S.E.C.

Shoreline Erosion Control

BAE 4023-Spring 2022

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Problem Statement

In the past, remediation of shorelines across the state has consisted of using riprap and other costly methods to stop shoreline erosion. A floating wetland with the ability to mitigate wave action at the shore could be more visually stimulating and cost-effective than using riprap. Past and current floating wetlands have proven to work but have not been durable enough to withstand the intense wave action in larger water bodies over extended periods of time. The traditional plastic/PVC structure degraded quickly in the intense Oklahoma sun causing structural failure and water quality issues from microplastics. This project must have a new, durable design that will have the ability to last for years through large wave action conditions. The design must also have a fool-proof anchoring system to ensure the large wetlands cannot float away. Prior designs had issues with wildlife such as geese, tampering with the wetlands, and floating structures. Methods to deter geese and other nuisances would be very desirable.

Work Breakdown Structure

The following work breakdown structure shows the project plan for the remainder of the fall semester and for the spring semester. The project was broken into four main sections: deliverables, planning, design, and product development.

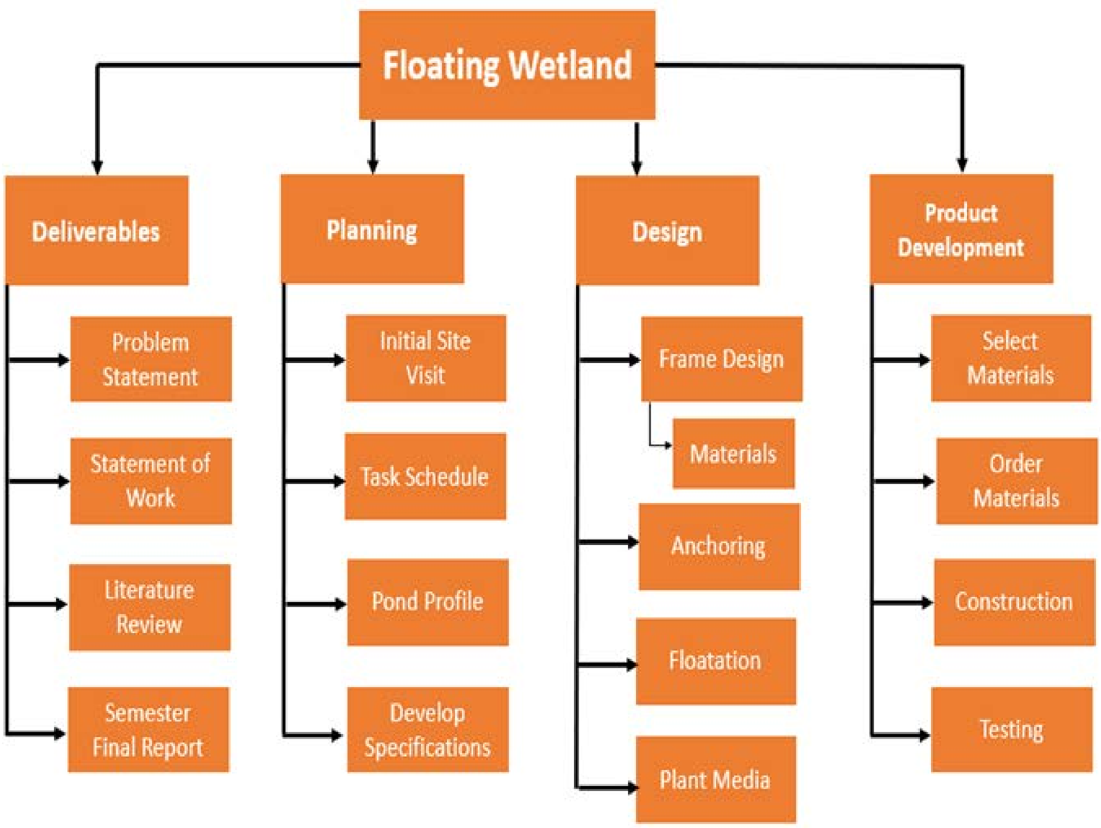


Figure 1. Shoreline Erosion Control Work Breakdown

Background

Project Location

The wetland will be placed in the OSU (Oklahoma State University) Research Technology Park Pond located about one mile west of OSU's campus on the corner of Sangre Road and 6th avenue. Per the client's request the proposed wetland will be set towards the middle of the lake, where it will be exposed to high winds and large wave action. The following figure shows a screenshot of the pond and proposed project site.

Figure 2. Project Site Location

The following figures show the shoreline of the lake when damaging erosion was taking place and the shoreline after rip rap was put in place. The riprap on the edge of the pond already serves as a viable erosion control method but, the floating wetland being designed in this project will be able to be used in place of riprap in other locations where erosion has been a problem. Since erosion has been an issue on this pond in the past, it will serve as a good testing site for the floating wetland.

Figure 3. Pond Erosion Prior to Riprap

Figure 4. Current Pond Conditions

One important piece of information regarding the project site was the depth of the pond. Without a surveying team to measure the bottom of the lake, there was no effective way to determine the depth of the Research Technology Park Pond, but the team managed to get some data using the resources that they had available to them. To get a rough estimate of the shoreline depth of the pond the team put on waders and walked out measuring the depth in increments of 1,2,3, and 3.5 feet. 19 different depth measurements were taken around the northeast shoreline where the erosion was causing the most damage prior to the installment of riprap. The depth measurements were taken 50 feet apart. The following figure shows a hand-drawn contour map of the pond.

Figure 5. Contour Map of North-East Corner

Customer Requirements

The requirements that the client wanted to include in the floating wetland were to make a durable structure capable of mitigating wave action in the lake to reduce and prevent erosion on the shoreline. The client suggested that the team should avoide using plastic as the design material . Along with designing the wetland, the team was tasked with producing a secure anchoring system for the wetland to prevent it from floating away during flood events. Another issue that the client uncovered was finding a way to deter geese and other waterfowl from using the wetland as a resting point and destroying it.

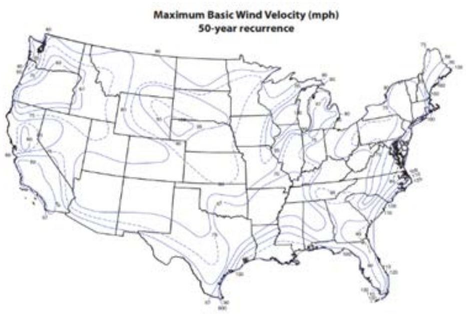
Environmental, Social, and Global Impacts

While it is unlikely that this project will have any real societal or global impacts, however, it has the potential to have many positive environmental effects. A floating wetland that could mitigate wave action would offer three main benefits. The first benefit we see in natural wetlands is in the form of waste and agricultural water treatment. The plants in the floating wetland would be able to take in the excess nutrients and harmful pollutants through biological processes, thus improving water quality. The next benefit is that our product is unique and not currently on the market. Our constructed wetland will to mitigate wave action. By absorbing wave energy before it reaches the shore, the wetland will protect the shoreline from erosion. The last positive impact the product offers is that it will have alow profile covered in plants to make it look natural and apart of the landscape. Therefore our floating wetland provides a desirable alternative to current wave mitigation tactics like riprap, which give a man-made look and take away from the pond. Overall, we hope to deliver an impactful product that can absorb wave action and treat wastewater pollutants, while looking natural and aesthetically pleasing on the waterbody. Something that has the potential to offer so many good qualities in one product could have environmental impacts.

Specifications and Codes

USDA-NRCS Technical Guide 56-A Guide for Design and Layout of Vegetated Wave Protection for Earthen Embankments and Shorelines.

This is technical guidance that our clients follow in their design work. It outlines their process for vegetated wave protection structures. The first major parameter this guidance offers is a simplified approach to assessing and classifying wave action. We have used the equations within the guidance to make some initial calculations on the significant height of waves that the pond experiences. These calculations have given us a starting point for the specifications our project needs to meet. It also defines the limits on the effectiveness of these structures and graphs the relationship between length of waterbody and wind. It also sets guidelines for the width and slope of the earthen structure. After further study, it was found that we will be unable to build our structure to the scale the guide lists for their earthen structure as it would just be too large.



$$H_s = 0.0232 \times V_w^{1.06} \times F_e^{0.47} \quad \text{(eq. 3)}$$

where:

H_s = significant wave height (ft)

F_e = effective fetch (miles) from equation 1

V_w = over water wind velocity (mph) from equation 2

Figure 7. Wind Velocity and Significant Wave Height

USDA-NRCS Code 656-A Guide for building a floating wetland for water quality improvement.

This is a standard code that is used for creating a floating wetland. Part of the requirements from the client was to include improvement of the water quality while providing a sturdy foundation to absorb wave action. It also mentions how we should perform a water quality test to find nutrients and pollutant load. This code provides guidance on width ratio for these constructed wetlands, which we will investigate using for our product. Maintenance requirements for a floating wetland that includes replacement of plants, control density of plants, and inspection of the interior and exterior after a large storm. It also specifies that the structure should be built for a 25-year frequency, with a 24-hour flood event.

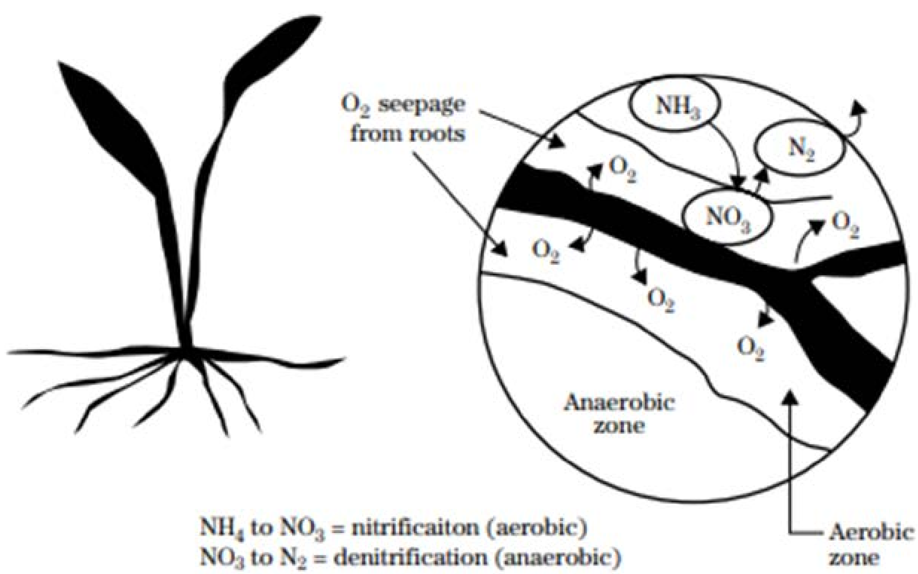


Figure 8. Plant Denitrification for Waste and Agricultural Water

USDA-NRCS Code 580-Conservation Practice Standard Streambank and Shoreline Protection

This standard is another document released from our client the NRCS (Natural Resource Conservation Service) that sets a general guidance for practices that protect streambank and shorelines. It is broad as it covers the overall practice but still serves as an outline to make sure all the bases are covered. This is potentially the document that our project or a future floating wetland would fall into.

Calculations

Buoyancy

Calculating the buoyancy allowed an understanding of how much volume was needed to support the ¼ scale prototype and find out the material needed to hold a certain amount of weight, the ¼ scale prototype could be determine using the the following:

$$F_b = V \times \rho \times g \qquad \textbf{Eq.1}$$

Where:

F_b= *The buoyant Force of the object (lbf)*

V = *Volume of the float (ft^3)*

ρ = *Fluid Density (slugs/ft^3)*

g = *the acceleration due to gravity (ft/s^2)*

Using Archimedes' Principle, which states that the buoyant force equals the weight of the liquid displaced on an object, an equation could be used to find the volume of the float needed to support a maximum weight of 90lbs of materials. The fluid density that is being applied around the float is water, making the density used in the equation to be 1000 (kg/m^3). The weight of 90 lb was an estimate used to have a safe maximum for the floats to support the frame. A conversion needed to be made in order to find the proper volume of the float.

Conversions Used:

- *Pounds to Newtons: 90 lb x (4.448 N/1lb) = 400.34 N*
- *Newtons and gravity to Velocity:*
- *400.34 N/(1000 kg/m^3 x 9.81 m/s^2) = V*
- *Changed SI units to English Units*
- V *= 0.0408 m^3 (61023.744 in^3/ 1m^3) = 2,489.77 in^3*

- *Volume to height of float*
- *Height = 2,489.77 in^3 / (3*(6in X 12in)) = 12.32 in*

The length and width was already determined to be (6 X 12) in so the unknown was the height of the float.

