop, place a 16-point compass over your aerial imagery to determine the direction the shoreline is oriented. To record the compass direction in the field, stand along the shoreline with shoulders parallel to the shoreline and looking towards the body of water being identified. If multiple bodies of water were recorded in the worksheet or if the site you are evaluating has multiple unique shoreline segments, separately identify a shoreline orientation for each unique reach of shoreline. Use the closest direction of a 16-point compass rose, as pictured in Figure 1.

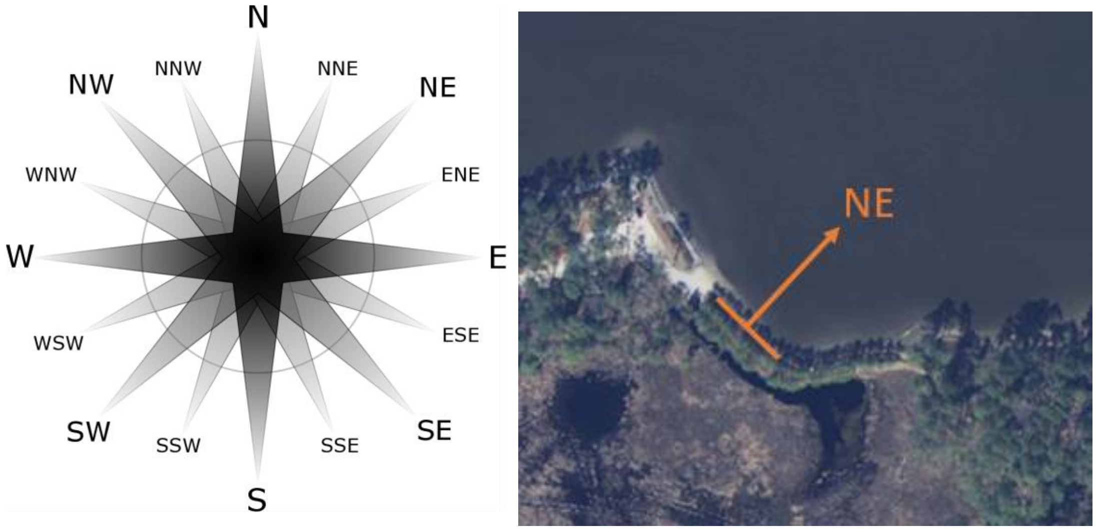

Figure 1. Sixteen (16) point compass rose applied to shoreline orientation

6. Shoreline Change Rate

Shorelines can advance or recede over time due to several factors including natural forces like wave-induced erosion, sea level rise, and accumulation of runoff sediments; or man-made factors including boat wake and development. The forces that cause shoreline change will not cease after construction of a living shoreline, so your design will need to account for ongoing exposure to the same erosion or accretion trends that you observe in this analysis.

If GPS survey data is not available, historical imagery may be used to assess shoreline change for sites along the Delaware Bay and Delaware River or any of the inland bays. Comparison of the shoreline at a project site at different times in history can provide perspective on the rates of shoreline change. It is best to compare multiple images from multiple points in time, and not only the oldest and newest images, in order to accurately calculate a long-term shoreline change rate. Individual imagery sets may be affected by recent storms and variable tidal cycles, and thus may not accurately represent long term trends. Web-based maps like Google Earth Pro or the Delaware First Map[5] platform allow users to look at the aerial imagery of an area at different times in history. An example of imagery along the Indian River Bay from the Historical Imagery on Delaware First Map can be found in Figure 2. The historical imagery from First Map includes aerial photographs collected as early as 1926. Comparison of the shoreline at a project site at different points in time can provide perspective on the rates of shoreline change.

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[5] https://firstmap.delaware.gov/arcgis/rest/services/DE_Imagery

Note that georeferencing of historic imagery has inherent uncertainty, so the best method of estimating shoreline change is to measure respective shorelines relative to a fixed object like a road or structure. Record your estimated shoreline change rate on the worksheet, noting whether it is erosional or accretional. The shoreline change rate does not provide information about the cause of erosion or accretion but is important information to consider while evaluating a site. New Jersey's Living Shorelines Engineering Guidelines[6] contains guidance relating various living shoreline techniques to long-term erosion rates.

Site Evaluation Tip:

The long-term shoreline change rate is a good indicator of the shoreline's exposure to the forces that will affect a living shoreline project. If the erosion rate is up to 2 feet per year, properly designed conventional living shoreline techniques can typically help stabilize the shoreline. If the erosion rate is higher, a successful design will likely need to include elements specifically designed to absorb or deflect wave energy.

Figure 2. Two historic aerial images of Indian River Bay shoreline on Delaware's First Map web service.

7. Geomorphology

Characterizing the geomorphology can be thought of as describing the lay of the land, or the shape of the land. In all areas relevant to the project, including offshore, at the shoreline, and upland from the site should be characterized. It may be easiest to describe elevations, slopes, and unique features by means of a site sketch. This guidance encourages the use of site sketches during your site visit. However, you may find enough information to draft a site sketch now, then refine it in the field.

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[6] http://www.nj.gov/dep/cmp/docs/living-shorelines-engineering-guidelines-final.pdf

Geomorphology is one of the most important limiting factors for site evaluation and ultimately in living shoreline design. Generally, tall and steep embankments are poor candidates for living shoreline techniques because of challenges in regrading large volumes of material, especially on developed lots that have permanent structures in close proximity to the shoreline, as seen in Figure 3.

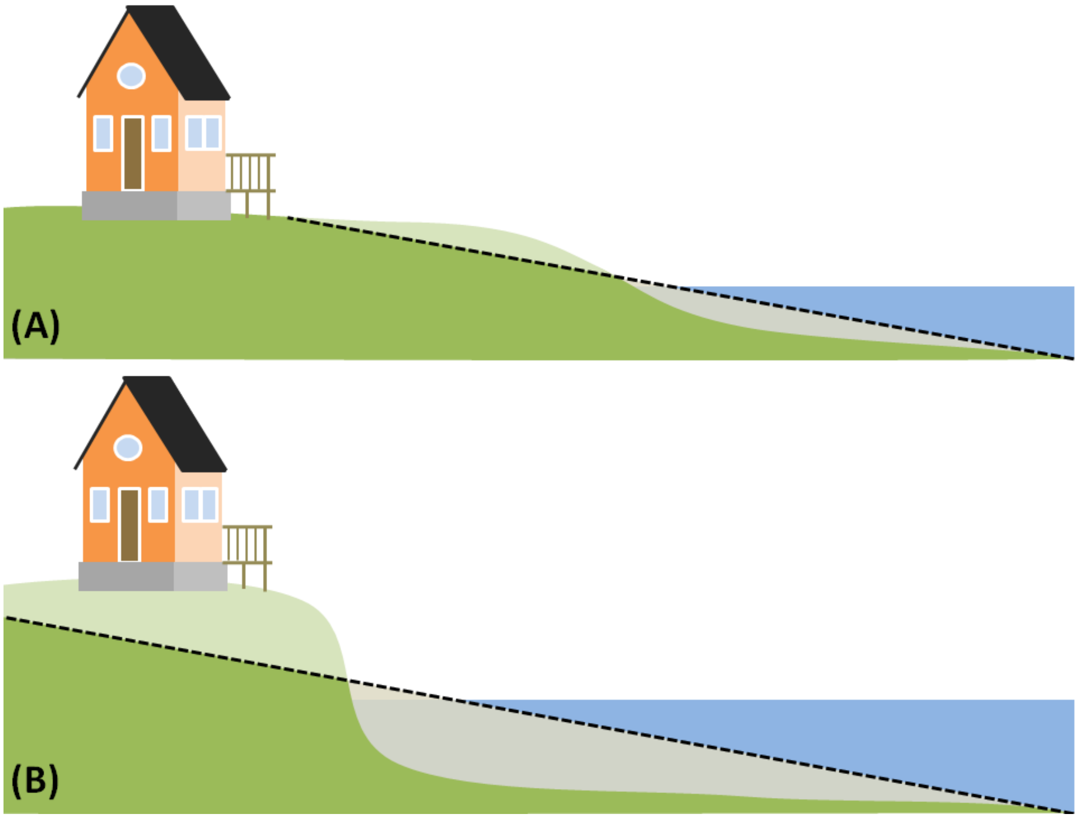

Figure 3. (A) A low, shallow sloping embankment with a structure set away from the bank provides adequate space for grading to the target slope (black dashed line). (B) A tall, steep embankment with a structure close to the top of the bank does not provide enough space for grading to the target slope.

In particular, geomorphic features in three zones should be considered: Submerged, Shoreline, Upland.

Submerged

The offshore depth and slope partly control the size of waves that reach the shoreline. Deeper water supports larger waves than shallower water. The average offshore depth will be part of the wave climate calculations that are described in Section 10. An approximate offshore depth can be determined using local survey data, Google Earth Pro, or navigation charts[7] [8].

Nearshore features like tidal flats or sand bars can block some wave energy from reaching the shoreline. Wave energy reduction by these features is a benefit to potential living shoreline projects because low-energy shorelines provide opportunities to use a wider range of living shoreline techniques. The features can sometimes be found on recent aerial imagery such as that available on Delaware First Map[9] or Google Earth, or on navigation charts. If nearshore features are not visible in aerial imagery, they may be visible during a site visit when the water level is low.

Shore/Bank

The slope or angle of land of the nearshore and intertidal zones controls the wave energy dissipation up to the shoreline. In a 2015 performance assessment of engineered shoreline projects along the Hudson River, slope was also found to affect resilience of living shoreline elements such as constructed wetlands[10].

> **Site Evaluation Tip:**
>
> **Site grading plans need to be compared with site dimensions to ensure the desired slopes are achievable within the footprint of your project site. A 4-foot vertical elevation change requires 12-foot horizontal distance at a 1:3 slope, the steepest recommended for upland bank grading; and the same 4 feet of vertical elevation change requires a 40-foot horizontal distance at a 1:10 slope, the steepest recommended for intertidal and nearshore grading.**

A slope no steeper than 1:10 (1 foot of vertical change for every 10 feet of horizontal distance) is recommended when constructing intertidal zone slopes intended to dissipate wave energy and support growth of wetland plants. If the existing slope is steeper than 1:10, site grading might be necessary (with or without the addition of fill material). Bank slope can be computed using elevation data from Delaware First Map[11] or contours on the United States Geological Survey (USGS) topographic maps[12].

Shoreline shape can affect how your shoreline is impacted by wave energy. If your project site is inside a cove it may be exposed to less wave energy compared to a headland shoreline. The effects of shoreline shape will factor into the Fetch analyses described in Section 8.

