User Guide for the Living Shoreline Feasibility Model

Partnership for the DELAWARE ESTUARY

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1.0 Introduction:

The living shoreline feasibility model (LSFM) is an integrative tool that evaluates a suite of metrics to assess considerations involved in constructing and maintaining a living shoreline at a specific location. It guides users in collecting information on the *physical and ecological characteristics* of a site as well as factors related to *site access and community resources*, which are subsequently integrated to provide baseline data on existing conditions and inform team building, design, and installation planning. The LSFM is not a landscape scanning tool, but provides a relative evaluation of sites brought to the model. As such, it can be used to:

1. Assist in site selection among a group of sites,
2. Inform the various types of expertise or relationships required for successful installation of a living shoreline at a particular site, and/or
3. Provide guidance on how to phase a multi-step project.

The LSFM guides the user in providing the following information sourced from field observations, communication with stakeholders, or desktop assessment from publically available data.

Physical	**Ecological**
Water Body Energy	Percent canopy cover
Positional Energy	Intertidal vegetation community status
Storm Event Energy	Intertidal vegetation substrate
Persistent Wave Energy	Subtidal vegetation community status
Boat Wake Energy	Subtidal vegetation substrate
Nearshore Slope	Upland vegetation community status
On-site shoreline condition	Upland vegetation substrate
Surrounding shoreline condition	Shellfish community

Site Access	**Community Resources**
Material delivery	Public outreach/education potential
Landowner agreement	Community stewardship
Personnel access	Resource/capital availability
Working window	Enthusiasm for nature based infrastructure
Regulatory considerations	Community protection
	Environmental justice leverage potentia

Each category is evaluated independently as a percentage (0-100%) of a total available score, with high percentages indicating ideal conditions (e.g., less physical intensity, great ecological baseline), and low percentages indicating problematic conditions (e.g., difficult site access, no community interest). Data are subsequently integrated in a variety of ways to provide a suite of outputs.

This user guide is associated with the Living Shoreline Feasibility Model version 1.0 and the associated data sheets.

2.0 Model Inputs and Outputs:

2.1 Data Input:

The LSFM calculates scores for four categories of metrics:

1. Physical Characteristics (8 metrics): These metrics characterize the water body, wind, wave, and positional energy at the site, as well as their interactions with existing characteristics such as slope, shoreline condition (on-site and surrounding) and boat activity.
2. Ecological Conditions (8 metrics): These metrics characterize the vegetation and shellfish communities and substrate conditions at the site.
3. Site Access (5 metrics): These metrics characterize the ease of access to the site itself, as well temporal constraints around working at the daily and seasonal levels.
4. Community Resources (6 metrics): These metrics characterize outreach and engagement potential, resources, and interest in living shorelines at the site, as well as larger characteristics such as demographics and scale of project impacts that help advance living shoreline projects.

Metrics are measured via desktop analysis, field data collection or personal communications (see data sheet for guidance) and entry is via excel spreadsheet as seen below.

	A	B
1	**Metric**	**Site 1**
2		
3		
4	Water Body Energy	
5	Positional Energy	
6	Storm Event Energy	
7	Persistent Wave Energy	
8	Boat Wake Energy	
9	Nearshore Slope (Stevens guide)	
10	On-site Shoreline Condition	
11	Surrounding Shoreline Condition	
12	**Physical Score**	#N/A
13		
14	Percent Canopy Shading	
15	Intertidal Vegetation Community Status	
16	Intertidal Vegetation Substrate	
17	Subtidal Vegetation Community Status	
18	Subtidal Vegetation Substrate	
19	Upland Vegetation Community Status	
20	Upland Vegetation Substrate	
21	Shellfish Community	
22	**Ecological Score**	#N/A
23	**Physical + Biological Score**	#N/A
24		
25		
26	Material Delivery	
27	Landowner Agreement	
28	Personnel Access	
29	Working Window	
30	Regulatory Considerations	
31	**Site Access Score**	#N/A
32		
33	Public Outreach/Education Potential	
34	Community Stewardship	
35	Resource/Capital Availability	
36	Enthusiasm for Nature Based Infrastructure	
37	Community Protection	
38	Environmental Justice Leverage Potential	
39	**Community Resources Score**	#N/A
40	**MC&C and CS Score**	#N/A
41		
42		Clear
43		
44		

All fields MUST be filled out, however, if there are no data for a particular metric, the hyphen (-) option should be selected. This will allow the model to calculate the final percentage based on an adjusted sum accounting for the removal of that particular metric's points from the total available. CELLS CANNOT BE LEFT BLANK. The more reliable and comprehensive data that is entered, the better the results will be at providing guidance. The user can click on each field name (column A) for a brief description of the metric. Data entry within each column corresponds to one site evaluation and proceeds from top to bottom of the spreadsheet as follows:

Site Name:

Row 1, Enter names for each site (or multiple collection dates, users, etc.) the user wishes to compare. The LSFM allows for five unique evaluation sites. If there are fewer sites, these cells can be left blank.

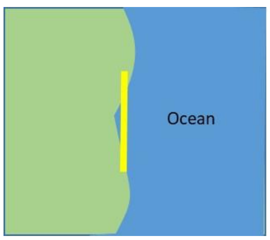
Physical Characteristics: Rows 4-11

In all graphics below, the yellow line indicates the location of the shoreline under consideration.

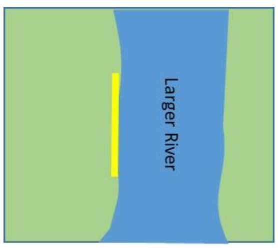
Water Body Energy:

This metric characterizes the typical level of *energy* experienced by a site due to the size of the water body and its movement along the site in which it is located, independent of wind and waves.

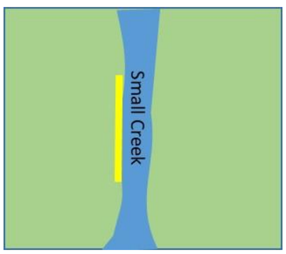
- Sites located along large, fast-moving water bodies such as ocean and bay fronts or in the lower reaches/mouths of large rivers experience a **high** degree of energy.
- Sites along either slow-moving, large water bodies (e.g., coves) or rivers/streams with either fast-moving or large volumes of water, experience **medium** ambient water body energy.
- Sites located along small creeks, ponds, or other water bodies with low volumes of slow-moving water experience **low** ambient water body energy.