Buoyant Force

Calculating the buoyant force allowed the discovery of how much force is being applied when all the materials are added into the wetlands. The weight of the prototype could be determined by going off of the Archimedes Principle in **Eq. 1**, a free body diagram was drawn to determine the sum of all forces in the vertical direction as in the following:

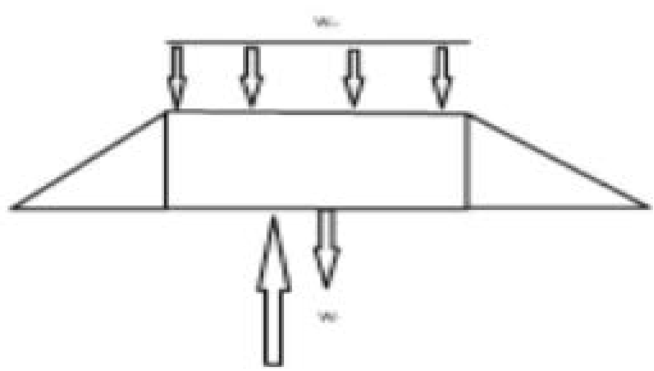


Figure 9. Free Body Diagram of Wetlands

$$\sum F_y = F_{disp} - F_m = 0 \qquad \text{Eq.2}$$

Where:

F_{disp} = *The buoyant Force (lbf)*

F_m = *The weight of the material on the dock float (lbf)*

When calculating for the buoyant force, the weight of materials is known in Table 1 from recording the materials used. The buoyant force can then be calculated to 260 lb. The dock float being used has a maximum rating of 350 lb, before point of complete submerge. Finding out how much weight is leftover before reaching the maximum rating, the dock float rating was subtracted from the buoyant force which allowed a leftover weight of 90 lbs.

Table 1. Weight Calculation

Material	Supplier	qty	Unit	Added Weight(lbs)	Surplus weight (lbs)
Structure					
Steel Angle Iron 2 in (qty. ft)	Stillwater steel	44	ft (2x2 inch, 1/8" thick	72.6	-72.6
Steel Angle Iron 1 in (qty. ft)	Stillwater steel	42	ft (1x1 inch, 1/8" thick	33.6	-33.6
Rebar	BAE Lab	8	ft	5.344	-5.344
Galvanized .5 " wire	Lowes	2	10' x 2'	20	-20
Galvanized Garden Fence	Lowes	1	50 ft x 3ft roll	20	-20
Bolts	Lowes	50	1/4 in x 1 inch	12.5	-12.5
Eye Bolts	Lowes	2	Large	0.5	-0.5
Bolts for Float	BAE Lab	2	3/8 in x 2 or 2.5 in	0.5	-0.5
Straw Blanket	Lowes	1	Roll	3	-3
Peat Moss	Lowes	2	Bags (20lb per bag)	40	-40
Better Than Rocks	Amazon	4	16 x 96 x 1.5 in	5	-5
Wood Chips	Botanical Gardens	2.5	Per 5 gallon bucket (14lbs)	35	-35
Dock Float	Walmart	1	in^3 (8x20x72)	0	350
Plants	Big Creek Nursery	8	lbs	12	-12
Total (lbs)				**260.044**	**89.956**

Wave Height Analysis

In order to begin the design process it was important to quantify the maximum hieght of waves that the structure could potentially experience. There are several methods that can be used to quantify the waves but we decided that it would be best to find a standard that would be familiar to our client the NRCS. This led us to the USDA-NRCS Technical Guide 56 - “A Guide for Design and Layout of Vegetated Wave Protection for Earthen Embankments and Shorelines.” This is a technical guidance that our client follows in their design work. It outlines their process for vegetated wave protection structures. This guidance offered a simplified approach to assessing and classifying wave action. It utilizes a wind velocity and fetch length to get a significant (or maximum) potential wave height. To perform this calculation we were able to use mapping software to find that the maximum fetch length across our water body was 0.3 miles. For the maximum wind velocity we used site extreme data for wind speed from the Stillwater Mesonet site that is less than a mile away to find that the max wind speed experienced was close to 70 mph.

Site Extremes Site Extremes since commissioning on 01/01/1994

Maximum air temperature (°F)	113	08/01/2012
Minimum air temperature (°F)	-19	02/10/2011
Maximum daily rainfall (in.)	5.32	06/01/2007
Maximum monthly rainfall (in.)	17.30	05/2019
Maximum annual rainfall (in.)	56.68	2007
Maximum wind speed (mph)	67.7	08/22/2015

Figure 10. Mesonet Data for Maximum Wind Speed

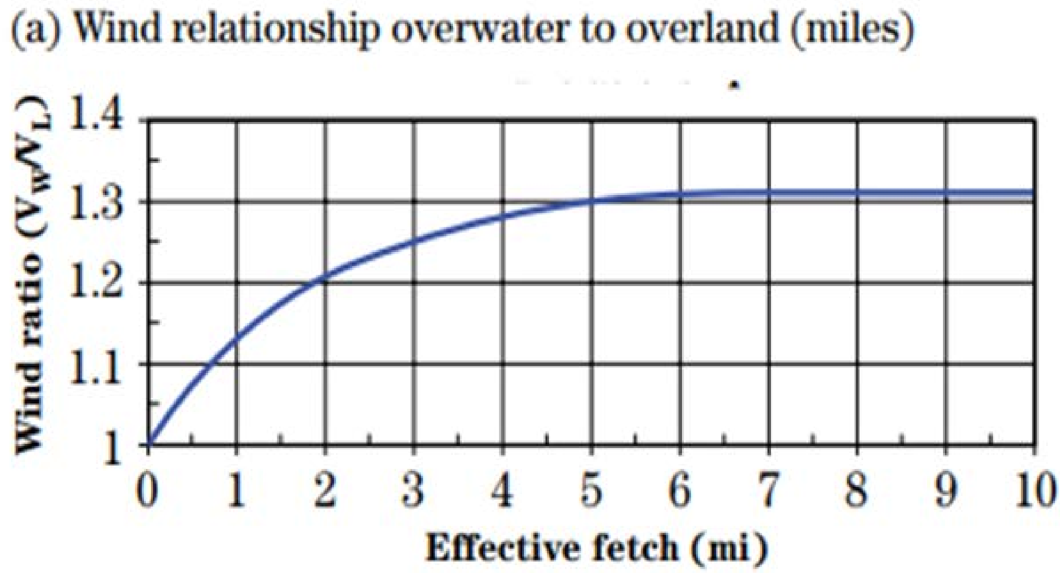


Figure 11. Wind Relationship Table from the NRCS Technical Guide 56

Significant Wave Height Calculation Equation

$$H_s = .0232 \times V_W^{1.06} \times F_e^{0.47} \qquad \textbf{Eq. 3}$$

where:

H_s = *significant wave height (ft)*

F_e = *effective fetch (miles)*

V_w = *overwater wind velocity (mph)*

Table 2. Significant Wave Height Calculation for Research Park Pond

Parameter	Variable	Unit	Value
Overwater Wind Velocity	Vw	mph	73.5
Wind Velocity Over Land	Vl	mph	70
Wind Ratio (Wind Relationship Table)	Vw/Vl		1.05
Effective Fetch	Fe	miles	0.3
Significant Wave Height	**Hs**	**ft**	**1.25314**

Using the equations shown in USDA-NRCS Technical Guide 56 the significant wave height was found to be 1.25 feet, as shown in the table above. It is unlikely that the research pond would experience this type of wave as the wind would have to be going across the absolute longest part of the pond while experiencing the highest wind velocity it has seen since before 1994. With this wave height being calculated on the absolute most extreme conditions it does offer us a good safety factor for our structure to handle even the most extreme conditions as well as be applicable to larger ponds. Using the wave height we were able to better determine the height that our structure needed to be in order to absorb the wave action.

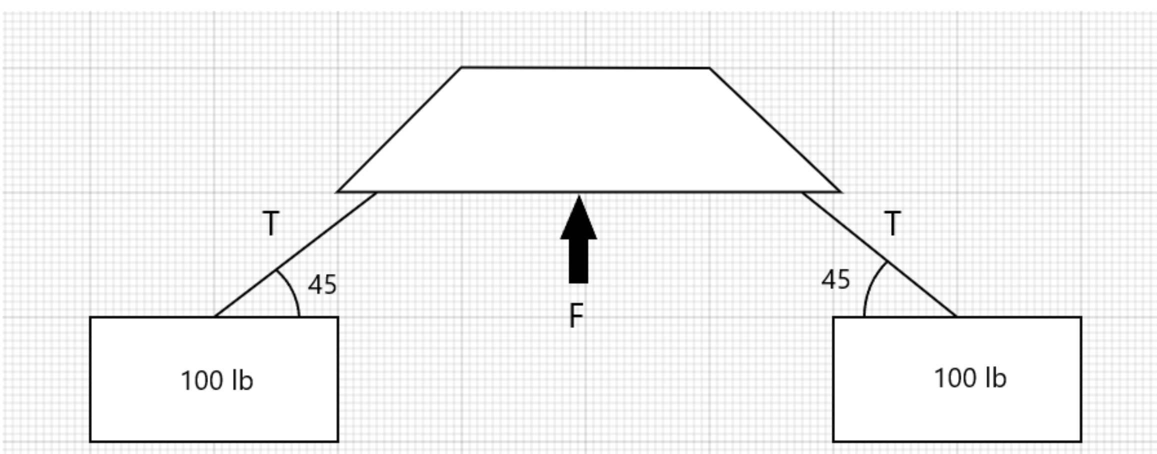


Figure 12. Free Body Diagram of Tension on the Anchor

Tension of Cable

To find the tension of each cable, both Archimedes' Principle and Newton's Second law was used. Another principle that is used from Archimedes is that when an object is completely submerged, then the volume of the fluid displaced is equal to the volume of the object. The sum of forces in the horizontal directions allows an understanding that both tensions are equal to each other. After knowing the sum of forces in the horizontal direction, it created the following equation:

$$T \sin(45°) = (F_A - F_b)/2 \quad \textbf{Eq. 4}$$

Where:

T = *Tension of the cables (lbf)*

F_A = *TThe force of the anchor on the cable (lbf)*

F_b = *The buoyant force applied on the cable (lbf)*

In order to find the sum of forces in the vertical direction the buoyant force needed to be calculated. Using Archimedes' Principle from **Eq. 1**, the buoyant force of the anchor was calculated to be 1,378.16 lbf. When calculating for the vertical forces, sine was used to calculate the angle of the cables. To find the force of the anchor the weight of the anchor was multiplied by the gravitational acceleration. Knowing that each anchor weighed 100 lbs, the force of each anchor was 3,220 lbf. Finding the tension of the cables can be seen in the following calculations:

Tension of Cable (continued) **Eq. 4**

$$T\sin(45°) = (F_A - F_b)/2$$

$$T\sin(45°) = (3{,}220 - 1{,}378.16)/2$$

$$T = 1{,}302.38 \text{ lbf (40 lb)}$$

Preliminary CAD Designs

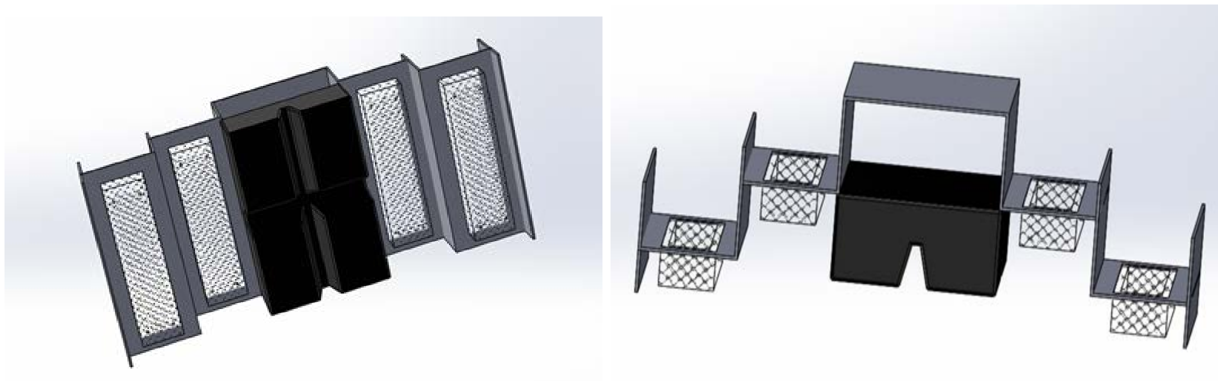


Figure 14. Stair-Step Design Option

Stair-Step

The stair step design is supposed to be able to take on primary and secondary waves. With this design the rectangular plated guards will take on and absorb most of the impact of the wave while protecting plants from being washed away. Each step will have mesh spaces for aquatic and native plants to grow around the wetland while the top will have a mesh section that will allow room for most of the wetland to have native plants.

