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Shoreline Restoration Solutions for Mason's Island, CT

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Introduction and Goals

When diving into this independent study, the first thing I considered was what would be of the most possible help to the citizens of Mason's Island. I knew I wanted my study to end with something actually having been done to help stop the erosion occurring on the island- whether it be the implementation of a "band aid" solution, cooperation with an engineering firm, or even a source of funding secured. I was lucky to be able to establish contact with Kristin Foster as well as the other participants of the "Mason's Island Shoreline Task Force" quite early on, and I was even able to experience an in person site visit. After my first meeting with Kristin Foster, I established the following goals, outlined below.

Goal one: Identify the Land Permitting for Mason's Island

I was asked by the Mason's Island Shoreline Task Force to identify and help explain any laws currently in place that would prohibit them from modifying the shoreline themselves. Knowing how long and difficult the process of getting an engineering firm to help them would be, and how quickly their shoreline was eroding, they wanted to see if there was anything that could possibly done themselves early on. We decided to refer to these short term or temporary solutions as "band aid" solutions, as they may not be the optimal solution and further action may be needed, but they would at least provide some protection until a better solution could be implemented.

Goal two: Explore potential shoreline resilience solutions as well as their drawbacks and benefits, and examine how they may work for Mason's Island.

The residents of Mason's island had already been working with several other environmental consultants and retired professionals before I became involved, and they had plenty of their own research to present to me. They had ideas of what they could do to protect their shoreline, but were unsure of which ideas may be feasible and which may cause more harm than good. My goal was to explore each of these solutions in depth, as well as research some of my own ideas. I wanted to look into the specifics of Mason's Island such as the fetch, erosion severity, and tide lines, and apply these conditions to determine which solutions may work. For example, in order to implement a strictly living shoreline solution it would be necessary for the waves hitting Mason's Island to have a low enough energy that they would not destroy any fragile new plantings. In addition, the salinity of the area would greatly affect what plants could be grown and which could not.

Goal three: Determine a possible living shoreline design that would build up the current shoreline and prevent further erosion

To help with my goal of providing something tangible to the residents of Mason's Island through this study, I wanted to come up with a "final" consensus to give them at the end of my project. This would include a thorough analysis of potential solutions as mentioned above, in addition to my thoughts on what would be the best possible solution or combination of solutions. Of course my advice would not be the end all be all, but it would allow them to get a glimpse into what could end up happening and what kinds of costs they could expect.

Goal four: Determine some expected long term results on the shoreline and nearby ecosystems of the optimal shoreline resilience strategy

After giving my advice on what type of solutions may be best for Mason's Island, I also wanted to explore the primary and secondary effects. I intended to look at as many similar case studies as possible as well as doing research into what kinds of primary ecosystems were on Mason's Island in order to predict some potential byproducts.

Mason's Island Background

Mason's Island is located just off the coast of Stonington, Connecticut, and is approximately 600 acres in area. The island is primarily made up of residential areas, with a retreat center on the southernmost tip and a protected marsh in the middle of the island. The area of concern is a portion of shoreline off of the main road, Chippechaug trail, which serves as the main and only access road to much of the island. Without this road, the residents of Mason's Island would be effectively trapped and separated from the mainland, causing a great safety issue. Picture one below shows an aerial view of the shoreline that is facing the extreme erosion, and how close it is to the road, which also just happens to be the lowest point elevation-wise on the island. Residents have recorded that in the last year alone the area between the mean high water line and the road has shrunken from 37 feet down to just 33.5 feet, highlighting the significance and urgency of this issue.

Picture 1: *Aerial view of the portion of Chippechaug Trail closest to the eroding marsh.*

Currently, a manicured strip of grass lies between the road and the small portion of marsh before the water. The high marsh grasses and lawn are cut down yearly to preserve the residents view of the ocean from their homes. The line where the marsh meets the water is highly uneven and varies greatly, as shown in the figure below. In some areas the water meets the marsh directly, and in others there is a short strip of sandy beach instead of a marsh between the manicured lawn and the water. In one of these areas a drainage pipe for storm water extends onto the sand.

