EDNS 151 Final Report

Ocean Busters

Analissia Wise
Abi Strait
Martin Vincé
Robert Davis
Keegan Dwyer

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Professor Mark Florida

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1.0 Problem Validation, User Empathy, Stakeholder Engagement

1.1 Introduction

1.1.1 Background

Sources and Types of Ocean Trash

As the issue of ocean trash, or more broadly, marine debris, becomes more prevalent in modern times, we find ourselves inquiring as to the sources of marine debris—who is responsible, who is putting it there, and why? For the purposes of our explanation, we can categorize marine debris into two primary sources: *land-based sources* and *ocean-based sources*.

[1] According to the National Oceanic and Atmospheric Administration (NOAA), Most marine debris comes from human activity on land. This might come in the form of littering and dumping, both accidental and purposeful. [1] This trash is then carried into bodies of water via stormwater (stormwater runoff) or debris being swept up by winds, which then flow into streams and rivers and eventually into larger bodies of water, the NOAA says. [1] According to the NOAA, while a large portion of marine debris is due to illegal, purposeful dumping, the overwhelming majority of marine debris either comes from poorer communities that typically have no other means of waste management than to dump trash into the ocean or is accidental littering. [2] According to the Ocean Conservancy, a Washington, D.C.-based environmental organization that released its 2022 list of trash collected during its International Coastal Cleanup, the top 10 greatest sources of land-based marine debris were:

1. Food Wrappers (candy, chips, etc.)
2. Cigarette Butts
3. Beverage Bottles (Plastic)
4. Other Trash (Clean Swell)
5. Bottle Caps (Plastic)
6. Grocery Bags (Plastic)
7. Beverage Bottles (Glass)
8. Beverage Cans
9. Straws, Stirrers
10. Cups, Plates (Plastic)

As we can see from the above list, the greatest source of marine debris is without a doubt plastics, and many other sources would agree. [5] According to the IUCN, "at least 14 million tons of plastic end up in the ocean every year, and plastic makes up 80% of all marine debris..." [5] Among the plastic debris found in the ocean, most of it is land-based, coming from urban and stormwater runoff, sewer overflows, littering, inadequate waste disposal and management, industrial activities, construction, and illegal dumping, the IUCN states.

> "[3] 80% of the world's ocean plastics enter the ocean via rivers and coastlines. The other 20% come from marine sources such as fishing nets, ropes, and fleets. To tackle plastic pollution, we need to know where these plastics are coming from. Previous studies suggested that a very small number of rivers were responsible for the vast majority of ocean plastics: 60% to 90% of plastics came from only ten rivers." *Our World In Data*

We can also categorize the types of plastics in the ocean into two categories: microplastics and macroplastics. [6] According to The Ocean Cleanup, macroplastics are defined as plastics greater than 5 mm in size, whereas microplastics are plastics less than 5 mm in size.

We see then that land-based activities cause the greatest amount of marine debris, but in order to understand the entire story of how marine debris comes about, we must also understand marine sources. [4] According to the NOAA, marine sources of marine debris come from fishing gear, including lines, nets, and waste associated with fishing and other marine activities, as well as other items lost from vessels at sea, or in some cases, the vessels themselves. [4] Furthermore, when disasters strike, the resulting debris is called *disaster debris*. Marine sources of disaster debris come from vessels or pieces of larger structures.

Environmental Impact

[5] The most apparent and obvious effect of marine debris on marine life is the digestion of this debris, which marine life mistakes for food; this leads to suffocation due to the plastics either damaging their internal organs directly (lacerations, infections, the inability to swim, internal injuries) or causing starvation since the debris can't be digested easily, occupying necessary space in their stomachs and leaving no room for nutritious foods. [7] According to the Smithsonian Environmental Research Center, macroplastics are especially buoyant and slow to degrade, and foreign, invasive species attached to these microplastics may attach themselves to this plastic debris. These invasive species may reduce biodiversity by interacting with species that have not evolved to deal with them, therefore posing threats to native species' food sources. [7] An extreme example of this is in 2011, when, following Japan's tsunami, approximately 5 million tons of disaster debris accumulated in the Pacific near their coasts. [7] Researchers over the next several years found over 289 different foreign species on or near the debris, 30 of which were invasive species.

[8] In addition to the threat posed to marine life by marine debris, marine ecosystems, particularly coral reefs, The EPA has identified four threats marine debris poses to coral reefs, including sedimentation—marine debris can exacerbate the rate at which coral reefs erode due to harmful chemicals; nutrients—while nutrients are great for coral reefs, marine debris can introduce too much, causing algae, which in excess can block sunlight and consume vital oxygen; pathogens—marine debris can introduce harmful pathogens, as we've previously discussed; toxic substances—marine debris can introduce harmful chemicals; and lastly, macroplastics—large plastics can entangle reefs, damaging or destroying them as well as the marine life in which inhabits them, which we've previously discussed.

Oftentimes overlooked is the threat marine debris poses to human health. [5] Microplastics have been found in water supplies as well as many sources of food. [7] Several of these microplastics have been identified as being carcinogenic in large quantities as well as having the ability to interfere with the body's endocrine system, causing developmental, reproductive, neurological, and immune disorders in both humans and wildlife if ingested in large quantities. [7] In addition, these plastics can contribute to climate change; when plastic is broken down, it can release carbon dioxide and methane into the atmosphere, accelerating climate change by increasing our fossil fuel emissions.