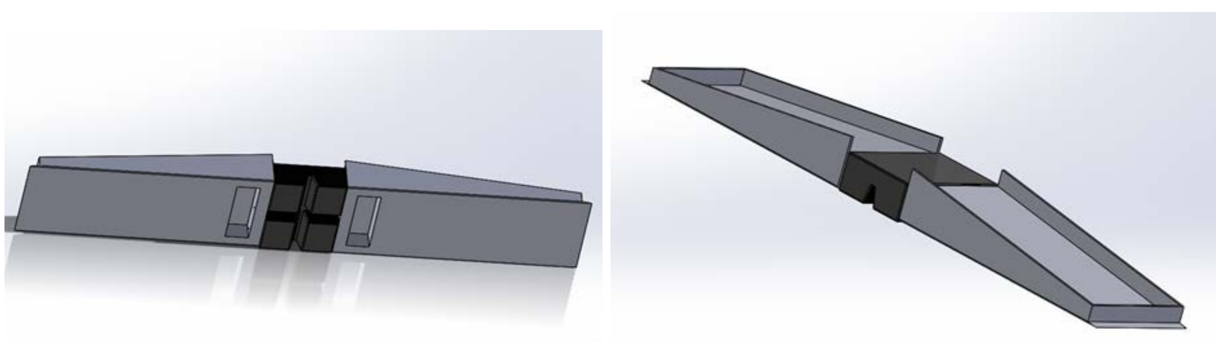


Figure 16. Flat Wing Design Option

Wing design

The wing design was created to allow the waves to naturally flow over the wing, with the incline of the wing reducing energy. This allows the waves to dissipate, creating a reduction of erosion on the shore. The floating wetland would use a coconut mesh or bio-haven material to support the plants growing on the floating wetland.

Prototype

After much discussion, the team decided to move forward with a metal frame structure in a curved shape. Since the decision of the shape and material of the frame came down to such a narrow margin, it was decided that the development and testing of a prototype could be beneficial to give us more clarity. We set the dimensions for this prototype by dividing all the designed full scale dimensions by four to have a quarter-scale model of what our larger scale would be. We then took the quarter scale prototype design to the shop for fabrication of the metal frame.

Figure 17. Prototype Metal Frame

Once the fabrication was finished the frame was covered in a mesh that was lined with tightly bound coconut fiber pot liners.These were found to be a cost effective option for keeping in the soil or other grow media. Next, two blocks of styrofoam were added to give the floatation to the metal frame.

Figure 18. Adding Media and Floatation to the Quarter Scale Prototype

The last step was to fill the center of the prototype with soil and plant the grass seeds. It was noticed at this point that once the soil was added it was significantly heavier than anticipated, but we proceeded to move forward to the testing phase. A simple boat anchor was then attached and the prototype was moved to the project site, OSU Research Park Pond.

Figure 19. Soil Filled Quarter Scale Prototype

As the prototype was placed in the pond the large mass of clay soil in the center became saturated and the prototype began to sink. Though the structure not being able to float was frustrating, once the prototype was placed near enough to the shore that it was able to sit on the bottom it was noticed that the small prototype was acting as a wave barrier to the shore.

Figure 20. Retrieving the Prototype From the Pond

After finding that the styrofoam blocks were not buoyant enough to support the weight of the prototype. The team realized that the styrofoam blocks were not calculated to be of proportional buoyancy to the dock float in our full scale design. Another factor was that the weight of the saturated soil was much heavier than the team was anticipating. The original prototype floats had buoyancy force that could hold 46 pounds and the soil filled prototype weighed around 60 pounds. Once this was realized, the team added more styrofoam inside the structure to create a proportional buoyancy force that could support a 90 pound structure. After the buoyancy adjustment the prototype was successful.

Figure 21. Successful Prototype Test

In making the prototype, there were definitely some constraints due to time as well as wanting to make the prototype as cost effective as possible. These constraints led to compounding problems of heavy materials and less buoyant floatation. In forming the prototype we didn't want to purchase a small dock float just for the prototype, so a styrofoam board of unequal buoyancy was used in its place. The other big difference between the prototype and our full scale design was that, in the full scale, we had the inner media being a mix of soil and plant media but buying costly plant media for a prototype didn't seem reasonable. Also the project would have been delayed while waiting for it to come in. Combined, this led to an ineffective initial prototype which cost us even more time, so we definitely learned that we could have better weighed some of our decisions when it came to cutting back on our prototype.

Once the prototype was complete, the team had several takeaways from the sinking prototype. The first being that prototyping can be more important than we realized. As frustrating as it was, the failed prototype led to a greater understanding of buoyancy and made us realize the need for increased safety factors when it came to the weight of our full scale model. Therefore, we decided to use more of the lightweight plant media and cut down some of the excess volume within our design that wasn't serving a purpose. This led to a final design that was four times the length of our prototype but almost the same height. These changes cut our calculated weight down immensely and decreased material cost.

Final Design

Shape Design

The frame design proved to be a greater obstacle than the team had originally anticipated. Following the presentation at the end of the fall semester, the group had narrowed the frame design down to two different shapes one being a stair-step structure and the other being an angled smooth tapering shape. It was thought that having parts of the structure submerged at different depths would allow for optimal plant growth from a few different species. The team came up with a few different ideas that were similar to the ones that were modeled in the meeting to construct a wetland that fit these shape requirements. As seen in table 3 below, four different design shapes were considered. The four designs were scored on cost, ease of fabrication, and durability. As seen in the table, the curved structure and angled structure were both ranked highest with scores of 15, while the other two structures were not far behind with scores of 13 and 14. All of the frame designs had the potential to work, but for the prototype the team decided to go with the curved frame structure because it was the easiest one to fabricate and test the design.

Table 3. Frame Design Decision Matrix

Material	Cost (1-5)	Durabilty (1-7)	Weight (1-7)	Plant Friendly (1-4)	Environmentally Friendly (1-7)	Score
Styrofoam	4	2	7	2	1	16
Better than Rocks	3	5	6	5	6	25
Dirt/Soil	5	3	1	5	7	21
Clay Planting Pellets	3	4	3	4	7	21
Dock Float	2	7	7	0	6	22
Galvanized Wire	3	6	5	4	6	24

After the prototype the team decided that the curved shape worked well for mitigating wave action. The team then made the shape less curved and more of a trapezoid to help break up waves better and it would be easier to fabricate. Therefore, the shape of our final design is an extruded trapezoid that is 8 feet by 4 feet and 2 feet tall. In the center, the frame encapsulates the dock float, leaving the side triangles and top to be filled with media and plants. This trapezoidal shape was chosen based on the prior design and prototype. The diagonal sides are used to break the waves and let the water crash onto the structure. The structure sits with one third of the structure submerged in water, this is used to help break up the wave action below the surface of the water. Then the exposed two thirds above the surface work to break wave action on the surface. Additionally, the team did not want the structure to be an eye-sore and wanted it to be aesthetically pleasing. By only two thirds of the structure being exposed it does not sit too high off of the water and looks more like a natural berm. The CAD drawing below outlines the shape of the final design.

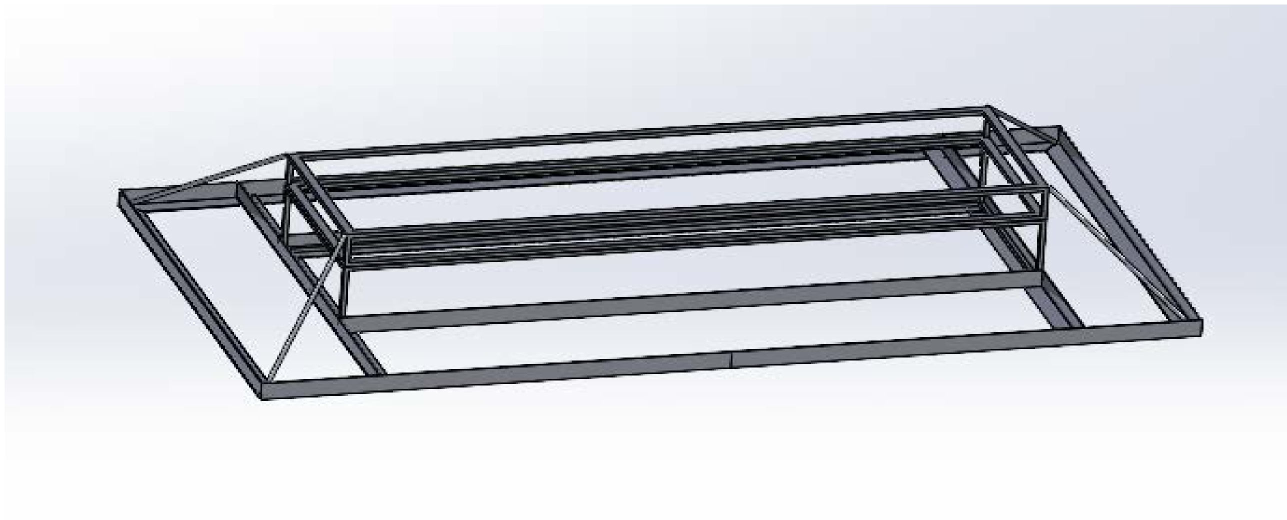


Figure 22. CAD Drawing of Final Design

Material Design

Many different materials were discussed in the design process. The team was ultimately most concerned with durability and ease of fabrication. The two materials that were considered the most were steel and fiberglass.Both of these materials would be sturdy and withstand the test of time, but steel would be easier for the team to work with and obtain materials for. Therefore, the team decided to use steel specifically angle iron and rebar as the structural material. The team was wary of the supply chain issues and sourced our material from Stillwater Steel. Additionally, the team was able to utilize the machine shop in the Biosystems lab to help them weld together the design. Therefore, making the design out of steel was the best option for this project.

Modular Design

To protect entire shorelines, multiple structures will be required to protect the shore. The team is proposing a modular system that will allow the structures to connect to cover long distances. Additionally, this design will allow for easy repair in that the individual systems can be easily swapped out if one gets damaged or needs repaired. The wetlands will hook together through a pin connection system. The following figure shows the proposed pin system as well as the final modular connection on the final structure. The difference between the proposed system and the final systems is that there are four connection points on the final design instead of two like on the proposed design.

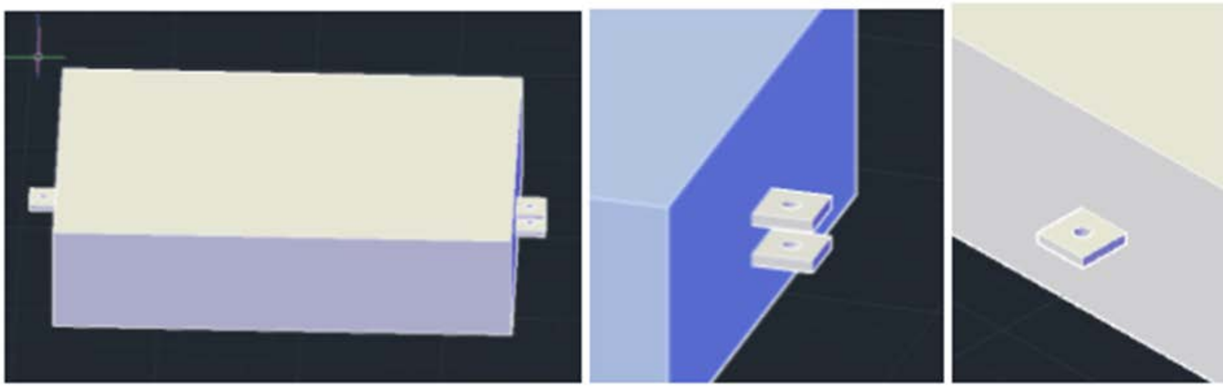


Figure 23. Modular Pin System

Figure 24. Fabricated Modular Pin System

Anchoring Design

Following the meeting in December the team decided to go with the concrete pad anchor design. The initial model presented stayed the same except for an adjustment made to the dimensions and the amount spikes were reduced. The construction of the anchor can be seen in the following section.