Causes for Shoreline Erosion

One important question to consider before researching potential shoreline resilience options is why this shoreline in particular is facing such extreme erosion. Kristin Foster, my main community partner in this project, shared with me in our first meeting that the Island had lost three feet six inches of shoreline between the road and the ocean since just last July alone. This seemed particularly startling to me for several reasons, and raised some questions. First of all, why was the shoreline only eroding so suddenly? Was it previously bad as well, but the residents just did not notice it? Secondly, it made me wonder if any green infrastructure would even be able to mitigate such strong erosion, and if whatever was causing this erosion would erode away any solution as well. In order to begin my research into what was causing this extreme erosion, I first looked at the geography of the area. As seen in figure one below, Fishers Island is directly to the South of Mason's Island. However, there is one portion of open ocean that diagonally reaches the southeast corner of the island, and is not sheltered by Fisher's Island. One important term that will be used for much of this report is fetch, or wave energy that is created by wind moving across the ocean's surface. The more open ocean there is for uninterrupted wind to travel across, the higher the fetch will be, and the larger and more powerful the waves reaching the shore will become. Based on this concept, it seems that fetch plays a role in the erosion the island is facing (14).

Figure 1: *Map of the area surrounding Mason's Island, showing how much of it is sheltered by Fisher's Island.*

Pictures 2 and 3: *Highlighting the visual difference between a highly sloped (left) and flat sloped (right) shoreline.*

Another factor that influences erosion is the steepness of a shoreline. Pictures one and two above highlight the two different types of shorelines, and the differences between a steep (left) and gentle (right) one. In shallow water, a wave increases in height due to bottom friction compressing the wave length, and eventually the wave will break once the height of the swell is approximately 80% of the water depth (15). The steeper the shoreline slope, the closer to shore the waves will break, bringing more sediment back out with them. If a wave travels gently up a flat slope the energy will be gradually dispersed, but a steep slope, or even worse no slope at all, means that the wave energy will hit the shoreline with full force at a perpendicular angle (14). In the case of Mason's Island, the shoreline is very steep. Because the area is a marsh, this slope is almost 90 degrees vertical, causing severe undercutting and scour.

Figure 2 (right): *Elevation map for Mason's Island showing the highly sloped shoreline. Figure created by Tao Wu.*

Picture 3 (above, left): *The eroding marsh of Mason's Island, CT (Picture by Mia Jordan)*

One other possible source of the extreme erosion that is suspected, but has not been confirmed, is the underground makeup of the area. Several soil tests were recently conducted in the area of interest that showed the makeup of the soil at least three feet down was entirely sand with no hard rock or root structure. Although these tests were done more inland and not on the marsh itself, they suggest that the entire area might be just as unstructured and easily erodible. Another suggested cause of the erosion is air or water pockets under the marsh itself that may contribute to the marsh collapsing and falling into the ocean when disturbed. Pictures four and five below show the undercutting and erosion of the marsh.


Pictures 4 and 5: *The erosion and undercutting of the marsh adjacent to Chippechaug Trail. Note the rocks on the shoreline in picture 5 (right), which were placed by the residents of the island in an attempt to protect the shoreline from storm waves.*

Overall, an unfortunate mix of factors contribute to the uncharacteristically extreme erosion on Mason's Island. The long fetch, short shoreline, and practically nonexistent soil structure make the area vulnerable, unprotected, and weak. As far as the reason why this erosion has not been noticed in the past but is now suddenly occurring- my research suggested that it actually may have been happening all along, and the residents did not notice it because there was still more land between the sea and road. In addition, the acceleration of sea level rise may have contributed to an exponentially harmful erosion that sped up the decay over time. Regardless of what is causing the erosion, it is important to note that a solution must be implemented as soon as possible to prevent any further loss of land. As will be explored in later sections, a combination of a living shoreline and some other more protective gray infrastructure may be needed to fully protect the shoreline.