High: Ocean and bay fronts or mouths of large rivers



Medium: Smaller creeks or rivers or areas with energy levels between high and low

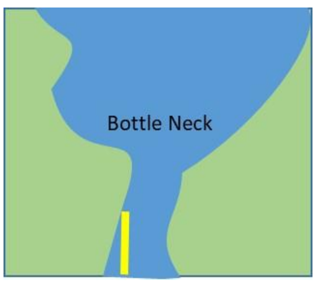


Low: Small creeks or ponds

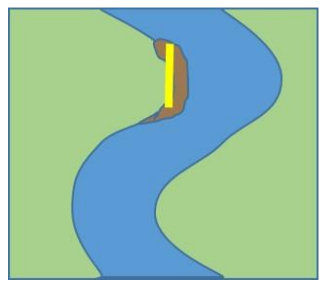
Positional Energy:

This metric intends to characterize energy at the site due to its position either along a single water body (e.g., inside/outside of a meander) or where multiple water bodies meet (i.e., confluence flow dynamics). Landscape position can impact the intensity of water velocity, potentially contributing to processes such as erosion, scour, and particle transport.

- Sites positioned either along areas of scour/erosion on the outside bend, bottle-necks, and inlets of a single water body, or down stream of stream confluence, are expected to have **high** impacts.
- Sites located along straight and/or narrow stretches of fast moving water are considered to experience **medium** impacts.
- Sites positioned along depositional areas either on the inside of bends (e.g., point bar) along a single water body, or in the stagnation zone (i.e., upriver intersection) of a confluence experience **low** impacts.



High: Sites along bottle-necks for downstream of a confluence



Low: Sites along depositional areas or stagnation zones

Storm Event Energy:

This describes the intensity of event-based energy due to periodic storms, as calculated through the integration of shoreline orientation and maximum expected wind speed. The metric selection allows for a combination of *shoreline orientation, with options for "unaligned or aligned"* in relation to the direction of max wind speeds, and the level of *max wind speed* expected during storms.

Shoreline orientation: Shoreline orientation refers to how the shoreline of interest is oriented towards the max wind speeds experienced during typical storms.

- Winds that generally blow onto the site (ex. SW winds on a westerly facing shoreline), the orientation is considered "**aligned**."
- Max winds that are generally in any direction except that closely aligned with the shoreline, are considered "**unaligned**."

Max Wind Speed: This is the speed of the winds during the time of year storms are likely to occur (when winds are highest).

To calculate max wind speeds and orientation:

1. Visit: https://www.windfinder.com/#12/39.2418/-75.2069

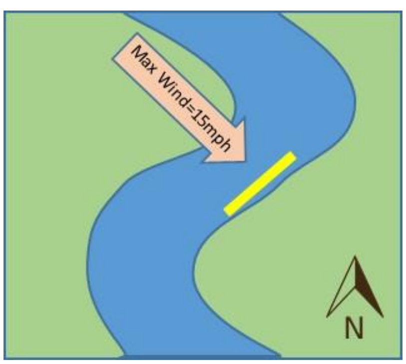
2. Use search features and locate station with conditions closest to shoreline of interest

3. Click “Statistics” Tab

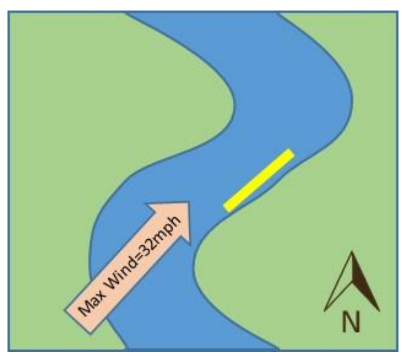
4. Scroll down to the “Dominant wind Direction” Graphic

Above, max wind speeds are marked by green circles, and the direction of the max wind speeds are in red circles. As in the example above, if there are two similar seasons with high winds, choose the speed and direction that would have the greatest impact of the area of interest. Storms with winds aligned with the shoreline will generally have a bigger impact.

- **High Winds, >30mph**
- **Medium Winds, 17-30mph**
- **Low Winds, <17mph**



Aligned, low wind (<17mph)



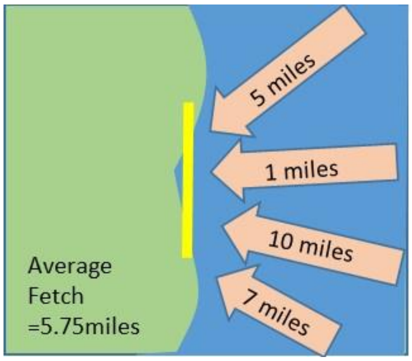
Unaligned, high winds (>30mph)

Persistent Wave Energy:

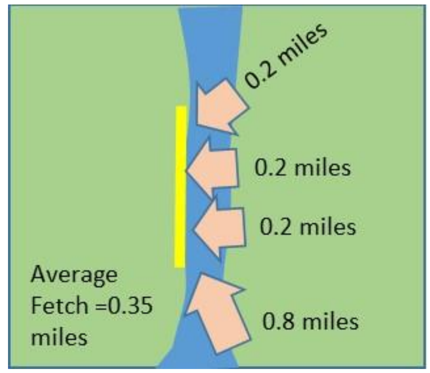
This metric intends to characterize the AVERAGE wave climate impacting the site. This is accomplished through the integration of the *average fetch* and the direction from which the wind originates (*alignment*). More intense persistent energy is expected at sites oriented towards the wind, and is expected to increase with fetch.

Average fetch: This can be calculated by taking the average distance of fetch from (at minimum) 4 different directions.

- **High, >5 miles**
- **Medium, 1-5miles**
- **Low, <5 miles**



High (>5 miles)



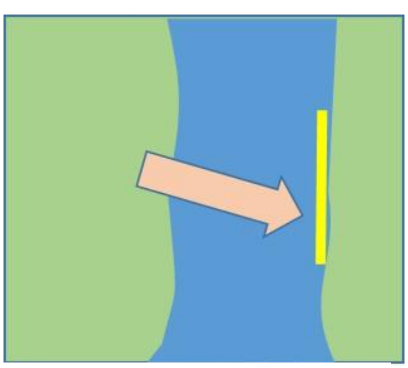
Low (<1 mile)

Alignment of persistent wave energy:

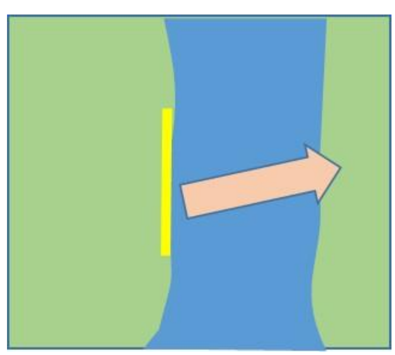
Under the same "statistics" tab used in the storm event energy metric, from https://www.windfinder.com/#12/39.2418/-75.2069

See the "annual wind and weather statistics" chart. The arrow will indicate the average direction of all winds.