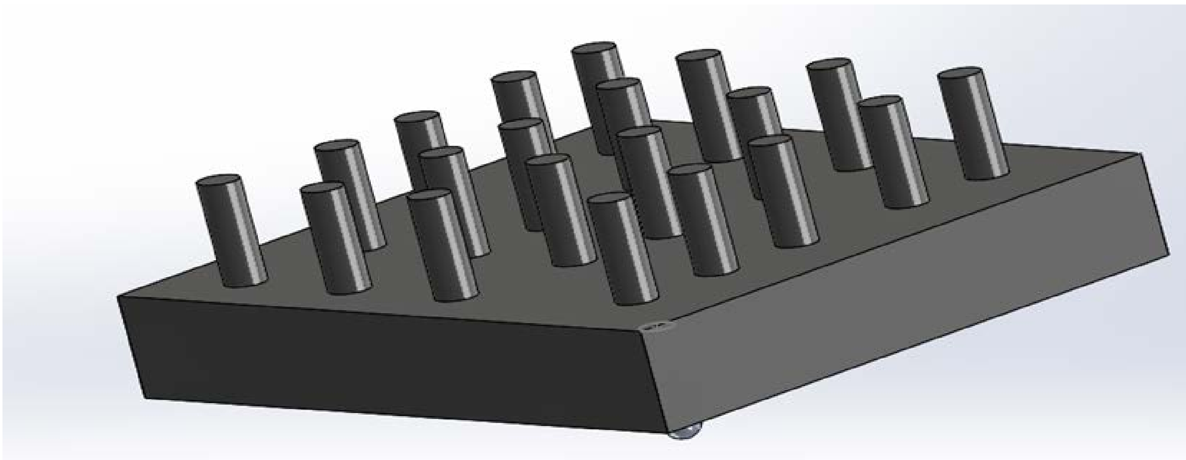


Figure 25. Initial Concrete Pad Anchor Design

The construction of the anchor was relatively simple. The team created wooden forms that were measured to be 18 inches by 18 inches by 6 inches deep. Rebar was then cut and wired together to make a grid within the concrete, attach the spikes, and create a loop for the mooring line to attach. The next two figures show the construction of the forms and the rebar.

Figure 27. Concrete Mold Construction

Figure 28. Anchor Construction

Figure 30. Completed Anchors

Two anchors were made to ensure the wetland would stay in place with less side-to-side movement. The anchors turned out well and have the capacity to hold the wetland in place. The biggest struggle that the team encountered when fabricating the anchors was getting the concrete mixed to the proper consistency. In the future when constructing the anchors, it is important to make sure the concrete is mixed well enough to ensure a smooth pour. The anchors will be connected to the structure by a steel cable and eye-bolt system. The eye bolts will be on both of the shorter sides of the frame.

Plants

There were many considerations that will go into choosing what plants should be utilized on the floating wetland. First, we want to pick plants that have little maintenance and can thrive in this wetland environment. We want to make sure we have minimal upkeep of the plants and that they can survive in the Oklahoma weather. Additionally, we want to make sure that the plants we pick are native and are not invasive species. The team picked fast growing and durable wetland grasses. The specific plants that we picked are mature Inflexus Blue Dart Juncus and bermuda grass seed. We picked these plants using the USDA Plant Database and a list of native Oklahoma plants. A full breakdown of the common and scientific names, blooming season, USDA indicator code, price, notes, and pictures are included in Appendix A.

Additionally, another vital component to consider is how the plants will grow and thrive in the wetland. It is important to have a growth media that plants can grow into and create a habitat and healthy root matrix. There are different media that can be bought from the market like Biohaven discussed above, but it is quite expensive. Instead, the team is making our own media by mixing peat moss, straw, and mulch. Then we will utilize Better Than Rocks as the bottom layer to aid with drainage of water. The top layer will be a straw blanket to hold in our media and protect the plants as they are starting out.

The following decision matrix shows plants that can be grown in wetland areas that deter geese.

Table 4. Goose Deterrent Decision Matrix

Options	Least Expensive	Unnatural	Least Required Upkeep	Deterrent Effectiveness	Least Harm to Geese	Score
	(Weight: 3)	(Weight: 3)	(Weight: 3)	(Weight: 8)	(Weight: 3)	
Visual Deterrents	2	2	3	4	3	14
Noise Deterrents	1.5	2.5	2	5.5	3	14.5
Liquid Repellents	0	3	1	7.5	2.5	14
Fishing Line	3	2	2	6	2	15
Egyptian Papyrus	2	1.5	1.5	8	2.5	15.5
Swamp Fern	2	2.5	2.5	6	3	16
Starrush Whitetop	1.5	3	2.5	7	3	17

These plants would be ideal to use in the future but for our wetland it would have taken too long to get the plants grown to a mature level and require a special order. Therefore, the team decided not to utilize geese deterring plants and will deter the geese away from the structure in another way that will be outlined later.

Fabrication Process for Final Design

Process

After the final design was finished the team started to outline and organize the fabrication process. The first step the team took was obtaining the material. The steel was ordered from Stillwater Steel, better than rocks media was ordered online along with the dock float and the rest of the hardware was obtained from Lowes. The fabrication process started immediately after the dock float came in. The first step was fitting the frame to the float using steel angle iron and rebar. This portion was completed by the shop technicians in the BAE lab. Cutting and welding the frame took a few days for the shop to complete. After the frame was completed, the team lined the whole surface with half inch by half inch chicken wire to serve as a base for the plant beds. The top of the outermost beds were covered in half inch by half inch wire and the top bed was covered in one inch by one inch wire. The wire was attached to the frame by using quarter inch nuts and bolts with a one inch washer to pinch the wire to the steel. The top one inch by one inch wire required the team to use 1.5 inch washers to pin down the mesh. Cutting the wire and bolting it to the frame took the team around 12 hours total to complete. After the wire was attached, the structure was moved back into the shop to get the modular pin connections attached to the corners of the structure. Cutting the pieces and welding them to the corners of the frame only took the shop a few hours to complete. Following the fabrication of the modular pin connection, the team started to insert the media into the beds along with the soil and wood chips. The outermost beds were filled first, and the center bed was filled immediately after. They were layered first with media, followed by a layer of wood chips and dirt. After the beds were set, team members bought plants and dug-up grass to place on the structure. Bermuda grass seed was also placed on all of the beds of the structure and then all of the beds were covered in grass seedIn total, filling the beds and placing the plants took the team around 6 hours to complete.

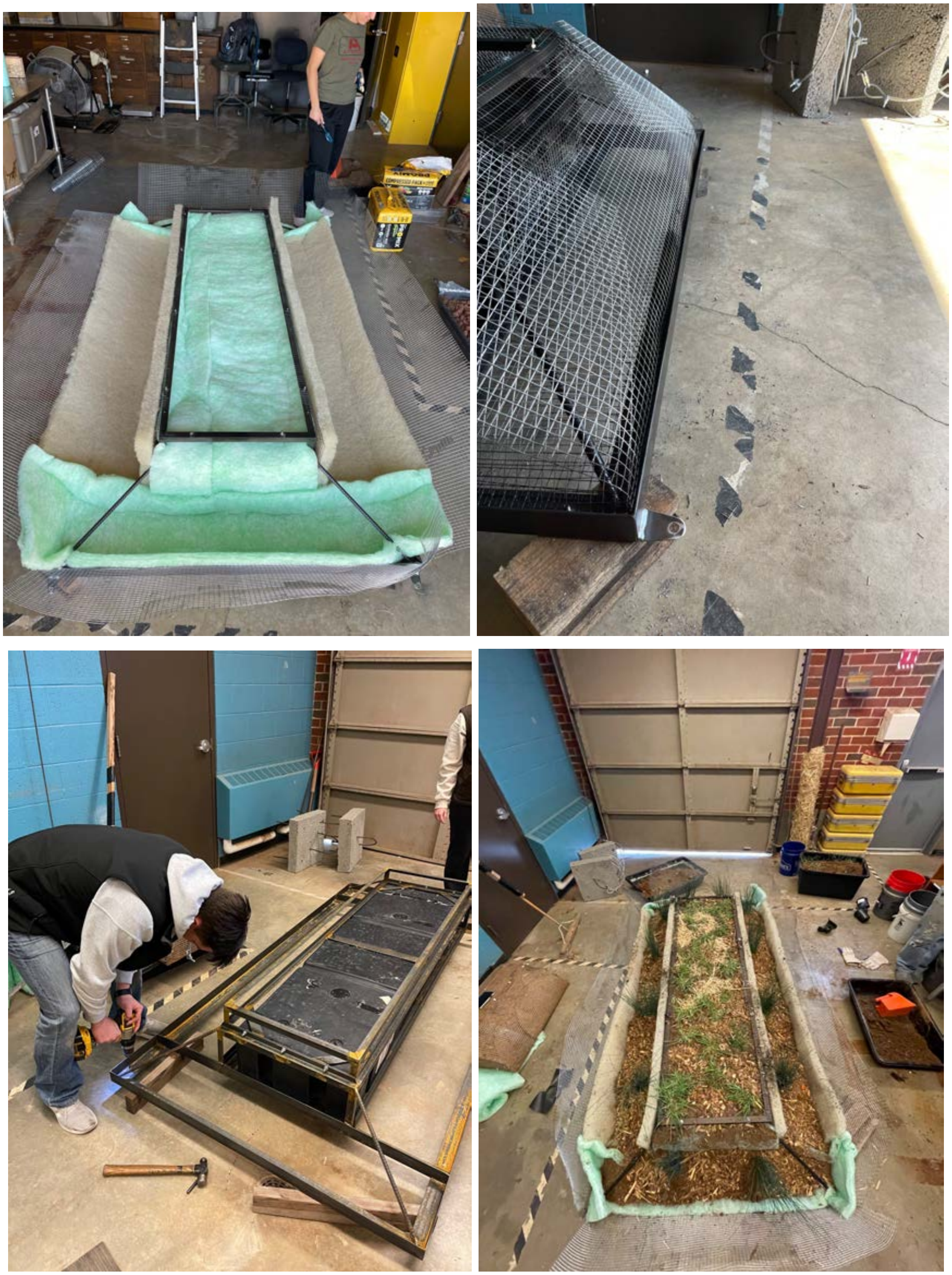


Figure 34. Final Construction

Figure 35. Completed Wetland

Challenges

The team did face a few challenges during the fabrication process. First of all, from the beginning of fabrication we were met with the realities of inflated materials and supply chain issues. Taking this into account there were many things that had to be adjusted between the design and construction phase due to cost and time constraints. The first construction challenge we faced was that when we received our metal frame back from the metal shop there was a sizing error when the inside steel frame was welded to hold in the dock float. This error had to be corrected by doubling the layer of the angle iron on the inside frame. This ultimately made the structure about 10 pounds heavier than the team originally designed for. The team also faced some trouble when pouring the concrete to create the anchors. This was their first time to mix concrete and not enough water was added to the quick-crete mix. However, the anchors are found to be sturdy enough and are still used in this project. Finally, the structure was designed for galvanized wire mesh to cover the structure to hold in the media because of this the actual fabrication of this took a lot longer than expected. Stretching the wire and bolting it into place takes several people and took much longer than the team anticipated. Lastly this project covered a wide variety of interest fields from energy absorption, water quality, materials and fabrication, to plants and everything in between. This kept the project interesting but also made it difficult to keep everything straight and to dig into one certain aspect. Overall, the team learned valuable skills working with metal structures and had to learn to adapt with changes in the overall design.

Figure 36. Wetland Dock Float and Frame

Weight Testing

After the prototype, the team was very wary of weight and buoyancy, therefore, they decided to weight test the structure before putting any plants or media into it. The team took the structure to the pond and tested it by placing tractor counter weights on it. Each counter weight was 32 kg. The team first placed one counter weight and recorded where the water was on the structure. Then the team repeated this with two and three counterweights. The team found that 3 counter weights or 96 kg is the maximum weight that the structure could hold. This was recorded and the team knew moving forward how much weight in media and plants that they could add to the structure. Below are the photos of the weight testing.