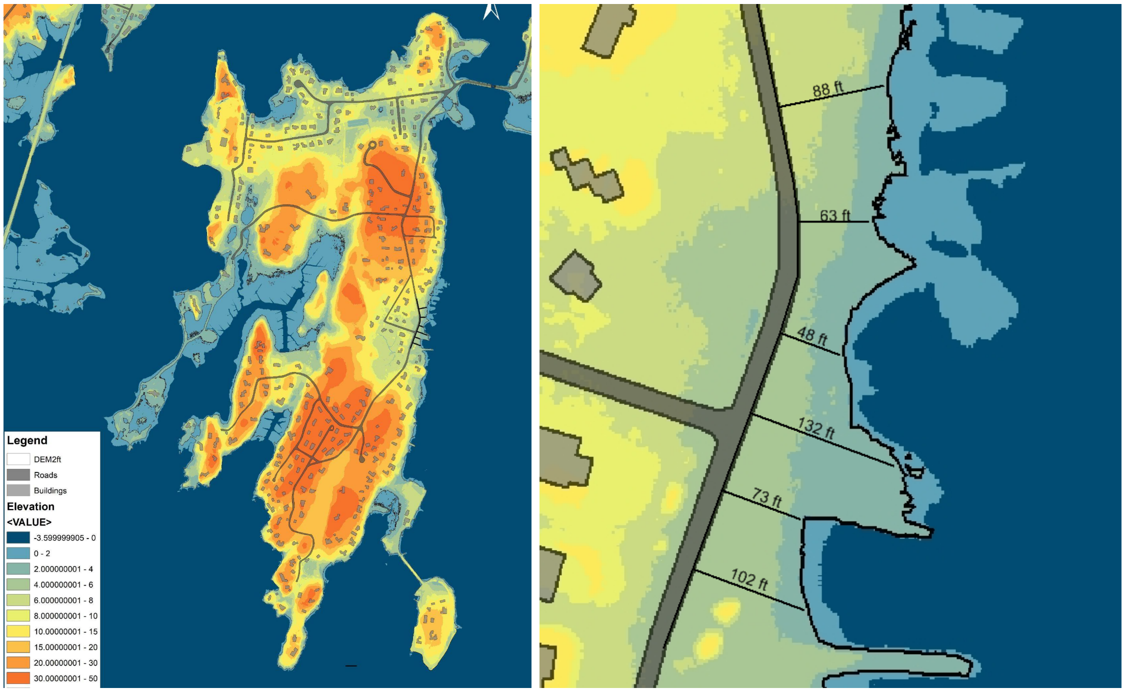
In Person Visit Observations

I was lucky enough to be able to do an in person site visit for this project quite early on in the process. Though it was in early February, so I was not able to see any of the plant life in bloom to identify it or establish how healthy it was, I was still able to make several useful observations during my time there. The first was that the area of marsh and grass leading up to the road was extremely flat. In contrast with the vertical elevation gain of the marsh edge, the rest of the area was nearly horizontal. This seemed alarming to me, as if the sea were to ever rise above the marsh, the whole area would be flooded relatively quickly. In addition, some sort of sand fill may need to be put on top of the marsh before implementing a living shoreline in order to stabilize it and repair lost sediment, which could be costly (9). Being able to see the site in person really showed me just how bad the erosion in the area is. Having had it described to me verbally and through pictures previously, I was still not prepared for how serious the situation was. I took pictures four and five above during my site visit, and they show not only how close the ocean is to the road, but how detrimental the erosion so far has been. One key observation to point out is the small sand beaches cutting through the marsh onto the grass lawn. According to the residents of the island I spoke with, these beaches were not previously there, and were caused by the erosion. This led me to believe that my theory of the area having little to no underground support and structure may be true, as the water was able to cut right through the marsh and expose the sand underneath.

Project Goals

Permitting of the Area

The land permitting of the area can essentially be broken up by two different dividing lines, or three total subsections. First, it should be noted that the entire area is under the jurisdiction of whoever actually owns the land, which is in this case the Mason's Island Company. The other main group controlling what can and cannot be done to the land is the Connecticut Department of Energy and Environmental Protection, or DEEP for short. There are two main lines that dictate DEEP's involvement- the 1000 feet line and the coastal jurisdiction line. The former states that anything 1000 feet from a coastal resource and waterward is monitored by DEEP (3). Monitoring in this case means that DEEP needs to be made aware of any changes to the area, and can make suggestions, but they do not directly control what goes on there. The latter is a line based on elevation, and in the case of Stonington CT it is the line that marks three feet above sea level (4). The fact that this line is based on elevation means that it may change over time, which can cause some inconsistencies in permitting and legalities. Figure two below shows the elevation map for Mason's island, with a zoomed in version, figure three to the right of it showing the coastal jurisdiction line and several reference markers of how close Chippechaug Trail is to the line. The cross marks with numbers next to them indicate how many feet are currently in between the coastal jurisdiction line and Chippechaug Trail. Anything landward of the coastal jurisdiction line is monitored by DEEP, while anything waterward is enforced. DEEP enforcing an area means that they directly control what goes on, and permitting is necessary for any change to the land.