- When wind direction is towards your shoreline of interest than the winds are "**aligned**."
- When wind is any other direction besides towards the shoreline of interest, they are "**unaligned**."



Aligned

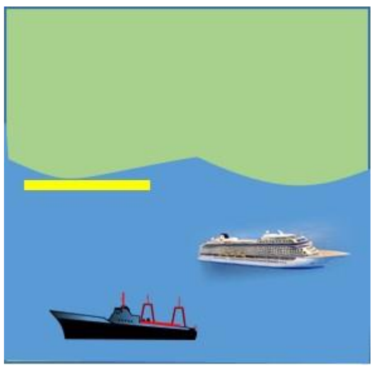


Unaligned

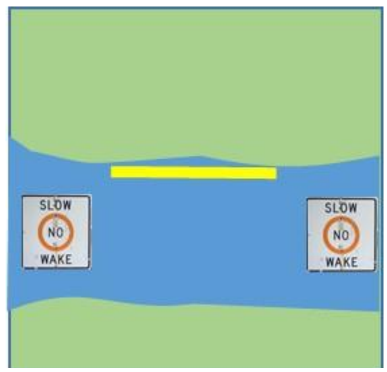
Boat Wake Energy:

This metric intends to characterize the energetic impact to a site based on the "typical" degree of boating/water sport activity along the adjacent waterbody.

- **High** energetic impacts are expected at sites along primary shipping channels, near marinas, or in areas where a high degree of seasonal water recreation occurs.
- **Medium** energetic impacts are expected at sites at which there are some local water sports, but they are generally not near marinas and are without public access.
- **Low** energetic impacts are expected in areas inside a "No Wake Zone", not accessible by boat, or infrequently traveled by watercraft.



High

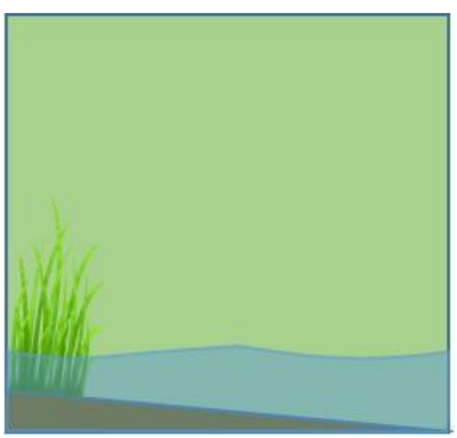


Low

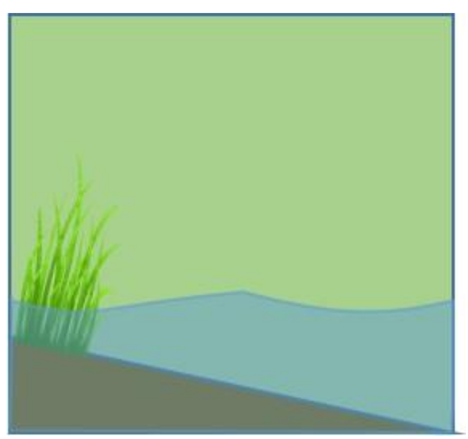
Nearshore Slope:

This metric intends to characterize the ability of waves to break in the nearshore environment by assessing the slope profile leading to the site. Metric categories were sourced directly from the Steven's [Living Shoreline Engineering Guidelines].

- **Low**, <10%
- **Medium**, 10-20%
  High, >20%



Low Slope (<10%)

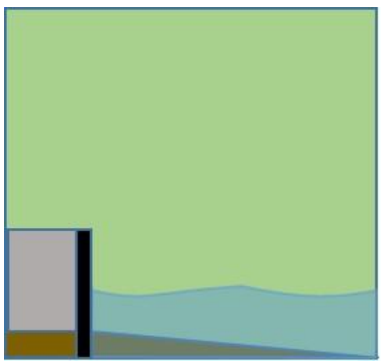


High Slope (>20%)

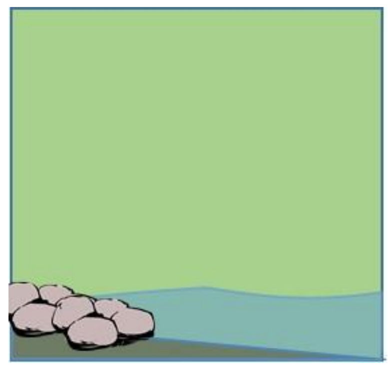
On Site Shoreline Conditions:

This metric intends to characterize the on-site energetics due to reflective and absorptive properties of any features currently present along the shoreline of interest.

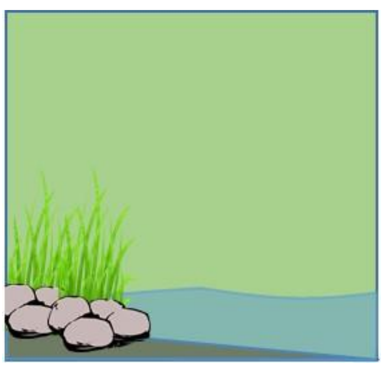
- Fully armored shorelines (e.g., bulkheads or **seawalls**) are expected to be associated with the highest on-site energetics.
- Sites containing **rip-rap** that is able to disrupt and compartmentalize some energy in the gaps between rocks is expected to have less on-site energy than a seawall.
- The lowest on-site energy is expected at shorelines that solely feature **natural** characteristics (e.g., vegetation, sand, mudflats, reefs).
- Slightly higher energy is expected on sites that have a combination of natural features and rip rap (i.e., **mixed**).



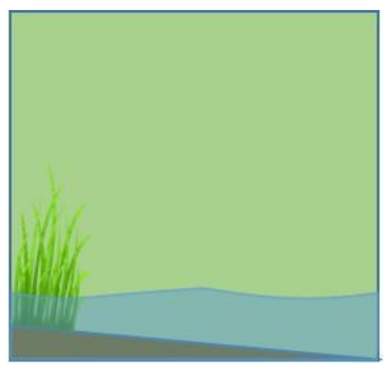
Seawall



Rip-Rap



Mixed



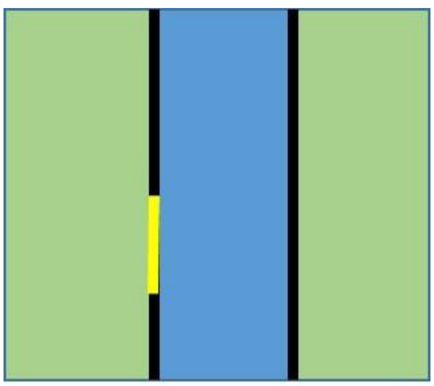
Natural

Surrounding Shoreline Condition:

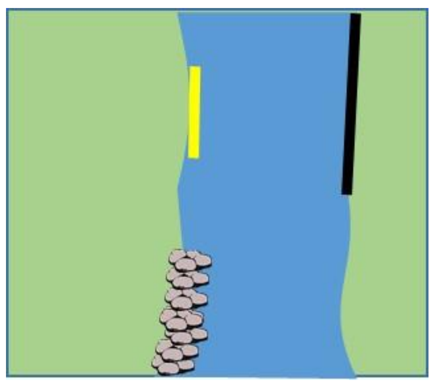
This metric intends to characterize the level of reflective energy impacting the site due to the dominant condition of surrounding shorelines.