Upland

The upland features, those landward of the high tide line, will partly determine what kind of protections you can install that will buffer a living shoreline from storm water runoff,

[7] https://oceanservice.noaa.gov/facts/find-charts.html

[8] https://nauticalcharts.noaa.gov/rnconline/rnconline.html

[9] https://firstmap.delaware.gov/

[10] https://www.hrnerr.org/doc?doc=273625839

[11] https://firstmap.delaware.gov/arcgis/rest/services/Elevation

[12] https://ngmdb.usgs.gov/topoview/

residential pollutants, or other disturbances. Upland slope can be computed using elevation data from Delaware First Map[13] or contours on USGS topographic maps[14]. Steep slopes may require grading to reduce erosion from storm water runoff or from extreme tides. The Virginia Institute for Marine Science (VIMS) Center for Coastal Resource Management published guidance on bank grading, including a recommended maximum steepness of 1:6, or 1:3 if additional shoreline stabilization measures are implemented[15].

Site Evaluation Tip:

New Jersey's *Living Shorelines Engineering Guidelines* contains information on relationships between fetch, wave energy, and living shoreline techniques. Use this resource to help determine if the average and longest fetch measurements at your site disqualify the use of any living shoreline techniques.

Regrading tall and steep upland banks requires more space than regrading low banks; consider if your project site is large enough to accommodate grading to the recommended slopes.

8. Fetch

Fetch is the distance over which wind blows on the water surface to generate waves. Fetch is a critical consideration in the design of shoreline stabilization measures because in most cases wind-driven waves are the primary erosive force acting on the shoreline.

Either GIS or a web map service such as Google Earth can be used to measure fetch distances. Ensure that you have a quality base map or recent aerial imagery that allows you to clearly identify the land/water boundary. Fetch should be measured from shoreline to shoreline. Keep in mind that sometimes very low-lying marshy areas could appear as land in an aerial image or on a map but may be underwater at high tide. Use your discretion to determine the best limits of your fetch measurements. Guidance on computing the wave climate is provided in Section 10. Alternately, you can refer to guidance directly relating average fetch to various shoreline stabilization techniques in Shoreline Management in Chesapeake Bay[16]. If performing your desktop evaluation in ArcGIS, the U.S. Geological Survey has a tool that can be used to compute fetch in an area[17].

The goal of computing the average fetch is to generalize a site's exposure to wave energy. The average of five fetch directions should be computed and recorded to represent the average fetch parameter. Using the compass rose in Figure 1, measure the fetch in the direction that you selected to represent shoreline orientation as well as two increments on either side of that direction. For example,

13 https://firstmap.delaware.gov/arcgis/rest/services/Elevation

14 https://ngmdb.usgs.gov/topoview/

15 http://ccrm.vims.edu/livingshorelines/design_options/bank_grading.html

16 http://www.dcr.virginia.gov/soil-and-water/document/shoreline-management-in-chesapeake-bay.pdf

17 https://umesc.usgs.gov/management/dss/wind_fetch_wave_models_2012update.html

in Figure 4 the shoreline orientation is East, so you would compute the average fetch using fetch distances measured in the NE, ENE, E, ESE, SE directions as shown.

The longest fetch is also an important consideration, especially in light of prevailing wind information, discussed in the next section. If the longest fetch aligns closely with prevailing winds or with expected storm wind directions, then the project site may have an increased exposure to wave energy.

This Site Evaluation document includes two considerations of fetch, the average fetch and the longest fetch.

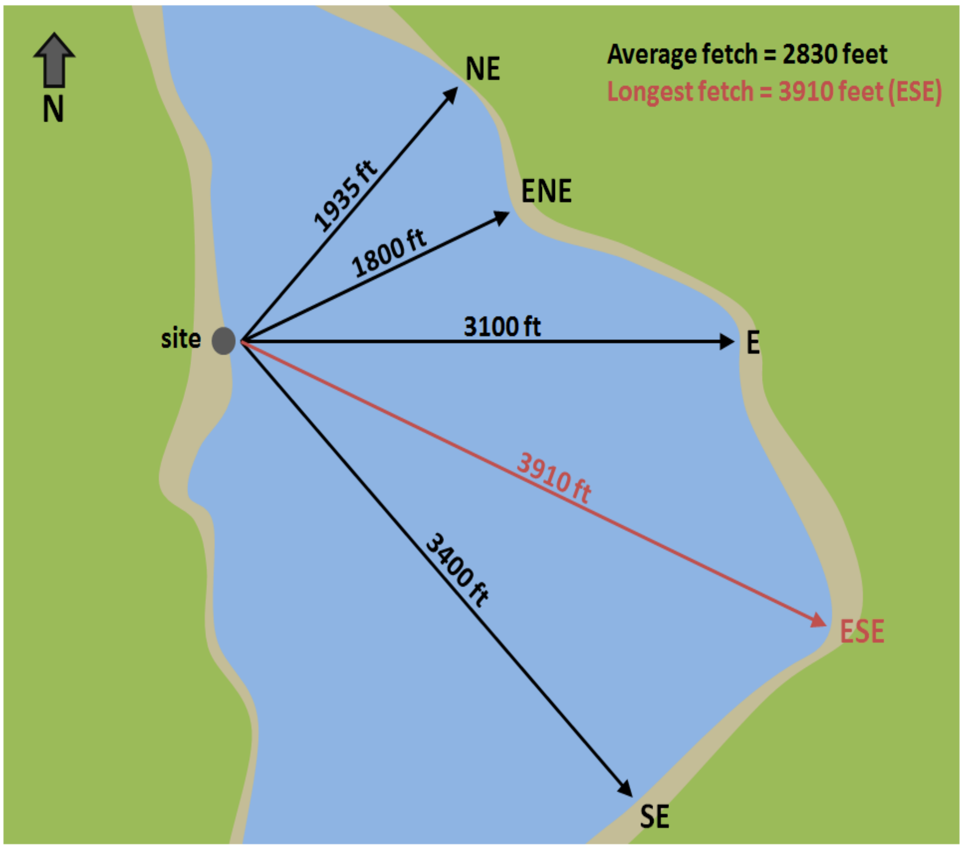

Figure 4. Schematic drawing of fetch calculations.

9. Wind

On calm days in Delaware, prevailing winds are typically out of the southwest, but storm winds are usually out of the northeast or southeast. These wind directions, especially the energetic storm wind directions, should be compared against the shoreline orientation and longest fetch directions while determining the expected wave energy exposure, discussed further in Section 10.

Wind data can be found at Delaware Environmental Observing System[18], from the National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center[19], airports, some NOAA tide gages[20], and at specialty websites for activities that are wind related like sailing or windsurfing such as www.iwindsurf.com.

Long-term wind climate data are relatively scarce; consequently, some default representative parameters are suggested here for your site evaluation and summarized in Table 2. Based on one year of historical wind data from NOAA Station 8557380 in Lewes, DE the prevailing wind speed was 11 miles per hour with winds coming from the SSW direction. At the Delaware Coastal Airport (GED) in Georgetown, DE the average prevailing wind speed was 7 miles per hour and the average storm wind speed was 40 miles per hour, based on a 10-year historical data record. During the same 10-year record from the Wilmington Airport (ILG) in New Castle County, DE the average prevailing wind speed was 8 miles per hour and the average storm wind speed was 45 miles per hour. Based on these resources, prevailing wind speeds in the range of 7-11 miles per hour out of the SW quadrant of the compass rose are appropriate if better data are not available. Storm wind speeds in the range of 40-45 miles per hour are reasonable and should be coupled with the conservative assumption that the storm winds align with your longest fetch distance if better data are not available.

Table 2. Summary of representative wind parameters for Delaware

Location	Prevailing Wind		Storm Wind		Record Duration
	Speed (mph)	Direction	Speed (mph)	Direction	
NOAA Station 8557380 Lewes, DE	11	SSW	N/A	N/A	1 year
Delaware Coastal Airport (GED) Georgetown, DE	7	N/A	40	N/A	10 years
Wilmington Airport (ILG) Wilmington, DE	8	N/A	45	N/A	10 years
Representative	**7-11**	**-**	**40-45**	**Assume longest fetch direction**	**-**

If you elect to process wind data, pay strict attention to the units of the data, the type of data that are available, and the direction convention. Wind data are reported in different ways depending on the target audience; a service whose goal is weather reporting will typically describe wind speeds and directions 10 meters above ground level, whereas a specialty website may report winds at ground level. With regard to wind direction, the convention is typically the direction from which the wind is blowing; however, some sources may use a convention that describes the direction towards which it is blowing. Sustained ground wind speeds are the

[18] http://www.deos.udel.edu/

[19] https://www.ncdc.noaa.gov/societal-impacts/wind/overview

[20] https://tidesandcurrents.noaa.gov/met.html?id=8557380

important parameter for wind-wave generation, wind gusts represent wind behavior over too short a time to be relevant in wave calculations. Online tools are available for converting wind speeds observed at one elevation to a wind speed at another elevation.[21]

10. Wave Climate

The amount of wave energy that can potentially reach the shoreline is a critical element in determining the suitability of various living shoreline techniques. There is literature relating various wave energy climates to appropriate living shoreline techniques, including New Jersey's Living Shorelines Engineering Guidelines [22], New York's Tidal Wetlands Document: Living Shoreline Techniques in the Marine District of New York State [23], and Shoreline Management in Chesapeake Bay [24]. These capitalize on your average and longest fetch calculations to categorize the expected wave energy at the shoreline, and to suggest the viability of certain living shoreline techniques.

Site Evaluation Tip:

Shoreline Management in Chesapeake Bay **describes Low Wave-Energy shorelines with average fetch less than ½ nautical mile (.6 miles) as most suitable for marsh-only living shoreline techniques. If the fetch is larger than ½ nautical mile, additional shoreline protection is necessary to diminish wave energy.**

Boat wake may also represent an erosive force for a living shoreline site. At the time of this publication, there exists little information on predictive formulas for estimating boat wake energy at a site. Wake energy and characteristics are most certainly dependent on hull shape, propulsion type, and draft, among other parameters of the passing vessel. The proximity of a site along a heavily trafficked navigation channel or near a boat ramp, marina, or other docking/launching facility may indicate that wake ought to be considered in the design of the living shoreline. An in-situ measurement or visual observation of boat wake is likely the best method for estimating wake energy.

Similarly, the water use in the areas surrounding the potential living shoreline site can provide valuable information about the water quality and boat- and other water-based human traffic. For example, existing nearby aquatic habitats could suggest what the water quality is suitable for including an aquaculture component in the living shoreline design. Areas with high boat and human traffic may need toe protection in the living shoreline design to ensure it can withstand boat wake and other destructive forces.