Figures 3 and 4 (above): *The elevation map highlighting the 3 feet above sea level coastal jurisdiction line for Mason's Island. Note that figure three (right) shows an approximation of how many feet are between Chippechaug Trail and the coastal jurisdiction line. Figures by Tao Wu.*

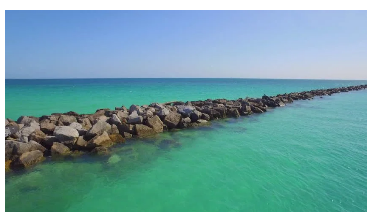
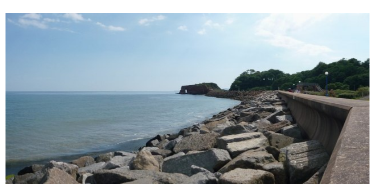
Overall, what these permitting lines mean for Mason's Island is that restoring the shoreline is going to be a lot more difficult than any type of simple do-it-yourself project. In order to complete a shoreline restoration legally and sustainably, involvement with the local and state governments will be necessary. Although DEEP's involvement with shorelines is for the better by ensuring their protection, it can be cumbersome. It essentially implies the following necessities for the residents of Mason's island to take to protect their shoreline: getting permission from the local government and land owners, cooperating with an engineering firm and DEEP to come up with a plan, and combining all of those partners to build and or plant the solution.

Potential Erosion Solutions

Green and Gray Infrastructure

A large part of my research focused on green and gray shoreline infrastructure, the differences between them, and if it would be possible to use them in conjunction. In general, gray shoreline infrastructure is anything that is hard, made with man made materials (concrete, etc), and works against the water movement and ecosystems rather than with them. These types of shoreline infrastructure were almost always used in the past, but now as sea level rise accelerates and coastal storms are at an all time high, these shoreline protectors have become much more useless. Green shoreline infrastructure on the other hand, is most generally made out of some sort of plant or animal matter, and it focuses on working with the water and ecosystems (11). The most common example of this is a living shoreline, which is when marsh grasses and other hardy plants are placed in an area once devoid of vegetation, stabilizing the ground and protecting the shoreline.

Though it seemed from the start that the best solution for Mason's Island would be to avoid gray infrastructure to the highest degree possible, I still researched the different types of gray infrastructure that could be implemented. This was done both as a double check that they would not be suited for the area, and so that I could educate the residents of Mason's island on the differences between green and gray infrastructure, and the benefits and drawbacks of each. Table one below summarizes my research on each infrastructure type, as well as what conditions each is best suited for. It should be noted that this table does not cover every existing shoreline protection device, and many others exist, often made up of a combination of several of the devices below.

Type of Infrastructure	Best Conditions for Implementation	Diagram	Pros	Cons
Seawalls / Bulkheads	Any		Study building materials, instant protection	Protection does not last (erosion under the wall), causes more erosion down the beach, harms ecosystems
Groynes / Jetties	Any		Easily accessible building materials, creates pathways for boats, benefits some rock based ecosystems, keeps sediment in desired area	Pulls sediment away from other areas down drift of the structure, can be damaged by storms, not always effective, costly to build
Rip rap	Any		Benefits ecosystems, sturdy, disperses wave energy	Can experience some wave energy deflection, storms can move rocks
Rock sills	Best with low bathymetric slope- generally put in from of living shoreline with space for marsh to grow in		Benefits ecosystems, protects marsh behind it, disperses wave energy	Can fail with high water events, same cons as rip rap

Living Shorelines	Low to moderate fetch and erodibility levels, low landward sloping		Benefits ecosystems, all natural, can adapt to changing conditions, filters water, disperses wave energy	Will not survive high wave energy or storms, often need to be protected, costly, require maintenance, block ocean views
Offshore breakwaters	Any		Extremely effective at reducing wave energy, can benefit ecosystems depending on type	Very costly to implement

Table 1: *Comparison of common shoreline protection devices, noting the conditions best for implementation, a figure of each, and pros and cons of each (1,5,7,11).*

As this research project was initially brought to my attention as a living shoreline design, I wanted to try to stick to that theme as much as possible in my determination of the optimal solution. As such, much of my focus when researching was on living shorelines, and how they may be particularly beneficial in this situation. Living shorelines typically consist of a variety of plantings that will grow to fill the chosen area over time (12). Care must be taken when selecting which plants will work best for the shoreline, as some thrive in upper wetland areas that are not continuously wet, while others do best in the low marsh near the water (5). Plants in a living shoreline have two features that make them useful to combat shoreline erosion- their roots, and their stalks. The roots of the plant stabilize the ground below, and hold in sediment. The stalks are beneficial because they focus on dissipating wave energy, rather than deflecting it to cause erosion in another area as a sea wall would (1). The plants serve numerous ecosystem benefits by providing homes to fish, macroinvertebrates, and birds. Living shorelines as a whole not only stop ocean water from affecting the land, but they stop surface land runoff from affecting the ocean by acting as a sponge after severe rain events, filtering and gradually releasing runoff (12). Research studies have shown that living shorelines hold up much better during storms than hardened shorelines, which is crucial with the increase in severe storms occurring due to climate change (2).