Figure 37. Frame Float Test 32 kg

Figure 38. Frame Float Test 64 kg

Figure 39. Frame Float Test 96 kg

Wetland Location

The location of the wetland was chosen based off of the original shoreline erosion issues back in 2019. The North shore of the Research Park Pond was eroded almost completely to the walking path. Therefore, this is the side of the pond that is more prone to erosion and this is where the team placed the floating wetland. The team also placed the wetland far enough away from the shore in order to avoid it being tampered with by the public which is approximately 40 feet from shore. It is important to note that if this were actually implemented along shorelines it would be much closer to the shore.

Figure 40. Anchor Cable Attachment

Figure 41. Wetland Placement on Pond (NE Corner)

Final Evaluation

The final evaluation was done on a warm day when the wind was blowing at 35 miles per hour out of the south causing the wave action to be focused on the north shoreline. The first action taken when the team got to the structure was to wade out and adjust the anchors so the wetland was facing the waves correctly. After the wetland was adjusted, the team observed and measured the effect of wave mitigation. The wetland was successfully able to stop wave action across the entire eight foot length of the structure. The waves were not reformed until 6 feet behind the structure.

Figure 42. Final Evaluation of Wetland

FMEA

The following FMEA chart displays the main failure modes that the team foresees occuring on the wetland. The failures that are highlighted explain the potential causes and effects that they could have on the wetland.

Table 5. Failure Modes Effects Analysis

Key Process	Potential Failure Mode	Potential Effects	SEV	Potential Causes	OCC	Current Controls	DET
Anchors	Could break or detach	Wetland floats away	5	Disintegration of concrete attachment error	2	Strong connection points	5
Frame	Could break apart	Release dock float or lose media beds	5	Metal could rust, could get hit by a boat,or bashed on shoreline/rock	2	Keep wetlands in a safe location	5
Dock Float	Could sink/lose buoyancy	Wetland will sink	5	Float could get punctured and the foam could deteriorate	1	Thick plastic covering and foam filled	5
Wire Mesh	Could come loose or break	Plant beds break apart	4	Metal could rust, structure could get hit	3	Bolts and washers are keeping it attached and the metal is galvanized	5
Plants/Media	The plants could die or the media could wash out	Exposed metal structure less wave mitigation	3	Too little media protection, a large storm, high-prolonged wind	5	Mesh media is holding the soil and plants	5
Recommended Actions : Replace all components when broken and monitor regularly to fix problems as they arise. Full structure will likely need to be replaced after 8-10 years of use.							

Gantt Chart

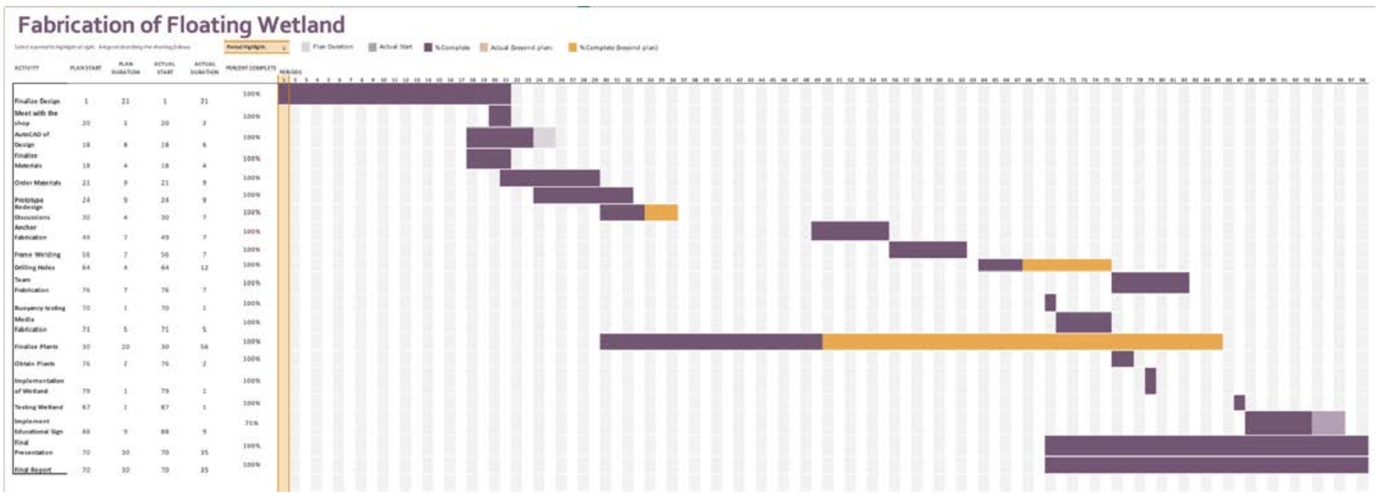


Figure 43. Gantt Chart

Above is the gantt chart that outlines the Spring semester schedule of the team. The team was able to complete the fabrication of the floating wetland on schedule. This allowed the team to conduct some wave break analysis and work on the deliverables to the client.

Budget

The final design consists of a single model with a metal frame and float. To hold the design, two anchors are used to hold the wetland in place. The construction of the anchors was not very expensive, only costing around 45 dollars per anchor. Both of the anchors cost a total of 90 dollars to build. The total cost of the frame came out to be 690 dollars.

The proposed budget presented in the fall was predicted to be just over 1000 dollars for the metal frame, dock float, and anchor. After all of the construction was finished, the final total for the finished product was 780 dollars. The team diligently worked to keep the cost of the floating wetland as low as possible. A few products like rebar and media from previous projects were obtained for free. This helped keep the cost down for the project.

In the future, if the design is replicated the cost will be elevated if all of the raw material is purchased from the start. The cost of labor is also not included in our budget because we are all students working for free. The NRCS or other industries that replicate the design will need to add in extra contingency for the cost of labor.

Table 6. Final Cost

Material	Supplier	qty	Unit	Price	Unit price
Structure					
Steel Angle Iron 2 in (qty. ft)	Stillwater steel	44	ft (2x2 inch, 1/8" thick	$1.60	$70.40
Steel Angle Iron 1 in (qty. ft)	Stillwater steel	42	ft (1x1 inch, 1/8" thick	$0.85	$35.70
Rebar	BAE Lab	8	ft	$-	$-
Galvanized .5 " wire	Lowes	2	10' x 2'	$20.00	$40.00
Galvanized Garden Fence	Lowes	1	50 ft x 3ft roll	$30.00	$30.00
Bolts	Lowes	50	1/4 in x 1 inch	$0.15	$7.50
Eye Bolts	Lowes	2	Large	$7.00	$14.00
Bolts for Float	BAE Lab	2	3/8 in x 2 or 2.5 in	$-	$-
Straw Blanket	Lowes	1	Roll	$25.00	$25.00
Peat Moss	Lowes	3	Bags	$6.00	$18.00
Better Than Rocks	Amazon	4	16 x 96 x 1.5 in	$42.99	$171.96
Wood Chips	Botanical Gardens			$-	$-
Dock Float	Walmart	1	in^3 (8x20x72)	$181.00	$181.00
Plants	Big Creek Nursery	8	Per Plant	$12.00	$96.00
Total					**$689.56**
Anchor					

Concrete	*Lowes*	*4*	*Bag (50 lb)*	*$6.00*	*$24.00*
Rebar	*BAE Lab*	*12*	*ft*	*$-*	*$-*
Eye Bolt	*Lowes*	*2*	*Per Bolt*	*$6.28*	*$12.56*
Cable Clips	*Lowes*	*8*	*Per Clip*	*$2.00*	*$16.00*
Steel Cable	*Lowes*	*20*	*ft*	*$1.00*	*$20.00*
Wood Frame	*Lowes*	*2*	*8 ft (6inch wide)*	*$9.00*	*$18.00*
Total					***$90.56***
Grand Total					***$780.12***

Future Plans

The goal of this project was to create a floating wetland structure that could be replicated for use to prevent erosion and mitigation of waves in lakes across Oklahoma. With this being the first iteration for this design and taking into consideration the priorities of the NRCS we chose to make a robust structure that could be easily replicated by NRCS field offices with materials that could all be locally sourced. For the 8 foot final structure it cost approximately $780 to fabricate. Its modular structure also enables the design to stretch across long distances and shorelines if needed. First of all, we would plan to perform several experiments on the floating wetland. The first would be the potential addition of attachments that would hang down and off of the bottom of the structure to drag and absorb wave energy from below the surface. Next would be finding the distance from the shore that the structure is most effective rather than the current placement that allows for protection from vandalism and other issues. The last experiment would be to compare our current media to more expensive options like BioHaven which could allow us to cut down on both weight and the security needed. If the floating wetland performs well over time and if the client is happy with the look, overall shape, and wave mitigation abilities we recommend that a future iteration could be performed that is materials focused. We believe that even though our project is an acceptable option as it is, there is the opportunity for a large price cut for mass production options. These options would potentially include our design adapted to be fabricated using a fiberglass mold or plastic press. Finally, future designs should allow for plants to develop a root foundation before being placed in the water where they are subject to significant washing out.

Conclusion

The wetlands successfully blocked waves across the 8 foot length of the structure. Waves were not fully reformed until they were around six feet past the wetland. The wetland is about ⅓ above water and ⅔ submerged which ensures that it will not flip or roll when waves get large. The placement of the anchor cable connection points also keeps the wetland securely fastened and in place. In future implementation of this project replicating the model to allow coverage of larger lengths of shoreline will be more successful than the single model. Implementing the structures closer to the bank will also yield better wave mitigation and erosion control.

The cost of the rip-rap averages $158/CY. The floating wetland has a coverage of 8 linear feet of shoreline. With the cubic yards needed per linear foot of shoreline being so variable there isn't a way to determine the exact conversion on how many cubic yards will be needed per foot of shoreline. For our specific project site we can estimate that at the technology park pond 8 feet of shoreline contains approximately 3 CY of RipRap which would be $475. If the bank was taller it would easily double in cost. With the final cost of our project being $780 that would mean when the cost of RipRap exceeds $260 per linear yard the wetland will be a cheaper option. With our project being comparable in price and having the potential to offer better aesthetics and water improving aspects it could make it an attractive option regardless.

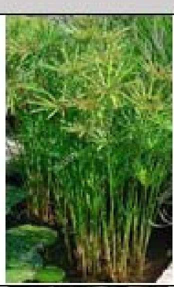
Lastly the team and our client the NRCS believe that this product being on such a high profile site lends it to being a great learning opportunity for people visiting the pond. Because of this we hope to be able to install an educational plaque near the shoreline that explains what the floating wetland is and its potential benefits.

Overall we hope this design is the first of many to come to find a more effective and multipurpose way to mitigate waves and help stop shoreline erosion. This project has been invaluable learning experience in a very wide variety of areas from wave energy, to water loving plants, to physical fabrication.

Appendix A: Construction Steps

1. Obtain angle iron steel
2. Cut the steel to the correct dimensions
3. Weld the steel frame together and drill the holes for the hardwire cloth connections
4. Place dock float in middle of steek frame
5. Attach hardware cloth to the steel frame
6. Cut media to size and place on hardware cloth
7. Fill media with mix of dirt and wood chips
8. Add plants to plant beds
9. Wrap hardware cloth around and on top of plant beds
10. Sprinkle seeds around the plant beds
11. Allow time for plants to grow and establish roots

Appendix B: Geese Deterring Plants

Image	Common Name	Scientific Name	Blooming Season	USDA Wetland Indicator Code	Price	Notes
	Egyptian Papyrus	papyrus alternifolius	July-September	OBL	$12.00 for 1 bag of seeds	-grows well in hot humid conditions -dislikes ice and snow -deters geese
	Swamp Fern	Blechnum serrulatum	June-July	OBL	$30.00 for 1 bag of seeds	-deters geese
	Starrush Whitetop	Rhynchospora colorata	June-August	FACU	$136 for 32 plugs	-deters geese

Appendix C: Literature Review and Analysis

Introduction

Wave action generated by wind can be a huge problem on any type of shoreline. Wave energy builds across the water body and is absorbed when it crashes into the bank often causing erosion. This wave action left unmanaged can eat away at shorelines causing a host of problems that can be very costly and even dangerous. An example of this could be seen at the Oklahoma State University Research Park Pond as shown below.