- Surrounding shorelines that are dominated by **predominantly hardened** infrastructure (e.g., bulkheads, rip-rap, seawalls) are expected to transfer the most reflective energy.
- **Predominantly natural** landscape features (e.g., vegetation, sand, mudflats) are expected to transfer the least reflective energy.
- Some shorelines are **mixed hardened and natural**, and therefore likely have medium reflective energy.

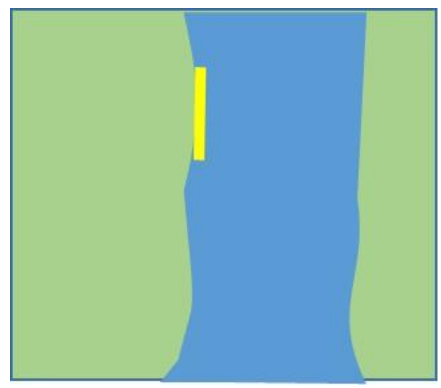
The distance from which features may impact the site will differ across space due to co-varying factors (e.g., water depth, water velocity, water direction, etc.) and as such, the user is expected to employ their knowledge of the site to determine the scale at which impacts are likely to be sourced.



Predominantly Hardened



Mixed Natural and Hardened



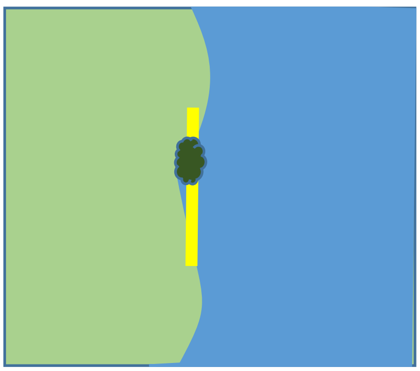
Predominantly Natural

Ecological Condition Metrics: Rows 14-21

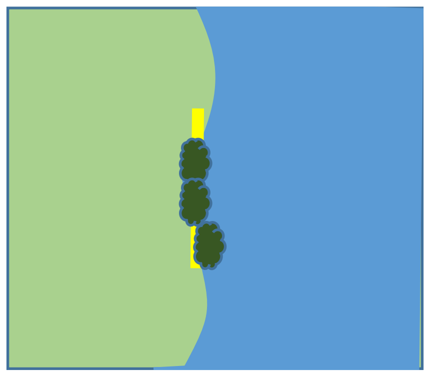
Percent Canopy Cover:

This metric is intended to characterize potential impacts to vegetation growth due to shading from trees/vegetation or other structures along the upland fringe. Greater percent shading is expected to decrease living shoreline plant growth relative to unshaded areas. In generally, it is best for the user to consider the entire shoreline as a whole.

- **76-100%**
- **51-75%**
- **26-50%**
- **0-25%**



0-25% Canopy Cover



75-100% Canopy Cover

Intertidal Vegetation Community Status:

This metric is intended to characterize the type of vegetation community present between the low and high tide lines (intertidal). The options for the metric are a combination of the existing community and whether action taken will be active or passive.

- Sites with pre-existing, **desired** vegetation communities bordering or in close proximity can benefit from enhanced ecological baseline conditions that can facilitate the migration of the pre-existing community into the living shoreline. Mixed communities of desired/undesired communities may also fit this category if **passive** action would be used to establish vegetation.
- Sites with **no vegetation** present require the establishment of the desired community, which imparts an added degree of difficulty.
- Sites with a **mixed plant** community may require slightly more effort if there are desirable community members to occupy vacated niches, and **active** action will be taken to remove undesirable communities.
- Sites with **undesired** (e.g., invasive) vegetation communities require additional effort IF a goal of the project is to ***actively*** eradicate this community (e.g., directly remove, spray, etc).

If a potential project does not include this vegetation component, choose the null option (-).

Intertidal Vegetation Substrate:

This metric intends to characterize the existing potential of the substrate at the intertidal portion of the site to promote plant establishment and growth. Different vegetation types have different substrate requirements. Some plant types have enhanced persistence when substrates are firm (salt marsh cordgrass), while others can flourish in softer sediments (many freshwater species including Nuphar). No matter the preferred substrate type, stable substrate is preferred to unstable, or frequently scoured (i.e., washed away), substrate which can lead to the loss of young, shallow rooted vegetation before it is able to become established.

- The most desirable scenario is one in which the **desired** substrate for your target vegetation community is present and is **stable**.
- Slightly less desirable is the presence of the **desired** substrate, but it is **unstable**. Providing stability for maximizing vegetation success requires extra effort in the design and implementation phases.
- Less desirable, are scenarios in which an **undesirable**, but penetrable, substrate is present (e.g., deep soft inorganic sediments at a site where salt marsh cordgrass is the desired species). Here, the substrate may either need to excavated or augmented.
- Sites with **impenetrable** foundations (e.g, bedrock) within which plants are unable to root exemplify the least desirable scenario, as effort will be required to provide and maintain an appropriate substrate.

Subtidal Vegetation Community Status:

This metric is intended to characterize the type of vegetation community present below the low tide line (subtidal). The options for the metric are a combination of the existing community and whether action taken will be active or passive.

- Sites with pre-existing, **desired** vegetation communities bordering or in close proximity can benefit from enhanced ecological baseline conditions that can facilitate the migration of the pre-existing community into the living shoreline. Mixed communities of desired/undesired communities may also fit this category if **passive** action would be used to establish vegetation.
- Sites with **no vegetation** present require the establishment of the desired community which imparts an added degree of difficulty.
- Sites with a **mixed plant** community may require slightly more effort if there are desirable community members to occupy vacated niches, and **active** action will be taken to remove undesirable communities.
- Sites with **undesired** (e.g., invasive) vegetation communities require additional effort IF a goal of the project is to ***actively*** eradicate this community (e.g., directly remove, spray, etc).

If a potential project does not include this vegetation component, choose the null option (-).