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[21] https://websites.pmc.ucsc.edu/~jnoble/wind/extrap/

[22] http://www.nj.gov/dep/cmp/docs/living-shorelines-engineering-guidelines-final.pdf

[23] http://www.dec.ny.gov/docs/fish_marine_pdf/dmrlivingshoreguide.pdf

[24] http://www.dcr.virginia.gov/soil-and-water/document/shoreline-management-in-chesapeake-bay.pdf

Boat wakes can sometimes be the largest waves to consistently affect some sites, especially where a minimal fetch exists. Understanding the frequency and size of boat wakes along your site will aid in characterizing some of the erosional forces that may be affecting the shoreline, which may require attenuation (dampening) by the living shoreline design. Landowners may have a rough estimate of the frequency and size of boat wakes during different seasons. Nearby marinas, navigational channels, docks, etc. are indicators that energy from boat wakes will need to be considered during the initial evaluation and design effort. During the desktop and field site visit analyses, note:

- Whether your site is along a federal, state, or private navigational channel
- What are the typical sizes of vessels passing the site
- What is the passage frequency of the vessels
- If there is a "no wake zone" signage present, etc.

Generally, these simple observations will provide enough detail to assess boat wakes at your site. Observe how the boat wake interacts with the shoreline, photograph or video record this occurrence for later viewing. If boat wakes appear to be the primary cause of erosion at a site, a more detailed examination of boat wakes should be executed.

Site Evaluation Tip:

Low-energy wave climates, where wave heights are not expected to exceed 1 foot, are most appropriate for conventional living shoreline techniques. Higher wave energy climates should incorporate hybrid living shoreline techniques to achieve project goals.

If you want additional information on wave climate at your site, you can use the offshore depth, fetch, and wind information that you have compiled to estimate the size of waves that can reach your site. The following simple qualitative generalizations describe the role of each parameter:

- deeper water supports larger waves than shallower water
- longer fetch distances allow waves to grow to larger heights
- stronger winds acting on the water surface produce larger waves

The USGS Fetch- and Depth- Limited Waves Calculator[25] can be used to compute wave height and wave period using your site information (Figure 5) Check that the units on the calculator website match the units of your inputs. Consider calculating the wave height and period using both average and longest fetch, and a range of prevailing and storm wind speeds in order to get a comprehensive understanding of expected wave characteristics at your site.

The computed wave height range is a good indicator of the wave climate at your site, and thus the wave climate that any living shoreline technique would need to endure. Classifying your site as a low-, moderate-, or high-energy wave climate can facilitate the selection or elimination of certain living shoreline techniques. Literature varies in describing the range of wave heights that correspond to each wave energy climate and in its conclusions regarding appropriateness of living shoreline techniques, so exercise caution when comparing across various guidance documents.

[25] http://csherwood-usgs.github.io/jsed/

The Wave Exposure Model (WEMo) from NOAA[26] can also be used to assess a site's exposure to wave energy. The Nature Conservancy and NOAA incorporated WEMo into a living shoreline site evaluation pre-screening application for North Carolina[27].

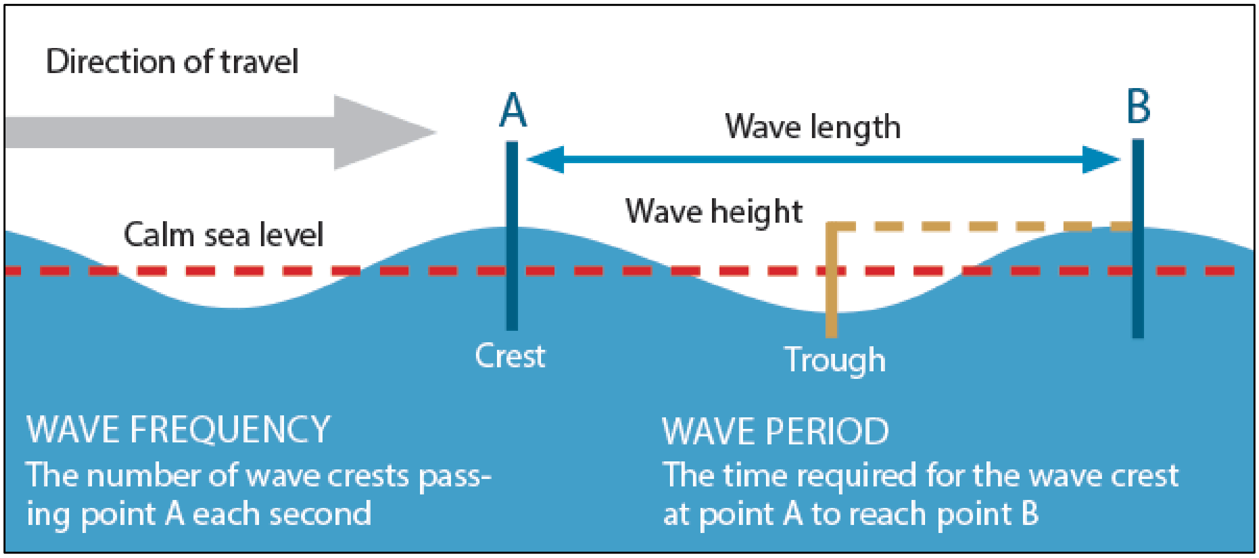

Figure 5. Wave characteristics to consider when designing a living shoreline.

11. Tide Information

Tidal datums, or common vertical reference points (e.g., elevations) based on local tidal behavior for certain tide phases, are important in the evaluation and design of living shorelines. Several components of living shorelines can be directly tied to tidal datums and are discussed throughout subsequent sections of this document. For example, marsh grasses will thrive in specific ranges approximately between Mean Tide Level (MTL) and Mean High Water (MHW). If your project goal is to create a wide marsh fringe, a small tide range will make it difficult to construct the particular grades necessary for healthy marsh grasses.

This site evaluation guidance recommends identifying the local elevations corresponding to Mean High Water (MHW), Mean Low Water (MLW), Mean Tide Level (MTL), and mean tide range (e.g., the difference between MHW and MLW) (Figure 6).

[26] https://products.coastalscience.noaa.gov/wemo/
[27] http://media.coastalresilience.org/NC/Living_Shorelines_Methods.pdf

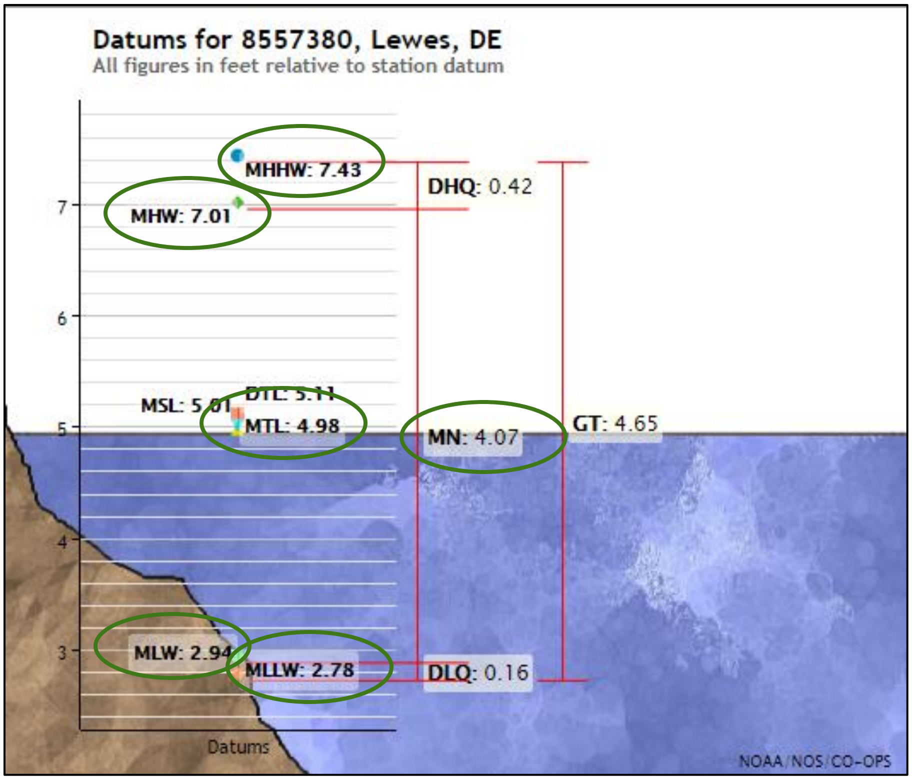

Figure 6. Visual representation of the tide levels for Lewes, DE using NOAA's Tides and Currents.

These local tidal datums can usually be derived from NOAA's Tides and Currents website[28], USGS's Water Information System[29], or using NOAA's VDatum[30] software. The NOAA website contains tidal elevation data for select gages. The USGS website offers time histories of water levels at gages that can be used to compute necessary tidal datums. VDatum software facilitates the computation of desired tidal datums at any water body within their model domain.

If using a NOAA or USGS gage, select the gage closest to your site within the same body of water and record or compute the desired tidal datums. Note the information may need to be converted to a datum consistent with your other project data.

VDatum's online platform or downloadable software can be used to derive local elevations for MHW, MLW, and MTL at almost any location within Delaware tidal waters. For best results and to prevent errors, use a point approximately 50-100 feet offshore from your site as Input to the software. Set your 'Source' datum to the desired tide level, set your 'Target' datum to NAVD88, and use a 0-foot height as Input. The Output is the elevation of your specified tide level relative to NAVD88 (Figure 7).