Figure 2: Erosion on pond prior to rip-rap placement. (C-Star, 2019)

In the past, remediation of shorelines across the state has consisted of using riprap and other costly methods to stop shoreline erosion. The purpose of this project would be to design a natural looking and cost-effective wave absorbing structure. A floating wetland with the ability to mitigate wave action at the shore would achieve this by being more visually stimulating and cost effective than current erosion prevention methods. There are floating wetlands on the market, but they are not specifically designed to absorb wave action and have proven not to be durable enough to withstand the intense wave action in larger water bodies over extended periods of time. The traditional plastic/PVC structure degraded too easily in the intense Oklahoma sun causing structural failure and water quality issues from microplastics. As outlined from our clients at the Natural Resource Conservation Service, this project must have a new, durable design that will have the ability to last for years through large wave action conditions. The design must also have a fool-proof anchoring system to ensure the large wetlands cannot float away. Prior designs had issues with wildlife such as geese, tampering with the wetlands and floating structure. Methods to deter geese and other nuisance would be very desirable. The purpose of this report is to gather information about the different areas and to analyze literature and current designs that could be considered and even implemented in our design.

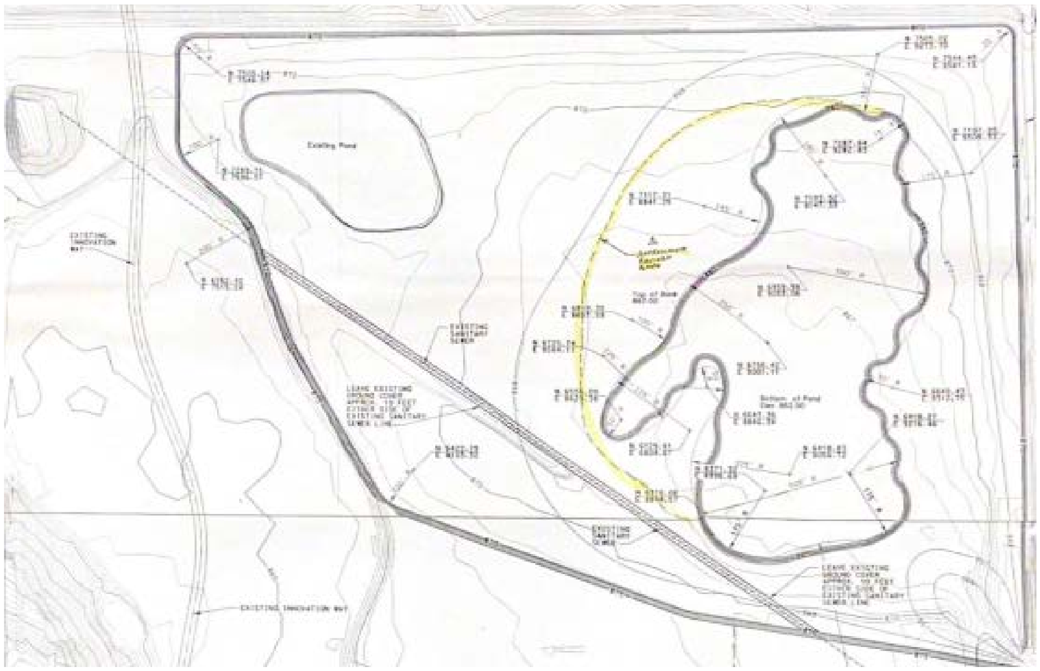


Figure 2: Map of the Oklahoma State University Research Pond where the wetland will be implemented. (C-Star, 2019)

Wave Mitigation

As mentioned, the main purpose of this floating wetland project is that it would protect shorelines by dissipating wave action. In order to build a structure that would fulfill this purpose we need to first be able to quantify and measure wave action. This will allow us to put specific quantities on what level of wave action the structure needs to be able to handle as well as understand what wave absorption is achievable for current structures that are available. Knowing both quantities will also allow for the analysis of the relationship between wave action and erosion. In an article published by the University of Hawaii at Manoa they explain that waves are generated by wind causing circulation in the water. Waves can carry a large amount of energy that can be measured in units of joules the same as other forms of energy. The energy developed is dependent on the water depth and the surface area. The energy is exerted in the form of work. (Manoa, 2021) That is an option that could be implemented in our project by estimating the amount of work that our different designs could withstand. The article defines the movement of the water as an orbital motion in deep water with the highest energy at the surface. As the wave reaches the shore and the depth starts to decrease the friction along the bottom absorbs the lower half of the wave and the top begins to break and crash into the shore. (Manoa, 2021)

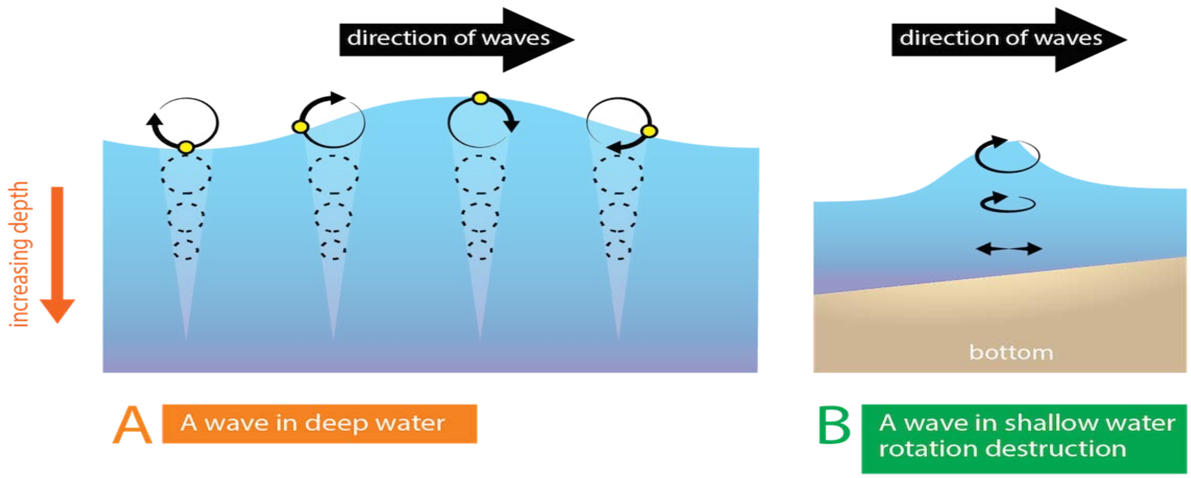


Figure 44. Diagram illustrating orbital wave motion and what happens as it comes into shore. (Manoa, 2021)

The application of this article is within the sphere of ocean waves which doesn't specifically apply to the types of waves that our structure will encounter so that could demonstrate some things that we won't see on the smaller scale of lakes but should still be similar. AquaVeo is a website that features "CGWave", a software developed by the Army Corp. of Engineers.

This software reports that it allows you to set basic parameters and then uses a wide variety of GIS and other data to give wave action specifications and a CAD model of wave action. The other aspect that makes this applicable to our project is that it states that it is an effective tool for shallow water waves which is the type of water energy that we will be studying. (AquaVeo, 2021) This could be important to the simplification of our studies in this area. It could be inefficient to the product schedule to spend a large amount of time quantifying wave action manually. Not only would using this tool offer ease of use but also since it is developed by the Army Corp. of Engineers, they often follow similar if not identical standards as our client, Natural Resource Conservation Service. As both are federal agencies, it would ensure a standardized and acceptable evaluation. After knowing how wave action works and how it can be measured, the next task is to study how the wave action can be dissipated. The Association for the Sciences of Limnology and Oceanography (ASLO) conducted a study on how well an artificial coral reef absorbs wave energy. The reef used artificial corals that were 10-15 inches tall with several branches. In this study waves with a .7 Hz frequency at the depths of .55 and .65 meters were analyzed. At these two depths the most artificial reef was able to absorb up to 69% of wave energy. It was interesting to see this high absorption from a subsurface system. This could have implications to our design in that we could build below the surface to add wave absorbance while still being aesthetically pleasing and a natural looking structure. (Ghiasian et al.,2020)

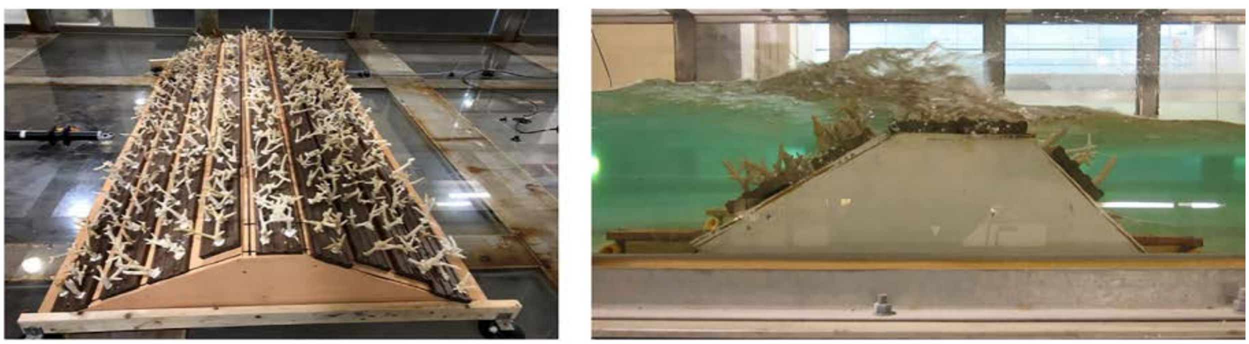


Figure 45. Artificial coral reef used in the wave study conducted by ASLO.

The downside of this structure is that ASLO states towards the end of the article that this structure is 19 times more expensive than the restoration of a live reef. (Ghiasian et al.,2020) This makes this project not super applicable to our purpose unless we can find a way to significantly reduce the costs. After reviewing these and other articles a patent study was conducted, centering around current patented designs that are used to achieve wave absorption that could be easily modified for our system.

Artificial reef to prevent shoreline erosion, patent number US4130994A. Issued in 1977 Expired in 1997.

This design essentially uses floating discs attached at different heights on cables spread throughout a grid system to absorb wave energy the same way a reef does. The foreseeable application is that these discs could potentially be attached either directly to the anchoring system or stationed around it as a simple addition to other wave mitigation measures.

Self-anchoring fiber block system, patent number US6893193B2. Issued in 2005-Active.

This design is a submerged barrier step structure that utilizes water plants growing roots through a fiber mesh, these roots act as an anchoring system to the bottom. The anchoring system, while an interesting approach, is not what was most interesting. The reason this patent was chosen is because of its use of a step edge to absorb energy. The stepped edge is an effective design for dissolving waves but is often overlooked because of the labor and cost to implement compared to a simple slope. Using a wire mesh fitted for a more robust structure in the form of steps with plants growing throughout, there would be the energy absorption of the stepped slope as well as the absorption from the wetland plants. This could be an interesting structure to investigate with a possibility of some of the stepped slope being submerged.

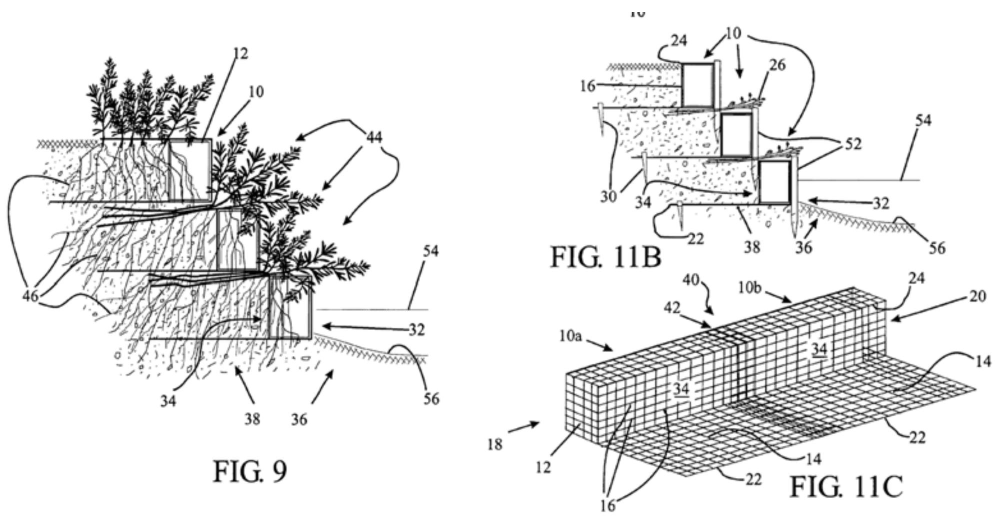


Figure 47. Diagrams of the structure of the self-anchoring fiber block system.(Santha, 2005)

Anchoring systems

There are four common anchoring type systems for floating docks, and they are as follows: piles system, stiff arm anchoring system, pole and sleeve system, and mooring lines/chain and anchor system. The pole and sleeve systems are generally used in areas that have little water level fluctuation and need greater stability. In our case, we do not need increased stability and we are planning for greater water fluctuation. The piles' system and still arm anchoring system both need connections to shore and have a lot of environmental considerations and will not be helpful in our case. Therefore, of these four systems, the most suitable system for our purpose of floating wetland would be the mooring/chain and anchor system.