Subtidal Vegetation Substrate:

This metric intends to characterize the existing potential of the substrate at the subtidal portion of the site to promote plant establishment and growth. Different vegetation types have different substrate requirements. Some plant types have enhanced persistence when substrates are firm (salt marsh cordgrass), while others can flourish in softer sediments (many freshwater species including Nuphar). No matter the preferred substrate type, stable substrate is preferred to unstable, or frequently scoured (i.e., washed away), substrate which can lead to the loss of young, shallow rooted vegetation before it is able to become established.

- The most desirable scenario is one in which the **desired** substrate for your target vegetation community is present and is **stable**.
- Slightly less desirable is the presence of the **desired** substrate, but it is **unstable**. Providing stability for maximizing vegetation success requires extra effort in the design and implementation phases.
- Less desirable, are scenarios in which an **undesirable**, but penetrable, substrate is present (e.g., deep soft inorganic sediments at a site where salt marsh cordgrass is the desired species). Here, the substrate may either need to excavated or augmented.
- Sites with **impenetrable** foundations (e.g, bedrock) within which plants are unable to root exemplify the least desirable scenario, as effort will be required to provide and maintain an appropriate substrate.

Upland Vegetation Community Status:

This metric is intended to characterize the type of vegetation community present above the high tide line (upland). The options for the metric are a combination of the existing community and whether action taken will be active or passive.

- Sites with pre-existing, **desired** vegetation communities bordering or in close proximity can benefit from enhanced ecological baseline conditions that can facilitate the migration of the pre-existing community into the living shoreline. Mixed communities of desired/undesired communities may also fit this category if **passive** action would be used to establish vegetation.
- Sites with **no vegetation** present require the establishment of the desired community which imparts an added degree of difficulty.
- Sites with a **mixed plant** community may require slightly more effort if there are desirable community members to occupy vacated niches, and **active** action will be taken to remove undesirable communities.
- Sites with **undesired** (e.g., invasive) vegetation communities require additional effort IF a goal of the project is to ***actively*** eradicate this community (e.g., directly remove, spray, etc).

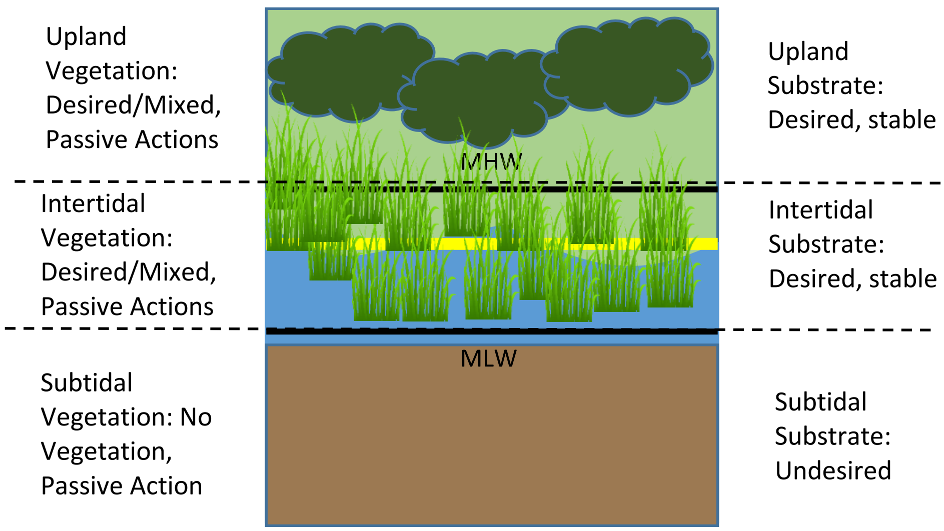
If a potential project does not include this vegetation component, choose the null option (-).

Upland Vegetation Substrate:

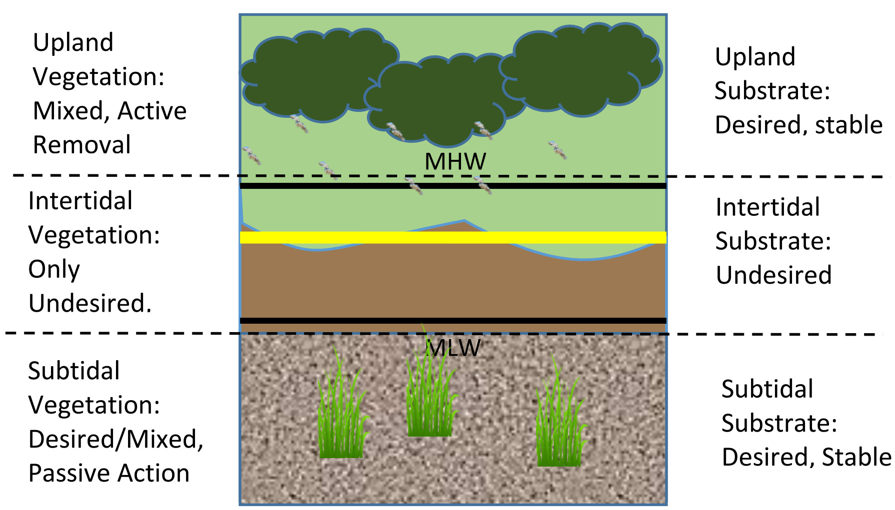
This metric intends to characterize the existing potential of the substrate at the subtidal portion of the site to promote plant establishment and growth. Different vegetation types have different substrate requirements. Some plant types have enhanced persistence when substrates are firm (salt marsh cordgrass), while others can flourish in softer sediments (many freshwater species including Nuphar). No matter the preferred substrate type, stable substrate is preferred to unstable, or frequently scoured (i.e., washed away), substrate which can lead to the loss of young, shallow rooted vegetation before it is able to become established.

- The most desirable scenario is one in which the **desired** substrate for your target vegetation community is present and is **stable**.
- Slightly less desirable is the presence of the **desired** substrate, but it is **unstable**. Providing stability for maximizing vegetation success requires extra effort in the design and implementation phases.
- Less desirable, are scenarios in which an **undesirable**, but penetrable, substrate is present (e.g., deep soft inorganic sediments at a site where salt marsh cordgrass is the desired species). Here, the substrate may either need to excavated or augmented.
- Sites with **impenetrable** foundations (e.g, bedrock) within which plants are unable to root exemplify the least desirable scenario, as effort will be required to provide and maintain an appropriate substrate.

Two Examples of Possible Vegetation + Substrate Selections:



Upland vegetation is native trees and shrubs on stable substrate, intertidal vegetation is native Spartina on stable substrate; subtidal is open mudflat with no vegetation where SAV and substrate for shellfish is desired.



Upland vegetation is shrubs mixed with Phragmites, active removal is planned, substrate is stable, intertidal vegetation is Phragmites, removal is planned and the shoreline is unstable, subtidal has cobble bottom and SAV present, both desired.