The issue on Mason's Island is not just that the area is susceptible to future erosion, but that it has been largely damaged by past erosion. Therefore, part of the solution should include a way to repair the shoreline, and this is where living shorelines are most helpful. Because they consist of natural plantings that will continuously grow, adapt, and spread, they would not only be able to restore the shoreline, but to protect it from further erosion damage. This key feature makes living shorelines essential as a measure for combating sea level rise, as they will continue to grow upland with the inward moving water.

One issue to note with living shorelines is how they hold up against wave energy. While fully established plants are able to withstand most moderate ocean waves, any new plantings will not survive areas with high fetch (1). This is an issue of concern for Mason's Island specifically, as the fetch in the area of concern is unusually high for a Connecticut island. In addition, the extreme sloping of the shoreline would only increase the impact of the waves on any plantings (1). With this in mind, the optimal solution for Mason's Island should also include some form of protection for the living shoreline. Based on figure one, living breakwaters seem like the most effective option in this case due to their supreme ability to disperse wave energy. Living breakwaters would not only increase the ecosystem benefits in the area, but would slow down and buff any waves heading towards new plantings in a living shoreline, allowing them to strengthen and fully establish (7).

Despite whatever seems to be the best solution for Mason's island just based on the physical conditions alone, another important factor to consider is cost. Though the Mason's Island Shoreline Task Force has been regularly applying for grants and funding opportunities to restore their shoreline, exactly how much money they will be receiving is not yet set in stone. In addition, the actual cost of implementing the shoreline will vary greatly based on the company who installs it, the solution chosen, and where the materials are from. Considering how expensive offshore breakwaters typically are, other options could be coupled with the living shoreline to protect it from the high fetch. Sea walls would not be a good idea due to their destructive nature, however rip rap or rock sills would both be good options. Boulders are much cheaper than specially designed underwater structures, and they could be placed slightly outwards into the water from the living shoreline in order to trap sediment behind and enhance marsh growth up to the rock wall. The following diagram shows what this might look like.

Figure 5: *Potential design for a living shoreline and protective devices (Photo taken from Google earth, overlay created using Microstation)*

Ideal Living Shoreline Plantings

When planning a living shoreline, one of the most important considerations is what type of plants will be used. In the case of Mason's Island, there are two main factors influencing the optimal plant species- preserving the view of the ocean, and preserving the shoreline itself. Although it may seem trivial, one of the greatest concerns brought to my attention by the Mason's Island Shoreline Task Force was that most of the people living on this island were there to see the ocean, and many of the people who hold the power to make a living shoreline happen may be opposed to it if it is not considered aesthetically pleasing. Based on this, the best plant selection would include plants that are deeply rooting yet short growing, which unfortunately are few and far inbetween due to the fact that most plants root deeper when they grow taller. Not considering height, Some of the potential best plants are summarized in the table two below, keeping in mind that they must be planted in the correct tidal zones.

Low marsh - Black Needlerush		Grows tall in low salinities but high salinity will keep it short, deep rooting
High marsh - Cordgrass		Can grow taller closer to the water but above the subtidal zone, grows slightly shorter higher up
High marsh - Switchgrass		Grows best in low salinity areas, easy to grow, can be trimmed for height with caution
Low marsh - Common Three Square		Can reach four feet tall, flowering, hardy

High marsh - Salt Marsh Hay		Easy to grow, prefers some salinity, can be harvested for gardening mulch
High marsh - Seaside Goldenrod		Perennial, flowering, grows well in sandy soils, can become tall (six feet or less)
High marsh - American Beachgrass		Extremely common in living shorelines or natural marshes, hardy, easy to grow, tall

Table two: *Different plant species that could be used in a living shoreline on Mason's Island, including marsh locations best suited for each plant, identifying pictures, and basic information on each (9,10,13).*

As previously stated, regardless of how much research is done on the optimal shoreline restoration solution for Mason's Island, most of the decisions are heavily influenced by cost. As such, I have chosen for the largest deliverable of my project to be an excel based living shoreline cost calculator. As of right now it can be used for the following purposes:

- Calculating how many plants are needed to fill an area based on spacing requirements
- Determining total plant cost based on square footage of design and percentage each species makes up
- Determining total plant cost based on square footage of design and square footage of each species

Long Term Expectations and Effects

Going off of the ideal solution of a living shoreline combined with some sort of harder structure (reef balls, rip rap, or breakwaters), the outlook for the future of Mason's Island is positive. By focusing on the use of green infrastructure, the ecosystems of the area will receive a large boost. Living shorelines attract fish , macroinvertebrates, and even birds to the area, which will increase biodiversity and resilience of organism populations (12). The ability of the living shoreline to survive and thrive depends on the quality of the initial installation, and the conditions afterwards. If the correct plants for the conditions of the area are chosen and they are properly planted with ideal spacing, they should be able to grow and expand. However, in the design of any living shoreline plans must be made for unforeseen circumstances, such as large coastal storms washing away recently installed plants or drowning them (2). To account for this, it is best to set aside additional funding if possible for any repairs. Similarly, any shoreline restoration project will require maintenance in the future. In this particular case, the most likely maintenance activities would include replacing uprooted or dead vegetation, removing debris or unwanted species, and ensuring that any protective structures are still in place (12).

To get an idea of what Mason's Island may look like in the future, several different completed living shoreline projects were explored. However, out of all of them, the living shoreline project at Stratford Point in CT seemed to be the closest in terms of site conditions. This living shoreline was created by Sacred Heart University, near the Housatonic river estuary. The goal of the project was similar to Mason's Island, with the hopes that it would reduce erosion and longshore sediment transport as well as restore the marsh in the area (8). In this project, the main strategy was to use a living shoreline, but to also back it up with artificial reef balls, a type of living breakwater that would allow for oyster growth. The project was completed in four phases- the artificial reef construction and implementation, the low marsh planting, the high marsh planting, and the coastal dune restoration (9). While any dune restoration would likely not be possible at Mason's Island due to the geography of the area and limited space, the remaining three steps apply quite well.

The two key takeaways from this project are relating to time, and order of construction. First, the Stratford point restoration proves that any living shoreline planted will not be immediately effective, and it will take years to fully grow and fill the area. As pictures six through eight show (left), while the middle point of the project right after planting was better than the before picture, it is still not nearly as full grown as the complete after picture. Secondly, it is important to note the order in which this project was completed. The artificial reef balls were constructed and implemented months before any plants were added to the area, so that their effectiveness could be checked beforehand. Then, once it was confirmed that they were reducing wave energy hitting the shore, the living shoreline could be planted. This similar technique would be largely useful for Mason's Island in order to lessen the chances of a failed living shoreline implementation.

Pictures 6 through 8 (left): *Before, middle, and after photos of the Stratford Point living shoreline project in Stratford, CT. Source: www.sacredheart.edu*

Concluding Remarks

This research project was an opportunity to become well versed in living shorelines, the differences between green and gray infrastructure, and the way site specific conditions influence which solution may be best for an eroding shoreline. Overall, I feel that I was successful in being able to accomplish my four main project goals, which were to determine the permitting of the area, go over potential solutions, come up with a living shoreline design, and determine any long term effects. Despite being able to achieve these goals, I feel that there were several things I was not able to cover in as much detail as I would have liked to. Additional site surveying will be necessary to truly determine how extreme the fetch of the area is, and that will therefore confirm the optimal solution. In addition, despite giving estimates on which plants could be used, I was not able to give any specific designs in terms of plantings due to the unknown factors of cost, pre existing plants in the area, and how exactly the plants would be obtained. However, I was able to offset this downside somewhat by developing the living shoreline cost calculator tool. I feel that the most useful takeaway from this project for others was this excel based calculator which could be helpful for the Mason's Island Shoreline Task Force in determining how much funding they may need from grants and other sources in the future.

Another limitation I discovered throughout the completion of this project was how much could actually be done by the residents of the Island themselves in the short term. In completing my first goal of identifying what permitting laws applied to the area, I discovered that the process of restoring a shoreline was much longer and more difficult than previously thought. Despite what research I was able to complete and what ideas I was able to offer, the involvement of an engineering firm will still be absolutely necessary to actually get the ball rolling on a living shoreline project. Even worse, getting all the proper permissions and funding for this project could take a matter of years, which is particularly frustrating considering how much of an immediate issue it is. Regardless, I am glad that I was able to roughly accomplish what I planned, and I am happy to say that I will remain involved in this project even after the independent study portion is over.

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