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[28] https://tidesandcurrents.noaa.gov/map/index.shtml?region=Delaware
[29] https://maps.waterdata.usgs.gov/mapper/index.html
[30] https://vdatum.noaa.gov/welcome.html

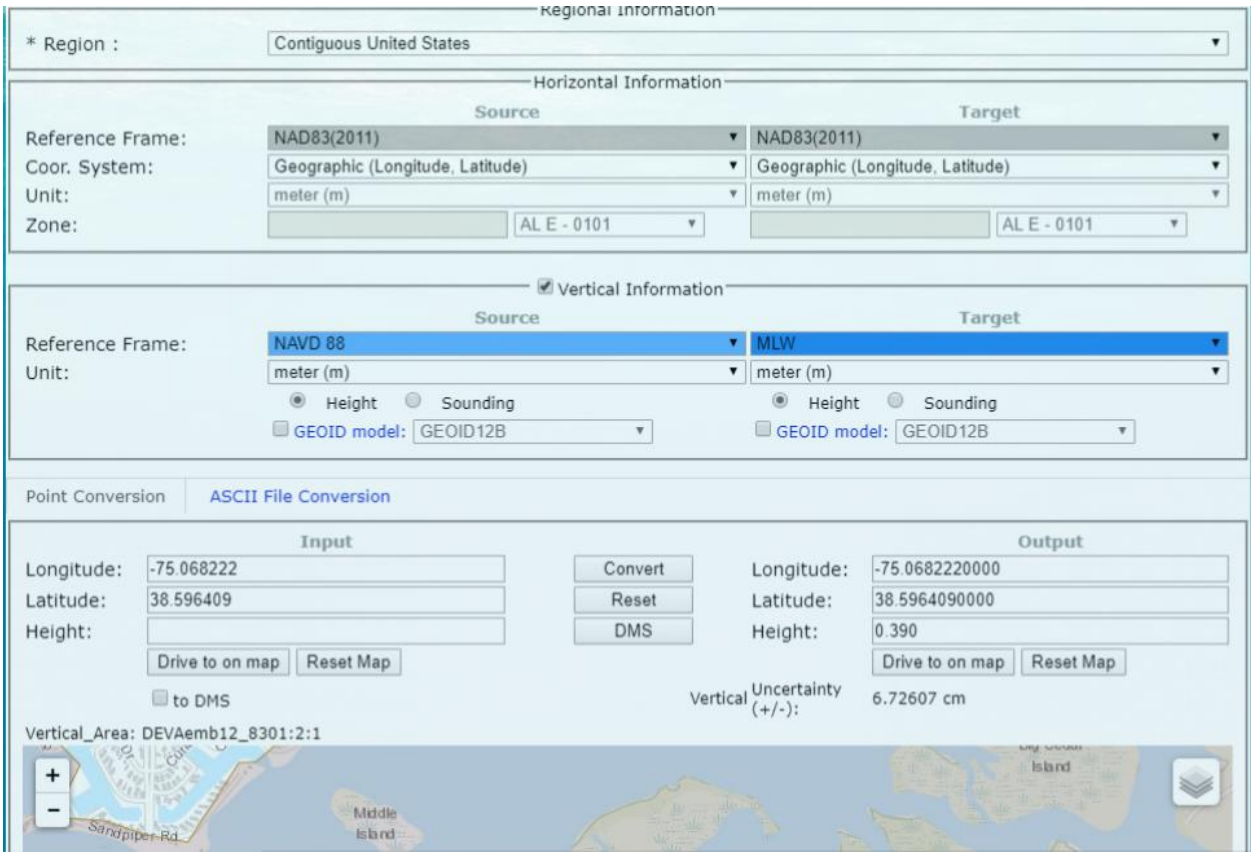

Figure 7. A screenshot of VDatum's online platform calculating MLW. The platform is showing the MLW for the specified location. By changing your target, you can calculate a local elevation for the various tidal water levels.

Alternatively, MLW, MHW, and MTL can be approximated at your site by taking measurements through a complete tide cycle. It may be best to perform a local tide measurement at your site if your location is far away from a tide gauge or you think your site experiences different tidal patterns than published data indicate. If you measure tides on site, it is a good idea to be aware of the tide characteristics at the nearest gage location as a method of ground truthing your observations.

It is best practice to compare recorded tides at a proposed site with a NOAA or USGS gage that is in proximity. For example, if a living shoreline it to be constructed upstream from a navigational inlet, at which NOAA maintains a gage, measured water levels at the site should be compared to NOAA's measurements. This will allow the designer to correlate the tide/water level at the site to the measured gage data. NOAA gages typically provide elevations for tidal datums such as Mean Higher High Water (MHHW), Mean Lower Low Water (MLLW), and the Mean

Tide Level (MTL). Common coastal water levels used by boaters and coastal/marine practitioners is exemplified by NOAA's datums[31].

Tidal datums can also play an important role in the type of permits needed to construct a living shoreline and may have other regulatory considerations, as well. For example, all lands water-ward of MHW are regulated by Delaware Department of Natural Resources and Environmental Control (DNREC). Furthermore, unless specifically designated as private, all lands water-ward of MLW in tidal waters are state regulated Public Subaqueous Lands. Any construction, including using living shoreline techniques, on such lands may be subject to lease fees[32]. DNREC's Wetlands and Subaqueous Lands Section can delineate the MHW line at the request of the property owner.

Certain federal permits may also impose restrictions tied to tidal datums. For instance, Nationwide Permit (NWP) 54, issued by the USACE to streamline permitting for certain types of living shoreline projects, limits the placement of structures or fill for a living shoreline to be no greater than 30 feet water-ward of Mean Low Water (MLW). The designer must also consider constraints on stabilizing banks, which may be authorized under NWP 13. This permit limits the volume of fill placed below the plane of the ordinary high-water mark or high tide line. NWP 27 could also be used to expedite your permitting process relating to restoration, enhancement, or establishment of wetlands, streams, or open water if a project results in a net increase in aquatic resources functions and services. While this discussion is not intended to provide detailed regulatory guidance, it demonstrates the role tidal datums can play in selecting among applicable permits, which may impose various restrictions that should be considered when planning and designing living shoreline projects.

12. FEMA Flood Hazard Zone and Base Flood Elevation (BFE)

The use of earthen fill material, and other natural or artificial material, is common in living shoreline designs. Local rules vary, but in some places the use of fill is controlled or restricted because of the Federal Emergency Management Agency (FEMA) Flood Hazard Zone[33]. In Delaware, floodplain ordinances are managed by the incorporated municipality or the county in unincorporated areas. In coastal areas the FEMA Flood Hazard Zone also provides information about extreme storm surge and waves; though rare in occurrence, the extremes are important to keep in mind when considering or designing living shoreline techniques. That is, the selected living shoreline design should be capable of withstanding typical wave energies, and salinities regarding vegetation, yet also being capable of enduring higher energies during acute events. All living shorelines projects should have the target storm conditions identified in the project

[31] https://tidesandcurrents.noaa.gov/stationhome.html?id=8557380

[32] http://dnrec.delaware.gov/wr/Information/Permits/Pages/WetlandsandSubaqueousLandsPermittingInfo.aspx

[33] https://www.fema.gov/fill

goal statements (e.g., built to withstand a 10 percent annual chance storm event, 50-year storm flood, etc.).

A FEMA Flood Insurance Rate Map (FIRM) depicts the floodplain, the geographic extent of flooding, associated with a 1-percent-annual-chance event (~100-year storm event) for the purpose of supporting flood insurance ratings for vulnerable houses and other structures. The elevation of flood hazard, referred to as the Base Flood Elevation (BFE) is also mapped within the floodplain area. BFEs in coastal areas include wave effects and are higher than storm surge Stillwater levels (e.g., water levels during non-storm conditions). The 1-percent-annual-chance event has a 1 in 100 chance of occurring in any given year. This translates into a 1 in 4 chance of occurring over the course of a 30-year mortgage.

In tidally-influenced areas, FEMA FIRMs are based on the combined effects of storm surge and wave hazards. The FIRMs describe the magnitude of waves throughout the floodplain using a zone designation of either VE or AE. Areas designated as Zone VE are expected to experience a wave height of 3 feet or larger during a 1-percent-annual-chance event. Areas designated as Zone AE are expected to experience a wave height between 0 and 3 feet. Zone AE areas can be further subdivided by a FIRM feature called the Limit of Moderate Wave Action (LiMWA) which delineates the location of the 1.5 wave height contour. Therefore, Zone AE areas inland of the LiMWA have a wave height of 0 to 1.5 feet and Zone AE areas seaward of the LiMWA have a wave height between 1.5 and 3 feet. Any area within the VE zone or LiMWA area is considered within a Coastal Flood Hazard Zone and is potentially subject to damaging waves during extreme coastal storms. FEMA considers the 1.5-foot-high wave sufficient to cause significant structural damage on a property.

The State of Delaware provides FEMA FIRM data through their First Map web platform[34]. The First Map platform allows users to search for a location by panning around the map or using the search field to enter a parcel ID or address. Once the site has been located, users can click on the map to launch the Results window which provides the Zone designation and BFE information for that location (Zone VE, BFE 10ft in the example Figure 8 below). The shapefiles contained in the DFIRM database can also be of other use when evaluating a shoreline, containing useful information such as significant wave heights and periods.

Record whether the project area is identified on a FIRM as being within a flood zone, and the specific flood zone designation and BFE.

[34] http://maps.dnrec.delaware.gov/floodplanning/default.html

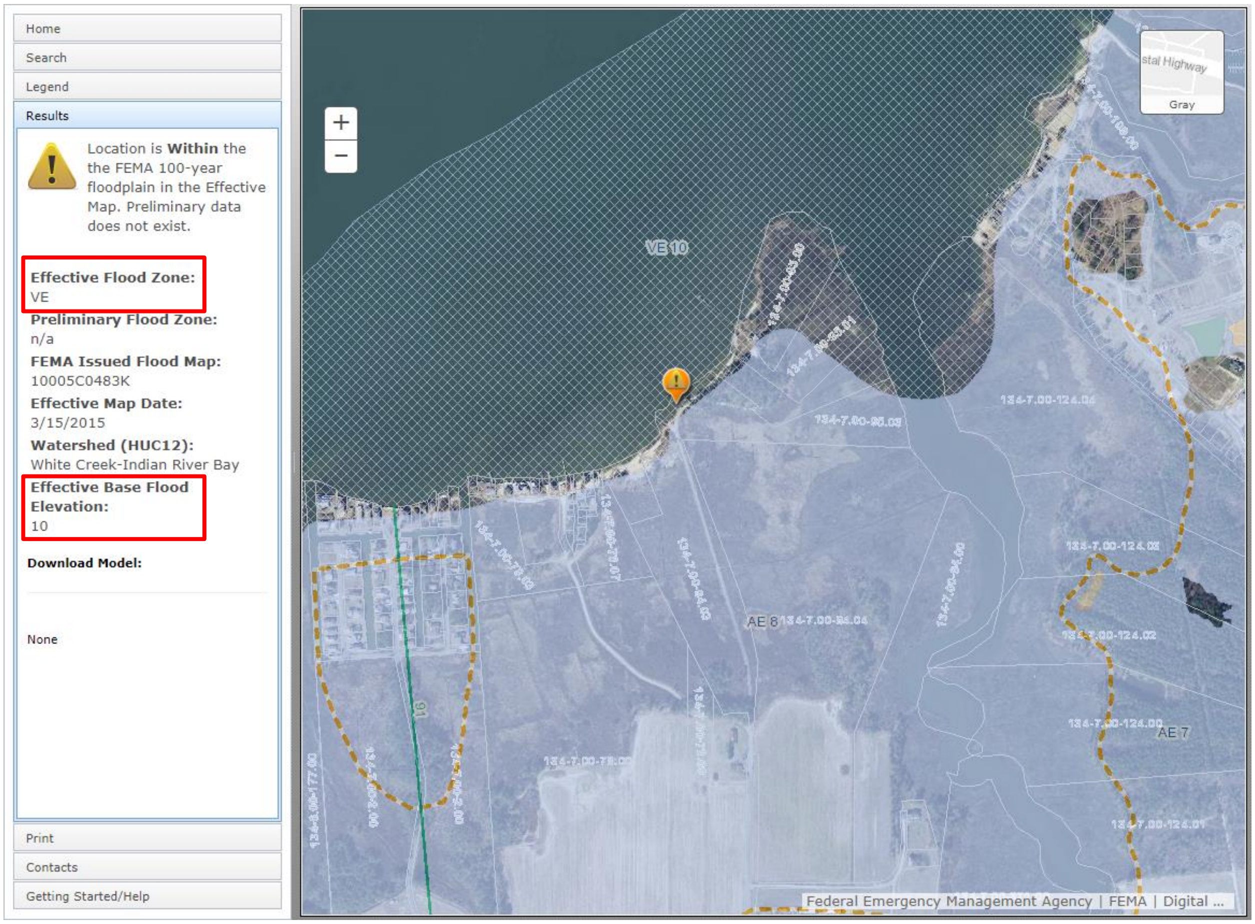

Figure 8. A screenshot of Delaware's Flood Planning Tool showing that the user-selected location is in Zone VE with a BFE of 10 feet relative to NAVD88. The locations of the flood zone and BFE information on the left-hand panel are highlighted with red boxes.