Shellfish Community:

This metric is intended to characterize the shellfish-mediated ecosystem engineering potential existing at a site if a shellfish community is of interest on the living shoreline. Shellfish help build, establish, and maintain ecosystems through their structural aggregation, nutrient cycling, and multiple ecological mutualisms.

- Sites with pre-existing, **desirable shellfish** communities provide enhanced ecological baseline conditions that may facilitate the establishment of a complex living shoreline community (flora and fauna).
- Sites without a baseline (**no shellfish**) community where one is desired require additional effort through either design or seeding considerations.
- Sites at which a high degree of **biofouling** is likely, require a higher level of effort as active cleaning will be required to provide suitable substrate and/or prevent smothering.
- The highest level of effort will be required at sites where an **undesired shellfish** community is present AND the project requires their removal/eradication.

If a potential project does not include this shellfish component, choose the null option (-).

Site Access Metrics: Rows 26-30

Material Delivery:

This metric is intended to describe the level of complexity involved with getting the materials to be used in living shoreline construction to the site for installation and subsequent maintenance.

- Areas accessible by roads where materials can be directly delivered to the location in a single step, with easy staging, and to which access can be obtained directly or is not required (e.g., a single phone call directly to the landowner) exhibit **low complexity**.
- Sites with **moderate complexity** have a few additional considerations related to material delivery and staging, such as frequent flooding along roadways to the site or more complex access pathways (e.g., multi-step emails/phone calls that can take time to organize, locked gates through which access through needs to be coordinated, etc.).
- **High complexity** sites exhibit multi-step delivery pathways (e.g., truck to boat), this could include heavy equipment for unloading materials, as well as difficult material staging, and/or site access permission requiring official letters that take time to obtain.

Landowner Agreement:

This metric intends to characterize the ease of acquiring landowner agreement if a living shoreline is desired for the site.

- A **single** (e.g., private landowner, a state or federal entity) **agreeable** landowner is the most desirable scenario for agreement to be provided.
- A less desirable scenario is one in which there are **multiple landowners** (e.g. homeowner's association) that are in **agreement** regarding project advancement. Due to multiple party involvement, this scenario requires extra time and effort in providing information and updates to all parties, which may not ultimately result in agreement.

- The least desirable scenario is one that involves either a **single or multiple reluctant landowners**. This scenario can occur either with multiple landowners or when an entity (e.g., government agency) would like to implement a project on privately owned land due to occurrences, such as flooding sourced from the site affecting other areas. If one or more landowners do not want a project implemented on their land, regardless of the reason, a large degree of additional effort will be required which may not ultimately result in agreement.

Personnel Access:

This metric intends to characterize complexity of personnel access for installation, maintenance, and/or monitoring at the intended site.

- A site with **low complexity** will be able to be directly accessed from land with just notification of landowners or adjacent property owners.
- Areas with **medium complexity** require 1-2 extra steps for access such as key acquisition, gate entry, escort requirements, or paperwork rather than emails for site visits, and /or special vehicle access (e.g., boat) that does not require outside coordination.
- Areas with many prohibitive conditions will involve more than 2 potential barriers to personnel access and/or coordination with other partners for special vehicle usage (e.g., boat) and would have **high complexity**.

Working Window:

This metric is intended to characterize duration of daily time available for activity at a site of interest, e.g. tide, employee availability or other restrictions.

- A site with a high tidal range may require that certain activities can only occur when the water is either at or near the minimum or maximum, thus introducing high scheduling complexity, with working hours <3 hrs.
- Sites with medium to low tide ranges exhibit some variability and therefore present a more consistent water level and access window, likely **3-6 hours**, compared to sites with more dramatic tidal ranges.
- Working windows at a site with little to no tidal variation will be greater, in a range of 6-12 hours, compared to sites with a high tide range

Regulatory Considerations:

This metric is intended to characterize the level of complexity required for installation, monitoring, and/or maintenance related to regulatory concerns (e.g., time of year restrictions for species of concern/endangered species at the area of interest).

- Sites that intersect with regulatory considerations (**Yes**) will have a high degree of complexity regarding scheduling activities relative to site where there are no regulatory considerations **(No**).

This metric can be broad to include any regulations or other legal concerns that may hinder the installation of a project.

Community Resources: Rows 33-38

Public Outreach/Education Potential:

This metric is intended to capture the level of educational resources available at the site of interest, either in terms of current outreach resources on site or nearby, or the potential for active or passive educational programming (signage, tours, etc.).

- An area with **active programming** will currently have ongoing engagement/outreach/education activities such as tours, programming, an active learning center, etc., or there will be favorable prospects for the future development of such resources.
- Sites characterized by **passive programming** are sites at which passers-by can directly see the living shoreline and where signage can be made available to provide further information regarding living shorelines.
- Sites with **no access/viewing** opportunities will have the least education potential due to difficulties involved with physically viewing the site or lack of access to nearby areas where educational resources could be added.

Community Stewardship:

This metric intends to characterize the local public's current interaction with the site and how engaged the community may be in the project as a whole.

- **Active positive engagement** indicates that there is an initiative to take care of the site by the local community (e.g., clean-ups, gardening, etc.) as shown through either past activity or current engagement in a proposed project.
- A site with **neutral engagement** implies that currently there are no positive or negative activities occurring at the site
- **Negative engagement** implies that the site is currently a host to activities that disrupt the site such as vandalism, dumping trash, and/or recreational disturbance.

A “community” does not need to be defined as the general public in an area, it can be any group of people (the public, governmental, local business etc.) that can support or have a stake in the future success of the project. Although people living in close proximity to a given site may have greater influence on whether engagement is positive, neutral, or negative, the user should use best judgment to decide which community interactions will ultimately characterize overall engagement with the site.

Resource/Capital Availability:

This metric is intended to characterize the financial state, or available financial leverage, of the interested parties/landowners/community partners to install the project.

- A project with **high resources** will have independently-available monetary, physical, or network resources with which to facilitate the design.
- Projects with **moderate resources** may provide improved opportunities for development through partial funding or resource leverage.
- **Low resource** projects will have no available funds or no network resources.

Enthusiasm for Nature Based Infrastructure:

This metric intends to characterize either the level of community and partner preference for living shorelines, or other nature-based infrastructure (NBI), relative to other methods of shoreline protection.

- **Very engaged** partners and communities partial to NBI will be more willing to lend help and support to living shoreline initiatives and may be more likely to provide long-term stewardship at the site of interest.
- **Moderately engaged** enthusiasm levels could indicate that involved parties desire increased protection and may be willing to try NBI, but are not actively for or against living shoreline initiatives.
- **Minimally engaged** partners and communities might find hard armoring desirable or prefer no intervention, which can lead to lower levels of short and long-term support.