Mooring lines or chain and anchor systems are the most common form for anchoring floating platforms and docks. This option is cheap as the costs are the chain/cable and the anchor. In shallow water up to 100 meters, it is common to use chains and steel wire ropes are usually saved for greater depths past 300 meters. To make this method work it is highly dependent on the angle between the waterbed and the hypotenuse connection to the dock. Therefore, when using chains, the system is reliant on the suspended weight of the chain and the resistance of the anchor. This can make large changes in the water level a difficult factor to work with. To work around this constraint with water levels, using an elastic mooring line is recommended. The elastic mooring lines can stretch like a rubber band to adapt to water levels. Additionally, they have been known to withstand sudden movements and storms like hurricanes. Finally, within the chain and anchor system, there is a chain and winch option which relies on manual adjusting to adapt to changing water levels. However, with our purpose, this option would require too much labor and maintenance. Therefore, within this anchoring option, the elastic mooring lines with an anchor are our recommendation.

There are a variety of anchoring systems that are used in this mooring line and anchor system. Most common would be blocks of concrete, manta ray, or a screw that would go into the waterbed depending on the composition of the waterbed which is depicted in the figure below. Picking a system greatly depends on what the waterbed is made up of. The concrete block with the eye bolt is the most common form and works well with little implementation cost.

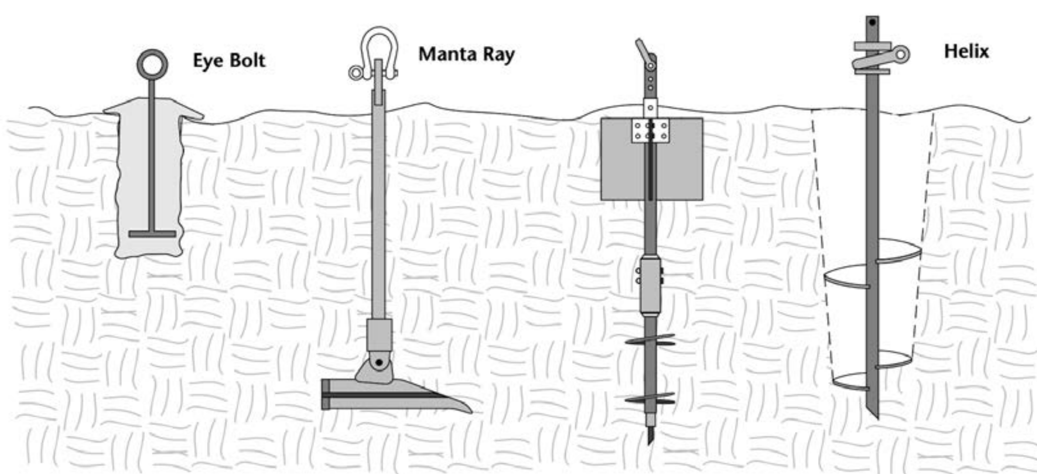


Figure 48. Three common anchoring systems. (Gjerde, 2021)

Strong ocean current resistant main and auxiliary double-buoy anchoring system, Patent Number CN202320724U

This patent provides a design to use when strong ocean currents or frequent storms are a concern for anchoring a buoy or floating platform. In this design there is the traditional anchor then a little farther down the mooring line is a sink block. The weight of this block depends on the platform size and the severity of currents. The patent claims that this is a simple, easy to apply, and effective measure to help with keeping buoys in place.

Floating berth system and method, Patent Number US 20050277344A1

This patent is a berth-type anchoring system. It is a buoy-type system that can be adjusted for many different depths. It has increased stabilization and can withstand impacts from docking large ships. Part of this includes these shock-absorbing panels on the sides of the structure. With the increase of stabilization to be able to withstand large impacts from ships, they also designed these systems to be able to withstand large waves and wind. This design could be helpful to create a very sturdy anchoring system for even the most extreme conditions.

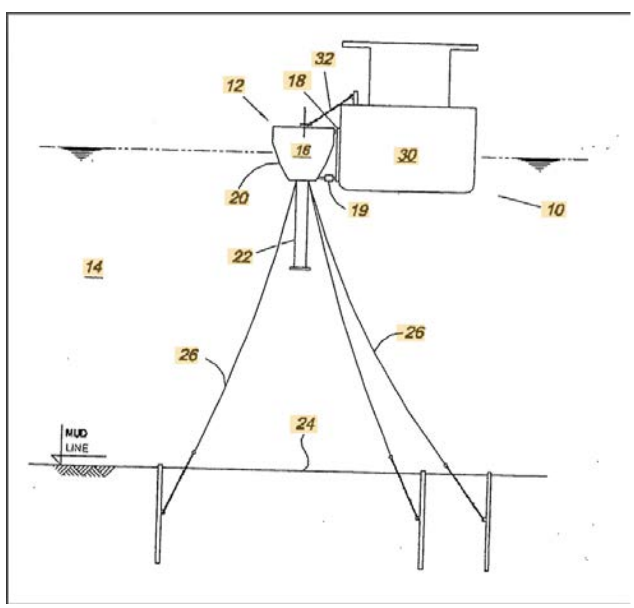


Figure 7: Schematic of the berth-type anchoring system. (Haun, 2005)

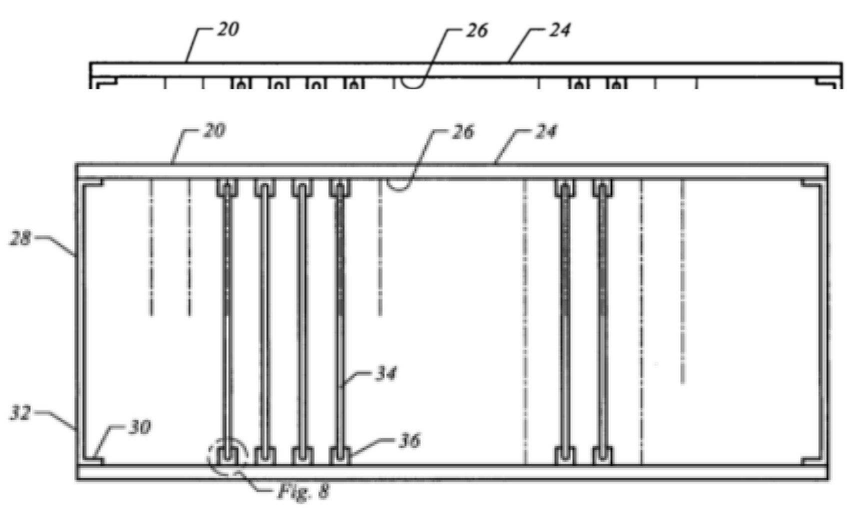
Mooring lines, Patent number US1509012A

This patent from 1924, is for adaptations for mooring lines, chains, ropes, and other parts thereof. Mooring lines are especially useful as their elastic ability makes them have less operation and maintenance as they adapt to changing water levels and can withstand storms. Many of these patents for floatation are used for dock structures that are made for places with fluctuating water levels. These patents use heavy materials to have solid structures.

Dock Structure 727S7273018B2

Modular floating dock frame and interconnection system, Patent number US7273018B2

This patent shows durable materials used to create a dock structure that could be utilized in tidal-like waterways to improve structural integrity (Strong 2005). Floating dock structures have been around for decades providing support for holding boat vessels and people to walk on. Floating docks are made to hold their structure through elements and heavy wave action. This structure uses four marine floats to keep the top deck afloat. This is shown in figure 9. A steel frame and connectors provides a sturdy structure while utilizing a cheaper metal. The dock uses reinforcing rods and clips to hold the docks frame in place. Looking at figure 8 below, the reinforcing rods go perpendicular to the side rails causing a solid bond for wave absorption and impacts. Considering that the wetland will undergo stresses and deflection from winds and wave action, it is crucial to build a structural wetland that could take on these stresses for long cycles of time (Burlac and Domnisoru 2018). Looking into this patent for senior design will allow possible solutions to make floating wetlands structures more durable to absorb high waves frequencies from the lake. The frame system needs to be simple to assemble and take apart



when repairs are needed. Looking at the bottom figure below, the spacing between floats looks to have parallel spacing.

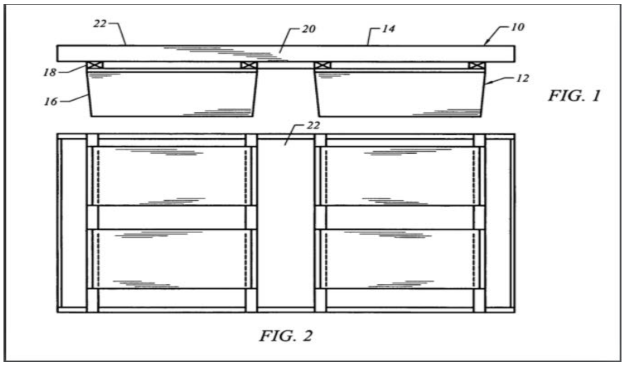


Figure 49. Reinforcing rod connection of the floating structure. (Strong, 2007)

Figure 9: Bottom view of the floating structure. (Strong, 2007)

Dock structure, Patent number US4078515A

The patent chosen here outlines a quicker and easier way to assemble a dock and compared to the other Patent US7273018B2, this structure shows a different way of constructing the floating structure with the solid dock structure. This patent was approved in 1978 and has been cited by many. It's designed to use aluminum for the deck and side rails for durability and lightweight construction. Looking at figure 10 below, the structure uses spacing between the deck and the float, allowing a better connection. The design could be useful for allowing soils and other materials to be filled in the spacing between the deck frame and the float. The use of side channels and webs could be used to easily assemble the structure without requiring welding. In this patent, aluminum is used as the side and end rails, as well as the slats to make the dock structure. The benefit of using aluminum is that it is lightweight, creating easier movement during assembly and preventing the float from being weighed down too much.

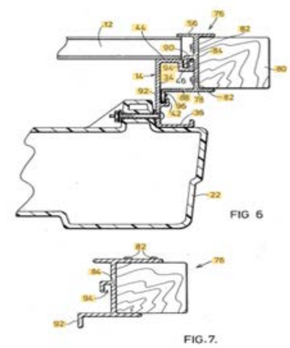


Figure 50. Shows the connection of a dock to a floating structure. (Svirklys, 1978)

Current Floating Wetland Designs

Most existing floating wetlands are designed for nutrient removal in wastewater/ stormwater detention ponds and not for mitigating shoreline erosion. These wetlands are not strong enough to endure the wave action on a large lake but the design of the media that houses the plants could be useful. Existing designs on lakes in Oklahoma have been made to reduce erosion but the PVC design quickly deteriorated in the harsh elements and wave action. The design consisted of air-tight PVC frames to float the wetlands and then to hold the plants, plastic erosion control netting and coconut fiber was used. (Floating Wetlands Project Underway, 2021) Though this design was not durable, it was successful in reducing the number of waves that reached the shore. This project should be taken into consideration when the team makes decisions for the new design. Through research, it appears that most of the existing wetlands are not very large. In order to mitigate erosion, our wetland needs to cover potentially hundreds of feet of shoreline. Pursuing a modular structural design, where multiple pieces can connect to form a large barrier could be beneficial when adjusting the amount of shoreline that needs to be covered on a lake. Another advantage to using a modular design is that it would allow for easier repairs to be made. If one of the pieces is broken it can just be changed out without removing the entire structure.

Figure 51. 11(Floating Wetlands Project Underway, 2021)

There are a few patents that outline designs for floating wetlands but none of them seem to use heavy materials that can withstand being on a large body of water. Most of the existing patents regarding floating wetlands are focused on water quality and not on mitigating erosion. The patents show different methods of suspending floating material and media to hold plants. A more detailed description of existing patents will be discussed further in the following sections. Though none of the patents are specifically geared towards shoreline erosion control, combining aspects of them could be beneficial in creating a design that fits the scope of work for the senior design project.