13. Notes

Record any special notes that may be relevant to the project area based upon your pre-visit desktop investigation. Indicate items that you want to revisit or verify during the site visit, and any uncertainty or special notes related to any of the desktop analysis parameters that might help someone else understand your worksheet.

Examples of Notes may include:

- List of items for ground-truthing, or for identifying features observed on aerial photography that is inconsistent or not clearly discernable during the desktop review;
- Identifying unique vegetation signatures that may represent unique plant communities, which can be further characterized during an on-site visit;
- Identifying portions of the site that appear to be vulnerable or subject to change on aerial photography, which can be further evaluated during a site visit;

Site Evaluation Tip:

Pay close attention to units of measure that are being used when collecting the multitude of data in this document, especially when working with a multidisciplinary team. E.g. meters vs feet, knots vs mph, scientist vs engineers

- Physical, readily located features, which offer a stable reference point in the field, which aids in identifying important information while on-site (e.g., property boundaries, surge limits, elevations of interest, site access infrastructure); and
- Locations for repetitive photograph stations.

Part 2: Site Visit Parameters

Pre-site visit characterization using existing datasets during the desktop analysis process described above is useful, but field observations provide additional information that cannot be collected in any other way. In most circumstances, a site visit is necessary to competently evaluate a site for a living shoreline project. Specific site information guides the design process by narrowing down which living shoreline techniques are possible, appropriate, and practical. It is also an important information gathering step in preparation for the design and permitting processes.

Consider planning your site visit to occur during the lower 1/3 tide so you can observe more features. Keep in mind that on Delaware's Inland Bays the daily wind can affect water levels as much as tides. If the site can be safely accessed, it is often helpful to visit the site during a low tide, high tide, and a high energy event (storm).

Site Evaluation Tip:

Document your site visit with photographs. Take as many pictures as you can, including wide and detail views. Provide context to your pictures by including scale features, such as a pen in detail photos or a team member in wide views. Photographs are a great tool for communicating the specifics of your site to others. Also, it is often helpful to provide notes that describe what you are trying to capture in each photo.

14. Site Boundaries

The site dimensions delineated during the desktop analysis can be refined during the site visit. In addition, the site visit provides an opportunity to investigate project constraints related to the boundaries. A description of the shoreline and accompanying photos will help envision how your potential project will tie into the adjacent shoreline. For example, note high ground that structures or sand fill could be tied into, existence of any bulkhead or revetment, and the condition of such features. These conditions will be an important design consideration to avoid any adverse effects to the project site or adjacent shorelines at the project edges, including neighboring properties.

Ideally, a robust design should address the full extent of any compromised shoreline regardless of property lines. An isolated shoreline stabilization feature, including living shorelines, may inadvertently make the problem worse at a neighboring shoreline. In addition, project elements may be undermined or fail due to continued erosion on an adjacent shoreline. Permitting agencies will particularly scrutinize the potential impact of your project to adjacent shorelines.

That said, regarding private properties, a design will often have to be limited by the property boundaries along the shoreline. Therefore, if the compromised shoreline exceeds the property boundary, coordination with neighboring properties may be necessary to address the full extent of the issue. If coordination with neighboring properties is not feasible, shoreline stabilization elements should be designed to prevent negative effects on adjacent properties.

A project may have inland constraints as well, including existing landscape features, structures, and above- or underground infrastructure on or near the property. Additional details on the upland constraints are discussed in Section 15. Permits may impose further constraints on project boundaries. For example, certain permits may have limitations on the offshore extent of project elements, length of shoreline that can be included in the project, setbacks from adjacent property lines or water access. Understanding the dimensions and boundaries of the project site will help determine which living shoreline techniques are viable and which permits will be applicable.

15. Land Use/Land Cover

Land Use

Existing land use presents design constraints and may preclude the use of certain living shoreline techniques. For example, the presence of a building near the shoreline may dictate the amount of regrading a site can accommodate. Note the land use on the potential project site as well as at nearby or adjacent properties, including upland land use (e.g., development, roads and sidewalks, drainage ways and culverts, and natural areas). The type of upland land use could present right-of-way limitations that could impact access and constructability of certain shore protection techniques.

The type of upland land use will also provide insight on the volume and type of human traffic the living shoreline might experience, which could factor into the design and construction plan. For example, a public developed area is likely to see high volumes of human traffic and might require fencing or other protection to prevent trampling of any newly planted marsh grasses. In addition, a living shoreline design may need to incorporate a corridor for water access, such as pathways for kayak launches or designated fishing areas.

Site Evaluation Tip:

While on site, look for storm water outflows in your project area. You may not be able to see a pipe, but perhaps you will observe local scour that indicates focused runoff flows. Your living shoreline project will need to resist erosion from below and above if storm water runoff is directed through your project area.

Land Cover

In addition to land and water use, the land cover can inform the design and selection of living shoreline techniques. Land cover can also affect permit conditions, such as when state regulated wetlands are present. Impervious land cover such as a large paved parking lot can contribute to erosion and other site issues. For example, a developed area with significant impervious surface may have considerable runoff during precipitation events compared to vegetated areas where precipitation can infiltrate the ground. When visiting a potential living shoreline site, observe the land cover of the site and surrounding areas to estimate the distribution of land cover types, and assess how they might influence a living shoreline. Note the presence of pervious and impervious surfaces, upland and wetland vegetation, mud flats, sand bars, and areas of open water.

Shoreline Structures

If shoreline modifications are present at your site or on immediately adjacent properties, their condition and effects on shoreline processes should be considered. Existing structures may indicate previous attempts to address erosion, or they may be exacerbating erosion at the site or on neighboring properties and act as an ecological barrier. Existing structures may need to be removed, modified, or incorporated (retrofitted) into living shoreline designs.

Note structures that are present at your site and on adjoining properties (e.g., docks, bulkheads, groins, revetments). Consider the extent to which these structures are intact and functional, and how they may be affecting the property owner's project goals.

16. Geology

Prior to the site visit, this guidance suggested a review of geomorphology. The site visit provides an opportunity to fill in gaps that may persist after the desktop analysis, and to collect information that can only be observed in the field such as sediment types. Site geology can indicate if there are existing erosion issues and will be an important consideration for many design elements, including grading and heavy components like fill and stone.

Submerged

The submerged portion of your project, or the nearshore, approximately refers to the area that regularly experiences wave breaking. The nearshore is highly dynamic and can experience sediment movement on, off, and along shore depending on weather patterns and water flow. The stability of the nearshore sediment influences the types of living shoreline techniques that are appropriate to create and sustain a minimum beach or marsh width to increase wave attenuation, maximize habitat value, and protect the shoreline. Observing where sediment accretes or is deficient in the nearshore, such as along groins, will help indicate the direction of sediment transport and the amount of sediment a living shoreline can potentially capture.

A thorough study of these factors is not practical for an initial site evaluation, but general observations can be made, and landowners may have anecdotal information that will provide a general sense of the area's sediment supply and stability. Determine whether there exist any sediment sources or sinks in the nearshore, including natural or manmade features that may obstruct the natural flow of sediments. Also try to determine the mechanisms by which sediment is mobilized (e.g. tidal currents, wave breaking, or storm water runoff) and any seasonality or periodicity to the sediment movement.

In addition to the movement of sediment, the composition of the sediment is important to consider. For example, whether sediment is firm sand or fine silt and clay will determine what kind of measure may be appropriate to create a sustainable living shoreline. The presence of sand can indicate a bottom that can support heavy features like fill and stone. A site with soft sediments will need to be assessed in more detail for its capabilities to hold the weight of your project components.

Shore/Bank

The shoreline is the area where the water meets the land. In tidal areas this can generally be interpreted as the area between MLW and MHW. The shoreline can be characterized in several different ways. In this section the user should focus on the geology of the shoreline including the physical forms and the sediments that make up the observed features.

A bank is a transition feature between the dry upland and a water body. Banks can lie immediately adjacent to the water body or some distance away with a sandy beach or low marsh at their toe. While visiting the site, identify the transition between dry upland and the water body basin at your site. Note the general components and condition of the shore or bank, including evidence of accretion or erosion. For example, a sharp stair-step shape near the shoreline can indicate chronic erosion issues caused by wave action or local currents. If possible, classify the sediments present and describe any layers observed. This information can be useful if detailed erosion analyses are necessary during the design process.

If working in an area covered by the VIMS Shoreline Inventory[35] (Appoquinimink, Blackbird, St. Jones, Indian River, and Rehoboth Bay), the data found therein can be helpful in describing the shore and bank. Geospatial information on shoreline condition, bank composition and shoreline features are available online for viewing.

Upland

Onshore or upland geology is important to note if any regrading of the site is necessary as part of a living shoreline design, or if the ground must bear the weight of heavy design components like large boulders. Typically detailed geotechnical analyses will be required to determine the bearing capacity of a site; however, you may be able to eliminate the feasibility of heavy components during a field visit by observation.

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[35] http://www.vims.edu/ccrm/research/inventory/delaware/index.php

17. Local Ecology

The local ecological variables at your site can be broken into biotic, including flora and fauna, and abiotic, such as water quality, sunlight/shade, and soil type. The abiotic variables are important for determining the presence or condition of the biotic variables or their future performance as part of a living shoreline. A cursory ecological analysis of your site will help indicate the condition of the site, the most suitable living shoreline techniques, potential special design considerations, potential permitting conditions, and ecological tradeoffs (e.g., loss of one type of habitat for another). If your site is heavily degraded, the ecology of a nearby shoreline that is in better condition may provide a reference point for how your site looked prior to becoming degraded and thus indicate viability of specific living shoreline techniques.