Community Protection:

This metric indicates whether or not a project is sought at the site to protect specific infrastructure that is either culturally or municipally essential to the community.

- Sites where projects are sought to protect specifi**c community infrastructure**, relevant to the community at large, are likely to garner more widespread support than sites where a project is desired for **personal or individual aesthetic** purposes.

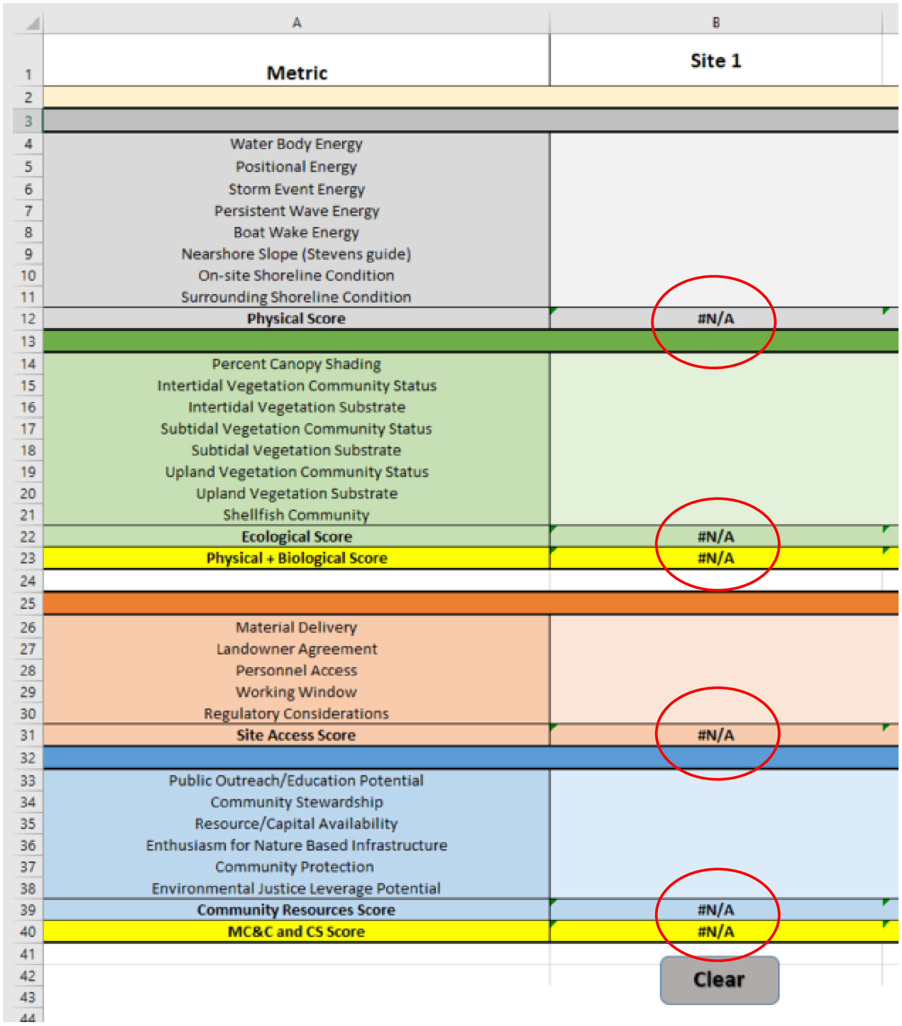
Environmental Justice Leverage Potential:

This metric intends to characterize the access or "leverage" of a community to resources such as state funding, or certain grants/support that would support the installation of a living shoreline.

- An EJ community would likely have access to leveraging resources **(Yes**), while other communities would not (**No**).

Resources such as EJ Screener tool can be useful in determining if the community has EJ leverage potential.

Score Calculations Rows 12, 22, 31 & 39:



Each individual metric has an initial available point range of 0-5. Options that are most favorable receive the maximum points (5), and those least favorable receive the minimum (0). The dispersion of points across options varies by the number of options available. For example, a metric with three options will have scores of 0 (least favorable), 2.5, and 5 (most favorable), and a metric with six options will have scores of 0 (least favorable), 1, 2, 3, 4, and 5 (most favorable). Metrics are not weighted evenly within categories, and each metric has an associated weighting factor of 1, 2, or 3. Metric-specific weights were finalized by LSFM review committee (See Appendix A). Weighting factors are applied to the initial point values for each metric option to calculate a final point value, which is calculated in the final row of each metric section (See 3.3 Data Reference for more information on metric weighting). See more about scores and weights in section 2.3 Data Reference.

2.2 Feasibility Output:

The feasibility output tab provides five tables of summary data and three output graphs depicting the summary data. The below section describes each output in the order that they inform each other and the assumed order that the user would view them. Each section also includes how summary data were calculated and basic interpretation.

Table 1: Score Totals

This table summarizes the total number of points per site per category based on user data input. Taken directly from input table, see "Score Calculations" in previous section for how these are calculated.

Table 2: Maximum Available Score

This table summarizes the total number of points available per category, which is used to calculate a percentage based on the user data input. Values in this table account for unevaluated metrics for which the user selected the "-"option for that specific field. Values can differ among evaluated sites if the evaluated metrics are not identical. For example, the physical characteristics field can have up-to 85 available points if all metrics are evaluated. If for a single site, the user does not have data for some fields and selects the "-" option, these total available points will be lower for that site. This table can be used to quickly identify sites for which few metrics were evaluated in a specific category (low available points), and confidence in results reflecting the totality of on-site conditions may be low.

Table 3: Score as Percentage of Max Score:

This table summarizes the percent score of each category per site using the values from Tables 1 & 2.

Figure 1: Score as Percentage of Max Score

This is a visualization of the percentages from Table 3. The bar graph shows each category (i.e., physical, ecological, site access, and community resources) individually, per site, and depicts all sites on the same graph for visual comparison.

Table 4: Team Building/Resource Inventory

This table provides the computational outputs of design and implementation complexity.

Design Complexity describes the expected complexity in developing a living shoreline design based on the physical characteristics and ecological conditions. The higher these scores, the greater the expected complexity in design required.