Floating Treatment Bed for Plants, Patent number US9988291B2, Issued in 2012

This design displayed in the following figure is unique in that a rigid buoyant sheet is used to hold plants in the water. It uses a mixer of airtight chambers, foam, and a plastic grid to hold the floating treatment bed up along with the topsoil and organic material layer. (Curry M.F., 2018) In this design, there are individual voids that the plants sit in. These voids allow the plant to reach the water and it securely stabilizes them to reduce failure. The following figure displays the gridded bed floating treatment system.

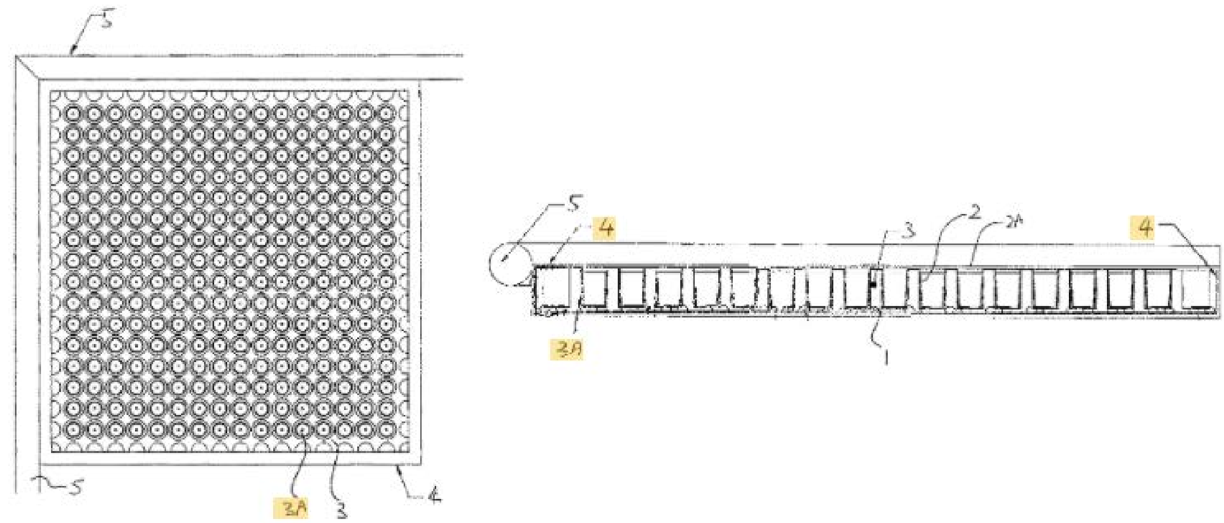


Figure 52. Floating Treatment System. (Curry M.F., 2018)

Floating Wetland Structures for use in Water Remediation, Patent number US7314562B2, Issued in 2004 now expired.

The next patent outlines a floating wetland structure that embodies many of the attributes needed for this project. The wetlands are connected to large floats (looks like dock floats) to stabilize the structure. The wetland media is held up by a foam layer that varies in density to allow water to infiltrate it so that it reaches the organic layer underneath. The organic layer that the plants set in is made up of topsoil, peat moss, sand, gravel, or any other material that is needed to sustain healthy plant growth. The invention shown in the following figure is large enough to hold a person. (Svirklys, F., Shanklin, D., 2008) The scope of work for the senior design project does not include people standing on the wetland so scaling down this model could be useful.

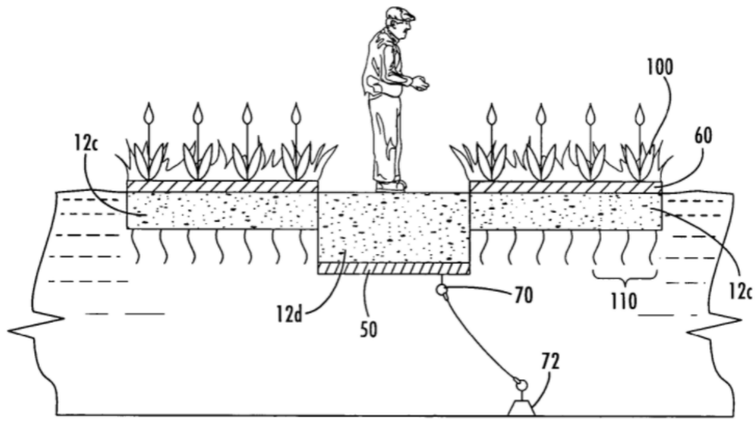


Figure 53. Floating wetland structure. (Svirklys, F., Shanklin, D., 2008)

Super-enhanced Aquatic Floating Island Plant Habitat, Patent number US20050183331A1, Issued in 2003 and is now abandoned.

This next patent describes a floating island that was designed to be used in ponds or lakes to help improve water quality and enhance the surrounding ecosystem. A mesh and matting system are used to hold the plants while a float system suspends the island in the waterbody. In this patent, there are multiple variations and designs that were outlined. The most relevant being the ones that were large structures floating on the surface of the water. These designs did not look to be very structurally sound, but they did provide good references for the floating mesh and how to suspend the wetland plants.

One of the designs consisted of an organic mesh (top layer) that the plants were put in, the mesh was suspended/floated by a thermoplastic elastomer (TPE) layer that sat directly under the organic layer. (Haun R., 2005) There then was a net that ran under the whole floating island that was anchored to the bottom of the water body to hold the island in place. This design did not include a rigid body, it was essentially a floating mat that the plants grew out of. The following figure shows the Floating Island with the TPE layer.

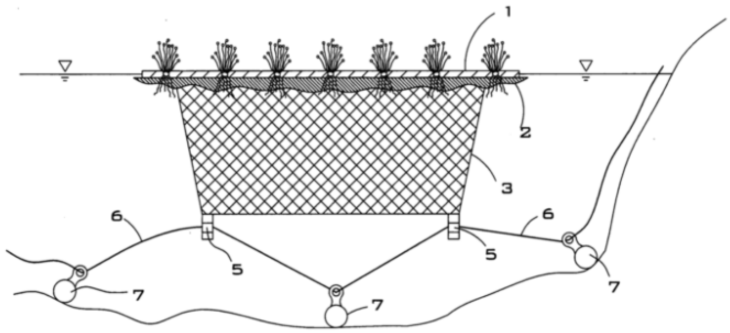


Figure 54. Floating Island with TPE layer. (Haun R., 2005)

System for growing plants on open waters, Patent number JP2006527984A, Issued in 2003 status is pending.

This next patent consists of using four cylindrical tanks to hold and suspend the floating growing system over a body of water. A rigid mesh is used to hold the plants between the two sets of floats. Three different conditions are covered in this design, all of which consist of the cylindrical floats being layered one on top of the other with a ballasted tank and air compressor that fills and drains the tanks to make the growing system media sit lower or higher in the water. Inputting air into the system causes the growing system to float while taking air out causes the structure to sink. The first design utilizes two hollow floats that are connected with valves to allow air to pass between them. An air compressor is used to regulate the depth of the mesh. The air pushes into the top tank or gets taken out of the top tank causing the bleeder valve on the bottom tank to intake or output water. The second and third designs consist of one hollow tank and one foam-filled tank. Both designs still consist of an air compressor and bleed valve that is connected to just the hollow cylinder to regulate depth. The difference between these two designs is in the placement of the foam-filled cylinders (either above or below the hollow cylinder). The three designs can be seen in the following figure. (ベッカー, 2006)

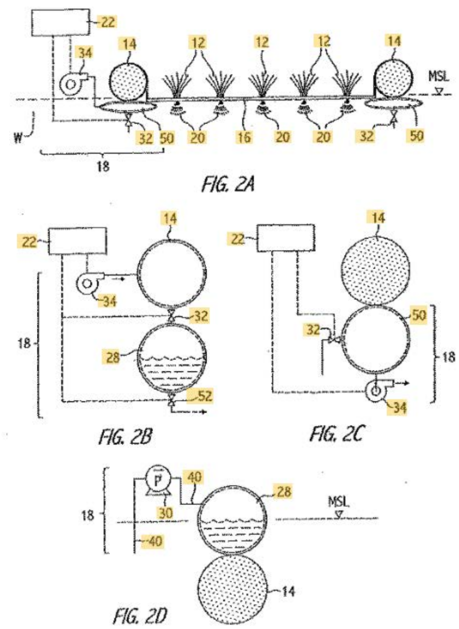


Figure 55. Open water growing system designs. (ベッカー, 2006)

This invention would be a good way to regulate depth for optimal plant growth on the wetland but for the senior design project it would be challenging to run the needed electrical equipment out to the project site to make this design work. The mesh used in this system was not heavily discussed but said that many types of materials could be utilized and woven together (metal wire, chain, cotton/organic rope).

Hybrid Artificial Wetland, Patent number KR20160104841A, Issued in 2015

This patent outlined a unique way to filter and clean water in a suspended manner. The pants are housed on a layered suspended media that sits submerged in the water body. The water has to run through the media (filtering the water) to get to the plants. The plants used in the design are carefully chosen to make sure that they will intake the correct nutrients to clean the body of water. (김이형, 최지연, 홍정선, 나유미, 2016)

Goose Deterrent

Geese can cause issues with floating wetlands by eating vegetation and overwhelming the structure. Without deterrent methods the geese could eat the plants on the structure and leave an abundance of feces on the structure making it less appealing to the eye. This source shows multiple ways of deterring geese from the structure with each method having its own unique benefits and downfalls. The two best deterrent techniques shown were the liquid goose repellent and the fencing. The liquid repellent is put on vegetation to irritate geese, keeping them from eating and associating with the plants. Many of these liquids have the key ingredient of grape seed extract which irritates the geese when they eat the plants (The easy way to keep geese out of your ponds and fields, 2021). The second method and probably the most reasonable is the use of wires or fencing around the floating wetlands. The fencing around the floating wetland should discourage geese from getting on the wetland. This method of deterrent is inexpensive and easy to set up around the wetland. The cheapest option to go with in the long run is fencing, it prevents geese from getting on the structure.

There are many methods in place to try and deter geese from messing with the floating wetlands, but since we are in an urban area, there are a few choices to choose from. Geese find floating wetlands as a haven for nesting and protection from land predators because it acts as an island. Putting a fence around the wetland seems to be the best option from both sources, however; using decoys or sounds at the right moment could startle the geese enough to push them away from the wetland. Another technique that can be used to deter urban geese is using something simple as a high-frequency sound to turn on when geese approach the floating wetland. A problem that might occur is how much the geese are accustomed to the area. Many simple techniques like quickly intensified sounds may not scare the local geese as much compared to migrant geese (Smith, Craven, and Curtis 1999). This narrows it down back to the original two options: using a liquid/ chemical treatment or using a fence. Looking at the floating wetland, the fence seems to be the best choice for the task at hand. Using materials like chicken wire, woven wire, steel wire, or possible netting should prevent geese from getting onto the structure or eating plants (Smith, Craven, and Curtis 1999). Also, when planting the floating wetland, using plants that geese tend to avoid eating and using the fence technique will reduce their desire to approach the wetland.

Applicable Standards

USDA-NRCS Technical Release 56-A Guide for Design and Layout of Vegetated Wave Protection for Earthen Embankments and Shorelines

This guidance is released from our client the USDA Natural Resource Conservation Service (NRCS). This guidance provides information about the advantages and limitations as well as effective plants for vegetated wave protection for embankments and shorelines. The other benefit of this release is a simplified way for calculating max wave height on bodies of water by considering fetch and max wind speed. This will help us give a standardized estimation of the waves our structure could experience on the OSU Research Pond. (NRCS Release 56,2014)

USDA-NRCS Conservation Practice Standard Streambank and Shoreline Protection-CODE 580

This standard is another document released from our client the NRCS that sets a general guidance for practices that protect streambank and shorelines. It is broad as it covers the overall practice but still serves as an outline to make sure all the bases are covered. This is potentially the document that our project or a future floating wetland would fall into. (NRCS Code 580,2020)

Conclusion

With the completion of this review, our team is much more familiar with many of the aspects that will go into creating floating wetlands that protects against shoreline erosion. The growth in understanding of wave quantification and mitigation, anchoring and float systems, as well as floating wetlands on the market today have answered our questions in some areas but multiplied them in others. This base of knowledge will allow for a good start in the design process of beginning to form some preliminary designs. Our future plans include a further investigation into potential materials that would fit all of our criteria and begin to format initial designs.

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