Biotic

The flora and fauna at a site are a strong indication of the condition of the shoreline, its relative ecological value, it's importance to rare/sensitive wildlife, and will indicate the ecological uplift that may be experienced from implementing a living shoreline project. Additionally, much of what ultimately will make a living shoreline both effective at stabilizing shoreline and providing ecological uplift relies on the use of local living flora and fauna.

Fauna

Most wildlife are transient by nature, many are only seasonally present, and when present may be hard to identify. The condition of the beach and marsh environment along with the general location of your site may be more important to suggest which wildlife currently rely on your site or would use your site more if stabilized with a living shoreline. Fortunately, several specific organisms that are found in Delaware's coastal zone that are ecologically most relevant are relatively easy to find and identify if present. For example, the frequent observation of species such as horseshoe crab (spring spawning) and diamondback terrapin (summer nesting) can be noted if your site visit overlaps with the time of year they are active on shore which is April to May and late May to mid-July, respectively. Some species, particularly oyster and ribbed mussel are integral parts of stable shorelines and have been found to positively affect living shoreline longevity. On the worksheet, note observations on any fauna present at your site or nearby comparable shoreline.

Horseshoe crabs are an iconic part of the coastal ecosystem of Delaware and critically important. A gradually sloping protected beach in spring time can be covered with spawning horseshoe crabs the eggs of which then provide an abundant food resource to migratory birds, fisheries, and other wildlife. Gradually sloping sites where extra sand rich sediment can be trapped through a living shoreline project may provide an opportunity to create habitat for horseshoe crabs. However, keep in mind that thousands of horseshoe crabs spawning at a site also create a lot of disturbance as they congregate in intertidal areas and dig down five inches or more to bury egg clusters along the mean high tide line where you may intend to plant as part of a living shoreline. During the spawning

Site Evaluation Tip:

Horseshoe crabs can be a desirable species on sites with habitat restoration goals, but their presence during the spring spawning season can damage living shoreline project components.

season, horseshoe crabs can remove large areas of newly planted vegetation. Species planted within the intertidal zone, such as *Spartina alterniflora*, are especially vulnerable to horseshoe crab disturbances following their planting. The extensive activity of the horseshoe crabs can also shred and damage other soft parts of living shoreline projects such as jute matting and coir logs leading to unexpected project failure. If you are evaluating a site for a living shoreline that hosts large numbers of horseshoe crabs in spring, consider leaving/enhancing the area in question as beach or plant after mid-June once the spawning has finished. Once intertidal plants are well established by the following spring, they are less likely to be uprooted by the activity of the horseshoe crabs.

Site Evaluation Tip:

If your project site area includes potential habitat for threatened and endangered species of flora or fauna, your permit may come with special conditions like time of year restrictions for certain construction activities.

Your site or the surrounding area may be important to sensitive wildlife species. A living shoreline design may enhance or degrade your site's value to these wildlife species and living shoreline techniques may need to be carefully tailored to avoid unintended disturbance of these species. For example, several bird species may frequently use some coastal sites in Delaware, including two species that are protected under the Endangered Species Act: piping plover (*Charadrius melodus*) and red knot (*Calidris canutus rufa*). Read more about Delaware's Endangered Species on DNREC Division of Fish & Wildlife's website[36]. Your project permits may come with conditions such as restricting construction to certain times of year in order to avoid disturbances to sensitive species. Note observations on any rare fauna known to use your site or neighboring shoreline (Figure 9).

Some of the most diverse and abundant wildlife at your site are the most difficult to observe. For example, your site may provide intertidal and shallow subtidal areas important for juvenile fish and numerous invertebrates. The presence of these species is best indicated by the condition of the shoreline or identifiable habitat that is known to be preferred. Although field observations are preferable, information on flora and fauna can be found through web-based sources. For example, IPAC[37] is a U.S. Fish and Wildlife (USFWS) map-based system that provides endangered species information for the general area of your project.

Figure 9. Ribbed Mussels (left), Red Knot (middle), and Horseshoe crabs (right) are important species to look and plan for when designing a living shoreline.

[36] http://www.dnrec.delaware.gov/fw/NHESP/information/Pages/Endangered.aspx
[37] https://ecos.fws.gov/ipac

Flora

Vegetation at your site and on nearby properties provides the easiest picture of current conditions and may serve as a biological benchmark for living shoreline design. A detailed list of species present is not necessary if unknown; however, as much information as possible about the flora present will help you select which living shoreline techniques would be most viable, identify which techniques are not suitable, and identify vegetation that could be inadvertently damaged by installing living shoreline. Similar to other observations like geology, the flora should be observed in segments according to its underlying landform and proximity to the shoreline, as described below.

Resources such as "*The Delaware Wetland Plant Field Guide*"[38], published resources, or other publicly available documents can help with identification wetland vegetation.

Aquatic

Any submerged aquatic vegetation (SAV) growing in shallow waters near your site should be noted. SAV generally refers to vascular plants that remain below the water surface. These vascular species of SAV are unlikely to occur in Delaware Bay and have been mostly eliminated from the Inland Bays due to water quality changes. However, these species may be returning as water quality in the Inland Bays improves and restoration projects continue.

Some of the most common and important vascular SAV species that occur elsewhere in the mid-Atlantic and may soon be restored to the Inland Bays include eelgrass (*Zostera marina*), wigeon grass (*Ruppia maritima*), and sago pondweed (*Stuckenia pectinata*). When present, vascular species of SAV are an important component of a healthy aquatic ecosystem and detrimental impacts to them should be avoided. These species of SAV can benefit from living shoreline techniques that improve water quality, especially reductions in turbidity. SAV is particularly important for juvenile fish, numerous invertebrates at the base of the food web, and as a primary waterfowl food. During the winter these species at least partly die back and may be hard to observe.

Within the Inland Bays, macroalgae (i.e., nonvascular plants and seaweeds) are far more likely to occur near your site because of their tolerance to poor water quality. Macroalgae are sometimes included in the definition of SAV. Macroalgae, such as sea lettuce (*Ulva lactusa*) and spaghetti algae (*Chaetomorpha spiralis*), that occur in the Inland Bays provide some of the same ecological benefits as vascular species of SAV but to a lesser extent. However, they can grow in dense mats that can become a nuisance in the water and along the shore.

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[38] Delaware Department of Natural Resources and Environmental Control. (2018). *The Delaware Wetland Plant Field Guide*. Dover, Delaware, USA. 146pp. https://bit.ly/3bF05ma

Wetland

Salt marsh is typically divided into low marsh and high marsh. Ground elevations relative to tides dictate where the transition between the low and high marsh occurs. Understanding where this transition falls on your site can help determine where marsh grass planting can occur during living shoreline construction. Often the existing marsh at your site or on nearby properties can be used to determine the transition line from low to high marsh (~MHW) and the seaward limit of marsh (~MTL), important benchmarks for appropriate planting elevations. These reference elevations, if available, are more meaningful than those from local tidal datums alone because they integrate any unique localized conditions that affect plant distribution such as restricted tidal ingress or egress.

High marsh generally occurs farther inland than low marsh, occupying an area from approximately MHW to bordering uplands and is flooded only during extreme tides or storm events. Under normal conditions, high marsh floods no more than twice a month.

Smooth cordgrass (*Spartina alterniflora*) is the most common species in low marsh marine and estuarine environments between MTL and MHW. Salt marsh hay (*Spartina patens*), spike grass (*Distichilis spicata*), and blackgrass (*Juncus gerardii*) are the most common species in high marsh. If your site is exposed to oligohaline water, then other species may occur such as giant cordgrass (*Spartina cynosuroides*) and narrowleaf cattail (*Typha angustifolia*). The presence of these species should be noted because they indicate your site's salinity and what species may do best as part of a living shoreline.

Some kinds of wetland vegetation are nonnative and not ecologically desirable; their presence should be noted. Most stands of common reed (*Phragmites australis*) along the Delaware Bayshore in brackish wetlands are nonnative and form dense monotypic stands that may reduce habitat value and alter hydrology. The presence of dense stands and the dense rhizomatous growth underground may require control or can influence living shoreline design. Common reed tends to migrate aggressively along coasts. Therefore, if it dominates a site or adjacent properties in the area, it should be noted and considered in design as likely needing follow-up management especially in areas of low salinity. Common reed thrives in a disturbed area of a certain elevation. When creating replanting plans make sure to target elevations of the surrounding native vegetation. Common reed is tolerant of brackish conditions but becomes significantly less aggressive when exposed to the salt concentrations present along the southern bayshore and Atlantic coast (Figure 10).

Figure 10. Smooth Cordgrass (left) and Salt marsh hay (middle) are the most prevalent wetland plants in Delaware, while Common reed (right) is the most common invasive species.

Upland

Note the vegetation community along the upland of your site, as well as its condition (e.g., whether an area is vegetated dune, shrubs, forested, or mostly bare). Note the extent, size, and condition of shrubs and trees along the upland edge, the stability of the edge, and the habitat value potentially worth protecting. The type and amount of vegetation growing on the upland edge indicates erosion potential and what type of living shoreline techniques may be required (e.g., grading). For example, mature upright trees indicate an upland edge that is stable and not exposed to tidal influence. Dead, dying, fallen, and leaning trees or exposed roots may indicate bank erosion and increased exposure to tides or saltwater intrusion into a previously freshwater environment. An upland edge dominated by herbaceous plants suggest a more unstable environment with erosion and/or salinity having an effect. Predominance of salt tolerant shrubs and grasses indicates likely exposure to brackish water, which should be considered in the selection of living shoreline techniques.

Resources such as “A Guide to the Natural Communities of the Delaware Estuary”[39], DNREC published resources, or other publicly available documents can help with identification of the vegetation community.

[39] Westervelt, K., E. Largay, R. Coxe, W. McAvoy, S. Perles, G. Podniesinski, L. Sneddon, and K. Walz. 2006. A Guide to the Natural Communities of the Delaware Estuary: Version I. NatureServe, Arlington, Virginia.

Abiotic

Abiotic variables to the local ecology include things such as water quality, soil/sediment type, and sunlight/shade that are critically important to the success of various biotic living shoreline components should be noted.

Water Quality

Water quality influences which species of flora and fauna can be present at the existing site and after living shoreline construction. For example, oysters have a range of water conditions in which they thrive relative to dissolved oxygen, turbidity, salinity, temperature, etc. A detailed water quality study is generally not necessary during site evaluation, but any known problems with dissolved oxygen, (e.g. fish kills, seasonal algal mats), unnatural water discoloration, water temperature fluctuations, turbidity, salinity fluctuations, etc. should be noted. Landowner accounts can be very useful for gathering this information. Some indicators of potential water quality issues include the presence of culverts or other outfall structures that may introduce sediment, pollutants, or freshwater at or near your site.