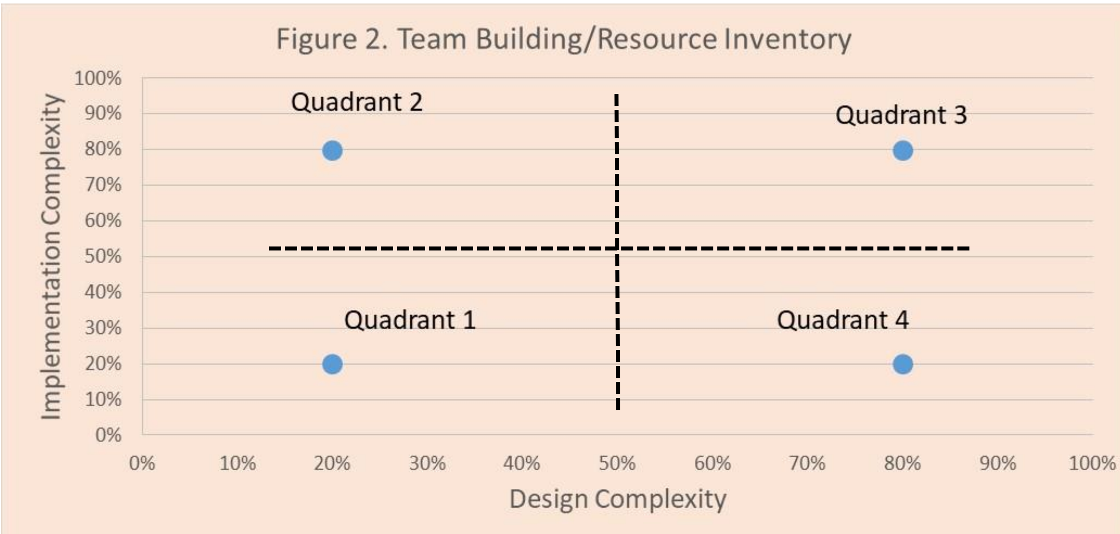
$$Design\ Complexity = 1 - (\frac{Physical\ Score + Ecological\ Score}{2})$$

Implementation Complexity describes the expected complexity of installation, monitoring, and maintenance of the living shoreline over time based on the site access and community resources scores. The higher these scores, the greater the expected complexity in facilitating the persistence of the living shoreline.

$$Implementation\ Complexity = 1 - (\frac{Site\ Access\ Score + Community\ Resources\ Score}{2}$$

Figure 2: Team Building/Resource Inventory:

This graph plots design and implementation complexity for each site on an X-Y axis, respectively. Together the two axes show the overall team building needs and resources available/still needed to move forward towards a successful design and installation. With the right team and resources, most projects are possible. Four outcome scenarios are described below with a brief guidance on how to interpret the results.



Quadrant 1: Sites that plot in the lower left quadrant have low design and implementation complexity and should be relatively simple to implement without major technical needs.

Quadrant 2: Sites that plot in the upper right quadrant will still likely have low technical design needs, but may be more difficult to implement. These sites may benefit from partnerships that either facilitate site access (e.g., providing transportation support, facilitating access through restricted areas), or engage the community more directly to build support and momentum for a project. In this situation, a team may benefit from additional outreach members or other local partners with access to the site.

Quadrant 3: Sites that plot in the upper right quadrant are likely the most difficult projects that will require both physical and/or ecological expertise as well additional work to facilitate access and/or build greater community support.

Quadrant 4: Sites that plot in the lower right quadrant likely have good access and community relationships/outreach potential, but may have greater technical needs regarding design due to more dire physical characteristics and ecological conditions. Projects at these sites likely require physical and/or ecological expertise on the team, but likely have few barrier to implementation.

Table 5: Overall Feasibility

This table provides the ease of construction, weighted ease of construction (50%) and weighted community resources (50%) scores, the latter two of which are combined into overall feasibility. Additionally, based on the physical score, a type of living shoreline is predicted for the site. This is not a definitive approach, but an estimate based on the data entered. For a physical score greater than 66% a natural living shoreline is suggested, for a score between 33-66% a hybrid living shoreline is suggested, and for a physical score less than 33% a structural shoreline is suggested.

Ease of Construction describes the expected level of ease in building the living shoreline itself based on the physical characteristics, ecological conditions, and site access scores. The integration of these three metrics aim to account for working under specific physical conditions, the level of ecological implantation required, as well as the ease in delivering, storing, and moving materials at the site. The greater the score (more ideal conditions), the greater the expected ease in building the living shoreline during the construction phase. Ease of construction is calculated as a weighted average where the weight of the physical characteristics and site access are double that of ecological conditions. As the implementation of specific ecological conditions largely focuses on designing the living shoreline to exist within specific physical parameters, many of the construction-based ecological considerations are accounted for in the physical characteristics. Certain ecological conditions such as removing invasive vegetation or augmenting substrate are not covered under physical conditions.

$$Ease\ of\ Construction = (Physical * 0.4) + (Ecological * 0.2) + (Site\ Access * 0.4)$$

Overall Feasibility describes the expected ease in designing, installing, and maintaining a living shoreline at a specific location. It is calculated as the weighted average of the ease of construction (50%) and community resources (50%) (Table 1). Community resources has the relatively largest input of all categories, as public support, opportunities for outreach, and local investment can be primary drivers in moving projects forward – with high levels of support and investment, almost any project is possible.

$$Overall\ Feasibility = (Ease\ of\ Construction * 0.50) + (Community\ Resources * 0.50)$$

Figure 3: Project Feasibility

The final graph shows the weighted “Ease of Construction” and “Community Resources” percentages of each site stacked into a final overall feasibility score that can be compared side-by-side.,

All outputs used together can start and guide conversations surrounding the future of the project in question. The goal is to better assess the needs for a project, where there might be obstacles, and some baseline information on what to expect from the physical and ecological conditions.

2.3 Data Reference:

The data reference tab is the source data for the working of the model. It is locked and cannot be changed. In column B, the four categories are delineated by color, with their respective metrics below in bold and their individual options, including “-“, in rows beneath. Initial point values for each metric option are denoted in column D, with the metric-specific weighting in bold in column E. The weighting is applied as a multiplier to each options initial value (column D) to calculate the final point value for each metric option in column C. If there is anything you would like to change for your specific project, please contact the Partnership for the Delaware Estuary and we can work to update the model for your specific needs.

3.0 Acknowledgements:

The living shoreline feasibility model was developed primarily by Dr. Joshua Moody, Sarah Bouboulis, Irina Beal, and Ella Rothermel at the Partnership for the Delaware Estuary, along with lots of input from our many partners, including members of the Delaware Living Shoreline Committee, Delaware Department of Natural Resources and Environmental Control and New Jersey Department of Environmental Protection, and we thank them all for their support, critique and effort in developing the model. Please see Appendix A for a comprehensive list.

If you have questions, concerns, or comments regarding the model or future updates, please reach out to Dr. Joshua Moody at jmoody@delawareestuary.org.

Appendix A: Work Group Reviewers

Member	Affiliation
Lance Butler	Philadelphia Water Department
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Ryan Anderson	NJ DEP Bureau of Coastal Regulation
Elizabeth Semple	The Nature Conservancy, formerly NJ DEP