Soil/Sediment Type

Soil/sediment type affects the likelihood of establishing vegetation and achieving the rapid growth rates that are needed to quickly establish strong root systems that stabilize a disturbed shoreline. Sand allows for the new plant anchoring, rapid root growth, and effective drainage. Silt and clay do not anchor plants as well, and also do not facilitate infiltration. Clay soils are hard to plant in and result in poor root growth. Detailed soil analysis is not needed during site evaluation, but as noted above in the Geology section of this document, it is important to at least characterize the particle size and type (e.g., gravel, sand, silt, clay). Also note if sediments are strongly anaerobic (strongly smelling of sulfur) which may indicate difficult conditions for establishing plants.

Characterizing the soil type will also ensure compatibility of any fill material used in living shoreline design with the existing sediments. Note that there may be permit restrictions on allowable types of sediment that can be used for fill in various portions of your project area. Consult with the permitting agencies for details.

Sunlight

The amount of sunlight available at your site influences aquatic and terrestrial habitat. For example, marsh vegetation used in living shoreline construction requires full sun exposure to thrive. Therefore, note the presence of any sources of shade at your site such as large trees or buildings. The surrounding area can provide a lot of hints about sun exposure and the influence it has on flora production. Also consider the direction the site faces relative to typical sun exposure. Portions of north facing sites may not receive enough light for salt marsh plants to readily establish.

Site Evaluation Tip:

Living shoreline techniques that include marsh grass require full sun in order to thrive. If your site is shaded by trees, buildings, or landforms, the project site is not suitable for marsh grass installation.

18. Site Sketches

Two dedicated pages are provided in the Site Evaluation Worksheet for site sketches. A profile or cross-section view shows the vertical features along a line perpendicular to the shoreline; a plan view is a bird's eye view looking straight down from above. Site sketches are the best way to quickly assess the spatial relationships between existing features, slopes, and land cover.

Sketch a site profile with key width and elevation measurements. Your site profile should be a cross-section perpendicular to the shore showing as much detail as possible from the bordering upland to the MLW line or beyond. Characterize what bounds the backshore (e.g., dune, trees, infrastructure) as much as possible. A site may vary considerably along the shore with irregular pockets of beach, marsh, uplands, and modifications; therefore, several sketched profiles may be needed to fully characterize one site.

Two types of landform, beach and marsh, will generally dominate a site unless the area is heavily disturbed by past modifications (e.g., rip-rap, bulkhead, seawall) that cause upland to abruptly border subtidal water. This document provides some brief information below on features to look for at various types of shoreline, so that your sketch can be as descriptive as possible. Consult the example site profile line sketches in Figure 11 and the example site plan sketch in Figure 12 for ideas about how to sketch different features.

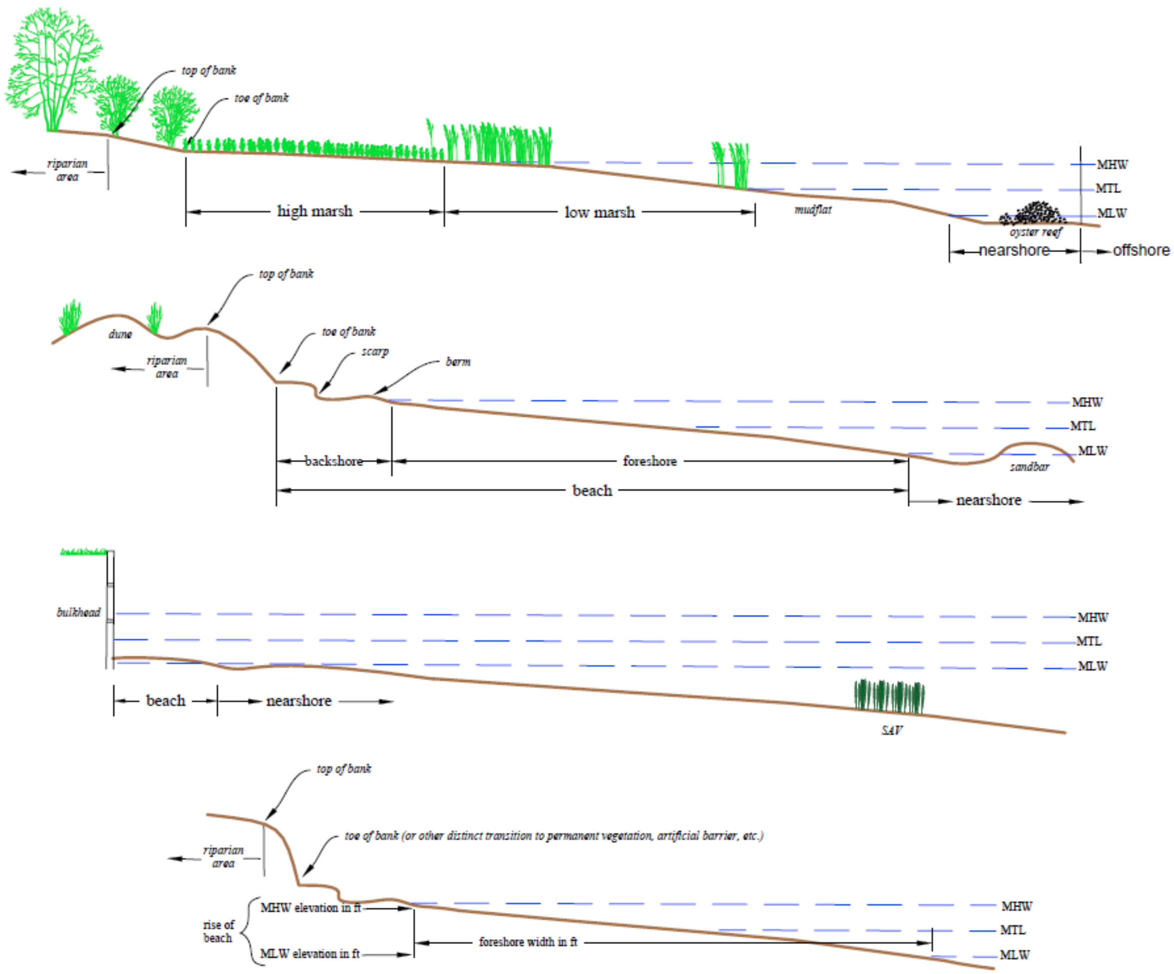

Figure 11. Example site profile sketches for various shoreline types and including a wide range of features.

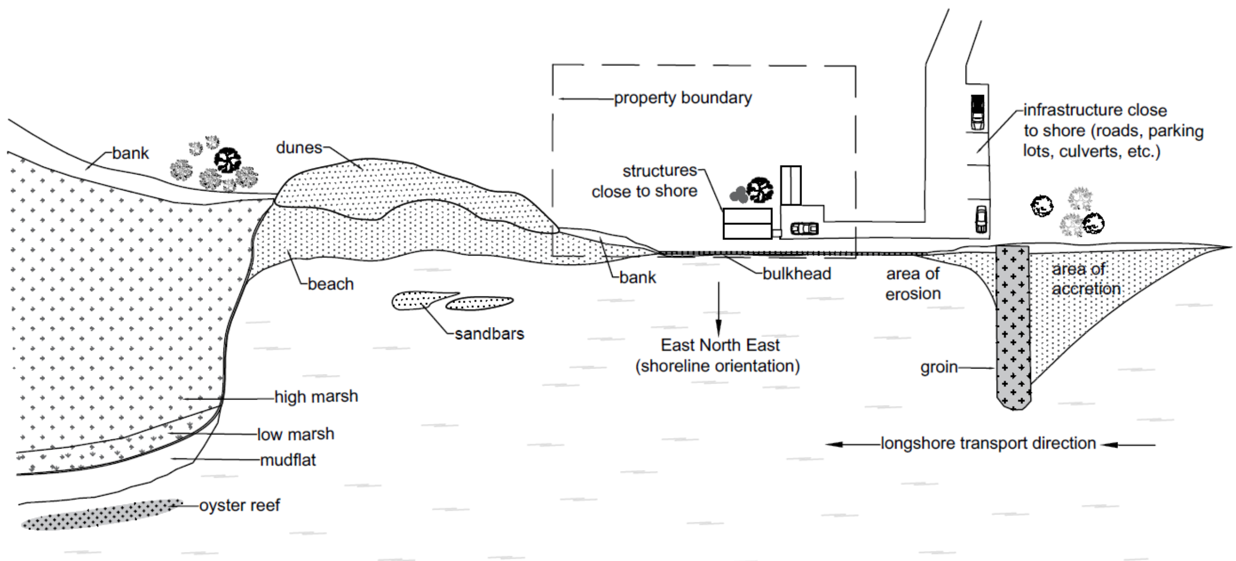

Figure 12. Example site plan view sketch showing a bird's eye view of a sample project site with a variety of features.

Beach

Generally, a beach is the area of unconsolidated material (including a range of sediments like gravel, sand, or silt) that extends landward from the MLW line up to upland vegetation or a structural barrier. Beach morphology is a function of local sediment characteristics as well as local wave energy and therefore subject to change over time, particularly as a result of a large storm event.

Your sketch should capture slope changes and describe the sediments and vegetation at each segment of the profile. MLW and MHW may also be estimated from field indicators. For example, there is often a wrack line at the MHW line or a storm wrack line post storm. The elevation of the MHW line on the beach indicates what part of a living shoreline design will be regularly exposed to the tidal cycle and typical wave energy.

Marsh

The presence of a marshy shoreline at or near the site is indicative that living shoreline techniques that include marsh creation will likely be viable. If marsh is not present on the site, take note of the nearest marsh and any differences that exist between that marsh and the site such as sunlight exposure, shoreline orientation, land use, and sediment type.

Tidal marshes have two distinct areas to identify and characterize: low marsh and high marsh. Low marsh is often a narrow fringe adjacent to open water extending from approximately MTL to MHW whereas high marsh may occur over a much broader and nearly flat plane up to the spring tide line. The distinction between low marsh and high marsh will become less clear as salinity decreases due to changes in resident plant species. Consult the

Local Ecology section of this document for more information on the different marsh zones and typical marsh vegetation.

Knowing marsh width and height helps determine the energy exposure of the upland at the site, the flora and fauna that may use the site, and potential living shoreline techniques. Include the dimensions of low and high marsh in your site sketches.

> **Site Evaluation Tip:**
>
> **Your photographs and your site sketches will be more meaningful when accompanied by detailed notes. Make it a standard practice to record observations associated with each during your site visit**

19. Notes

Record any special notes that may be relevant to the project area based upon your site visit. In particular, note the wind direction and estimate the wave height and water level at the time of your site visit. Also observe whether the water body at your site is subject to river flows or tidal currents as these can affect shoreline conditions. These observations will help ground truth your desktop analysis and provide further perspective on the suitability of your site for various living shoreline techniques.

Appendix A – Site Evaluation Worksheet

Delaware Living Shoreline Site Evaluation

Worksheet completed by:		Date:	
Site Address:			

This worksheet is intended to help property owners and professionals evaluate a particular stretch of shoreline for its suitability to support a successful living shoreline project. It is organized in two main sections: the first to be completed prior to a site visit using readily available data and the second to be completed on site. Remember to photograph your site thoroughly during the site visit, and to note what those photographs document.

Pre-Site Visit Desktop Analysis Parameters

1. Shoreline problem(s):			
2. Property owner's goal(s):			
3. Site Dimensions:			
4. Body of Water:		5. Shoreline Orientation:	
6. Shoreline Change Rate:			
7. Geomorphology:			
Submerged:	Shore/Bank:	Upland:	
8. Average Fetch:	Longest Fetch:	Direction:	
9. Wind:			
Prevailing Speed:	Prevailing Direction:	Storm Speed:	Storm Direction:
10. Wave Climate:			
11. Tide Information:			
MLW:	MHW:	MTL:	Range:

Site Visit Parameters			
12: FEMA Flood Hazard Zone and BFE:			
13. Notes:			
14. Site Boundaries:			
15. Land Use/Land Cover:			
16. Geology:			
	Submerged:	Shore/Bank:	Upland:
17. Local Ecology:			
	Flora:	Fauna:	Abiotic:
18. Site Sketches (Use next page):			
19. Notes:			

Plan-View Sketch

Profile Sketch

Profile Sketch

Appendix B – Living Shoreline Techniques

The following represents a partial list of common living shoreline techniques classified by their most appropriate usage in either conventional or hybrid living shoreline projects. For example, the marsh creation technique is appropriate in both conventional and hybrid living shorelines while shoreline revetments are only appropriate in hybrid projects.

	Classifications	
Technique	**Conventional**	**Hybrid**
Fiber logs	X	X
Fiber mats/geotextile	X	X
Wood logs/timber materials	X	X
Marsh sills		X
Shoreline revetments		X
Breakwaters		X
Groins		X
Vegetation	---	---
Marsh creation	X	X
Upland plants/vegetation	X	X
Subaquatic	X	X
Sand fill	X	X
Oyster shell bags/cages	X	X
Manufactured oyster substrate (e.g. Reef Balls, Oyster Castles)		X
Water quality techniques	X	X
Reuse of materials	---	---
Onsite (e.g. downed trees, loose grass clumps)	X	X
Offsite (e.g. reclaimed concrete for oyster substrate)	X	X
Reefs	---	---
Shallow water reef		X
Inter-tidal reef (e.g. oyster reef)		X
Deep water reefs		X

Glossary

Accretion: The gradual process of shoreline growth or expansion through the accumulation of sediment or other material usually by wind or wave action.

Advisory (Base) Flood Height (Elevation) (ABFE): An interim product (flood elevation) to assist communities in their rebuilding efforts while new Flood Insurance Rate Maps (FIRMs) are being completed. The ABFE is a coastal water surface elevation of a flood having a 1% annual chance of being equaled or exceeded in any given year. It is expressed in feet referenced to the North American Vertical Datum of 1988 (NAVD88) and can reflect the elevation of an Advisory Flood Zone V or A.

Alongshore or Longshore: Oriented parallel to the shoreline (waterline). Often refers to sediment transport parallel to the shoreline as a result of nearshore currents resulting from waves impacting the shoreline at an oblique angle.

Bank: The land alongside or sloping down to a water body, i.e., a river, stream, pond, etc.

Base Flood Elevation: The computed elevation to which the flood is anticipated to rise during the base flood. The base flood is also referred to as the 1-percent annual chance flood or 100-year flood. This elevation includes both the storm Stillwater elevation and wave height.

Bulkhead: A hardened structure meant to prevent erosion of land. Also known as a revetment

Cross Shore: Oriented perpendicular to the shoreline (waterline). Often refers to the direction of a cross-section taken perpendicular to shoreline contours to define the elevation profile.

End Effects: Impacts to an adjacent area caused by a constructed project including erosion, scour, or degradation of biota.

Erosion: The process by which shoreline sediment or other substrate is removed resulting in the narrowing or landward recession of shorelines. Erosion is typically the result of wave and wind action.

Fetch: The distance over which wind blows on the water surface to generate waves.

Flood Insurance Rate Map (FIRM): A flood map created by the Federal Emergency Management Agency (FEMA) used by the National Flood Insurance Program (NFIP) for floodplain management, mitigation, and insurance purposes. Digital versions of these maps are called DFIRMs. A FIRM will generally show:

a. Roads and map land marks;
b. A community's base flood elevations;
c. flood zones; and
d. floodplain boundaries.

Flood Insurance Study (FIS): A compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. When a flood study is completed for the National Flood Insurance Program (NFIP), the information and maps are assembled into an FIS.

Geomorphology: The scientific study of the characteristics, origin, and evolution of topographic and bathymetric features on the earth's surface created by physical, chemical, or biological processes.

Land Cover: Refers to physical surface of the area, this could include vegetation, soil, water, or anthropogenic elements like buildings.

Land Use: The purpose to which the land is being used. This could be residential, agricultural, forest, wetland, or industrial to name a few. The state of Delaware has a land use GIS layer that can be used to define the use if you have any questions on your site visit.

Limit of Moderate Wave Action (LiMWA): The inland limit of the area expected to receive 1.5-foot or greater breaking waves during the 1-percent-annual-chance flood event. The addition of the LiMWA area to FIRMs allows communities and individuals to better understand the flood risks to their property. [FEMA] FEMA recognizes a 1.5-foot-high wave as able to cause significant structural damage.

Intertidal Zone: The area between the highest and lowest tides.

Matrix, soil matrix: The portion of the soil with the dominant color, usually the portion with >50% of the same color.

Mean High Water (MHW): The average of all the high-water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

Mean Low Water (MLW): The average of all the low water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

Mean Tide Level (MTL): The arithmetic mean of mean high water and mean low water.

Morphology: Characterization of the physical processes and attributes of the shoreline and nearshore including slope, beach width, sediment characteristics, and wave and current dynamics.

Nationwide Permit 13: Permit issued by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act to authorize various bank stabilization projects that are necessary for erosion control or prevention.

Nationwide Permit 27: Permit issued by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act to authorize restoration, enhancement, or establishment of tidal and non-tidal wetlands, streams, and open water, provided those activities result in net increases in aquatic resource functions and services.

Nationwide Permit 54: Permit issued by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act to authorize structures and work in navigable waters and discharges of dredged or fill material into waters for the construction and maintenance of living shorelines.

Nearshore: The nearshore zone is that area of submerged land extending from the mean low water level seaward past the surf zone to the point where typical waves are not affected by the bottom. For practical purposes, it can be considered to be bounded by the MLW and the depth of closure on any given cross shore profile.

Nearshore Slope: The slope of the area of submerged land extending from the mean low water level (MLW) seaward past the surf zone to the point where typical waves are not affected by the bottom

North American Vertical Datum of 1988 (NAVD 88): A vertical datum of orthometric heights that was established for vertical control surveying of the United States. This datum was established in 1991 and is still in use to present day and is the official vertical datum in the National Spatial Reference System (NSRS) for the Conterminous United States and Alaska. Replaced the National Geodetic Vertical Datum of 1929 (NGVD 29).

Offshore: The offshore zone is that area of submerged land extending seaward beyond the nearshore zone. In the offshore zone, waves are not affected by the depth of water. Also, "offshore" by itself can be used to describe relative positioning of a feature with regard to the shoreline.

Prevailing Wind: The typical wind direction of a certain locale.

Retrofit: The addition of new technology and/or materials to a pre-existing technology or condition for the purposes of improving wave energy dampening, ecological function, and/or water quality benefit.

Revetment: A facing of stone or concrete to protect the upland from erosion by wave action, storm surge, and currents.

Riparian Buffer: A vegetated area near a body of water that protects from adjacent impacts and provides environmental benefits

Riprap: Rocky material that is used to armor shorelines against erosion by wave action, storm surge, and currents. The rocky material can range in size from a few inches up to a few feet in size, it is usually stacked to create a mound or laid along a shoreline bank.

Shore (also Shoreline): The intersection of the water surface and land. Also, the area between high and low tides that under typical circumstances could be identified as the shoreline at any time during a tidal cycle. NOAA defines the shoreline as equal to the MHW tidal datum.

Shoreline Orientation: The physical position of the shoreline. It is typically described relative to the direction it faces, looking from uplands toward the waterbody. Shoreline orientation is a significant factor when evaluating the vulnerability and resilience of a shoreline to flooding, wave energy, and wind energy.

Statewide Activity Approval (SAA) [for Shoreline Stabilization Projects in Tidal and Non-tidal Waters of the State of Delaware]: Simplified permitting process under Delaware Code Title 7, Chapter 72, Regulations Governing Use of Subaqueous Lands as administered by the Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, Wetlands and Subaqueous Lands Section for construction of shoreline stabilization projects less than 500 linear feet along the shoreline or bank in subaqueous lands including conventional, energy dissipating, and armored living shoreline. Projects must meet criteria and comply with all permit conditions outlined in the SAA.

Stillwater Elevation: The flood level not including the effects of waves or tsunamis but including storm surge and the astronomic tide.

Storm Surge: An abnormal rise of water generated by a storm, over and above the predicted astronomical tides.

Storm Tide: Defined as the water level rise due to the combination of storm surge and the astronomical tide.

Tidal Benchmark: The common vertical reference points based on local tide behavior.

Upland: That portion of land that is landward of MHW, that is typically dry during normal the normal tidal cycle. The transition between the intertidal zone and the upland zone may be best defined by reviewing the local flora.

Vertical Datum: A base measurement point or set of points from which all elevations are determined. Without a common vertical datum, it would be not be possible for surveyors to reproduce the same elevation values for the same points.

Zone AE: An area subject to inundation by the 1-percent-annual-chance flood event and is expected to experience a wave height between 0 and 3 feet. Zone AE areas can be further subdivided by a FIRM feature called the Limit of Moderate Wave Action (LiMWA) which delineates the location of the 1.5 wave height contour. Therefore, Zone AE areas inland of the LiMWA have a wave height of 0 to 1.5 feet and Zone AE areas seaward of the LiMWA have a wave height between 1.5 and 3 feet.

Zone VE: An area subject to inundation by the 1-percent-annual-chance flood event and additional hazards due to wave height of 3 feet or larger during a 1-percent-annual-chance event.