Economic Implications

In addition, due to marine life being killed or damaged due to marine debris, fishermen and those who rely on marine life face economic challenges. [9] Lost equipment such as lines, nets, etc. can cost fishermen a substantial amount of money to replace; in addition, this lost equipment can cause marine life to become caught accidentally, an issue called *ghost fishing,* which in turn costs fishermen due to the lack of fish coming about as a result. [9] According to the NOAA marine debris program, in just one example, it's estimated that approximately 3.3 million blue crabs are killed yearly due to ghost fishing, causing an estimated revenue loss of $33.3 million per year at the time of the study. [9] These losses in fishing make their way up the supply chain to businesses, which have to pay more for fish since scarcity makes fishing more costly.

An obvious yet oftentimes overlooked effect of marine debris on our economy is the effect on tourism that marine debris poses. [11] The ocean and tourism are the single largest employers in the ocean economy, with the industry accounting for over $144 billion in gross domestic product annually. [9] Due to ocean debris, the industry has lost millions. [9] A study by the NOAA that aimed to estimate the potential gains and losses due to marine debris and cleaning up marine debris, respectively, found that the loss in revenue due to tourist losses due to marine debris can reach up to $277 million in tourist value and up to $137 million in recreational spending in coastal Ohio and Orange County, California, alone.

Clean-Up Efforts

Several initiatives around the world are dedicated to clearing marine debris, the largest of which is the International Coastal Cleanup (ICC). [12] With over 14 million volunteers and counting, the ICC has collected over 330 million pounds of trash. [13] The most popular and technologically innovative group is The Ocean Cleanup. [13] Having developed the interceptor, an autonomous bot that automatically collects debris found in rivers, and deployed machine learning and other technologies that help detect and collect marine debris, they have quickly risen in popularity. Despite these efforts, the problem of marine debris has persisted and is not slowing down, but increasing annually. This tells us that we have a long way to go before we can even halt the increase in marine debris seen annually; it will take a global effort. A glimmer of hope: In recent years, ocean cleanup initiatives have gained support from millions of people in pop culture. Team Seas is one example. These efforts demonstrate a clear concern for our marine ecosystem and a strong drive and initiative to solve the problems that plague our oceans.

1.1.2 Team Problem Definition

Waste that ends up in bodies of water are harmful to living organisms, the environment, and the world's economy. In this report, the following problem statement will be employed to find a solution to this waste: "*How can we optimize the removal of aquatic debris through the innovative utilization of upcycled materials?*"

1.1.3 Context of The Problem

Introduction: Aquatic Debris

Currently, there are 5.25 trillion pieces of trash in the ocean, and 269,000 tons of that is visible from above water [10]. While, on the surface, this appears to be a lot, this number accounts for only the human-made aquatic debris in the ocean. This statistic doesn't include the trash, non-human made debris and other insoluble objects that follow the current into other bodies of water, such as rivers, streams, lakes, etc. These non-degradable items create issues for ecosystems, human health, and the economy.

Marine Life: How Will it Survive?

Aquatic debris includes a range of insoluble articles, such as trash, seaweed, oil spills, microplastics [18], fishing gear, etc. These items pose a danger for marine life and the ecosystems they live in. When people are taught about aquatic debris, the majority are shown pictures of videos of animals caught in fishing nets, or with plastic around them. The thinned animals are clearly affected by the debris, as they have been robbed of their ability to move, swim, fly, or hunt properly. These photos play to people's emotions and care for animals, incentivizing them to either maintain a responsibility to prevent debris from ending up in the ocean, or to aid in cleaning up the aquatic debris. These pictures capture the idea that debris is harmful to living organisms, however, the more severe consequences lie beneath the surface. Marine life consumes and digests this debris, thinking it's food, which causes the marine life to either fall extremely ill or die. This effect has two sub-consequences: 1) The food chain is altered, since food is thinned out in one section, the predators of those living organisms also diminish due to less food. 2) Humans who eat this diseased seafood are subject to either falling ill as well, or permanent damage from the debris now in their system.

Figure 1: A satirical cartoon depicting the effects that littering has on marine life

Maintaining Human Wellbeing

While the other issues are more focused on when discussing aquatic debris, human wellbeing is often overlooked because it is a secondhand consequence. This can be represented by a common issue of smoking. Those who live with smokers, but do not themselves smoke, breathe in secondhand smoke and reap similar consequences as the smoker. When humans don't take responsibility for collectively cleaning up after themselves, we push this new requirement to fix the original problem while it imposes consequences on the whole. Littering, poor waste-management practices, and other uncontrollable events, such as storms that carry trash to bodies of water, create garbage patches, or large areas of aquatic debris. This lack of cleanliness brings respiratory diseases, cardiovascular damage, gastrointestinal diseases [16], perinatal damage, neurological disorders [17], cancer, and even infant mortality.

Economic Decline

There are many cases where aquatic debris affects subsequent parts of tourism that the majority of countries, especially third world countries and islands, depend on. One prominent example is the excess sargasso (seaweed) that has washed up on nineteen islands in the Caribbean. Currents in the central Atlantic [15] have swept enormous amounts of seaweed onto the beaches of numerous Caribbean islands. This algae has cluttered and ruined the beauty of beaches, which has caused the tourism of these islands to decline, and with no natural resources of capitalism to depend on, subsequently their economy to also decline. So much of these countries' economy depends on tourism that the majority of those in power, including the governments, and even local hotels are paying locals to clean up the sargasso. While this one example with sargasso captures the idea that non-degrables negatively affect economies, trash, oil spills, and other insoluble substances affect worldwide economies similarly.

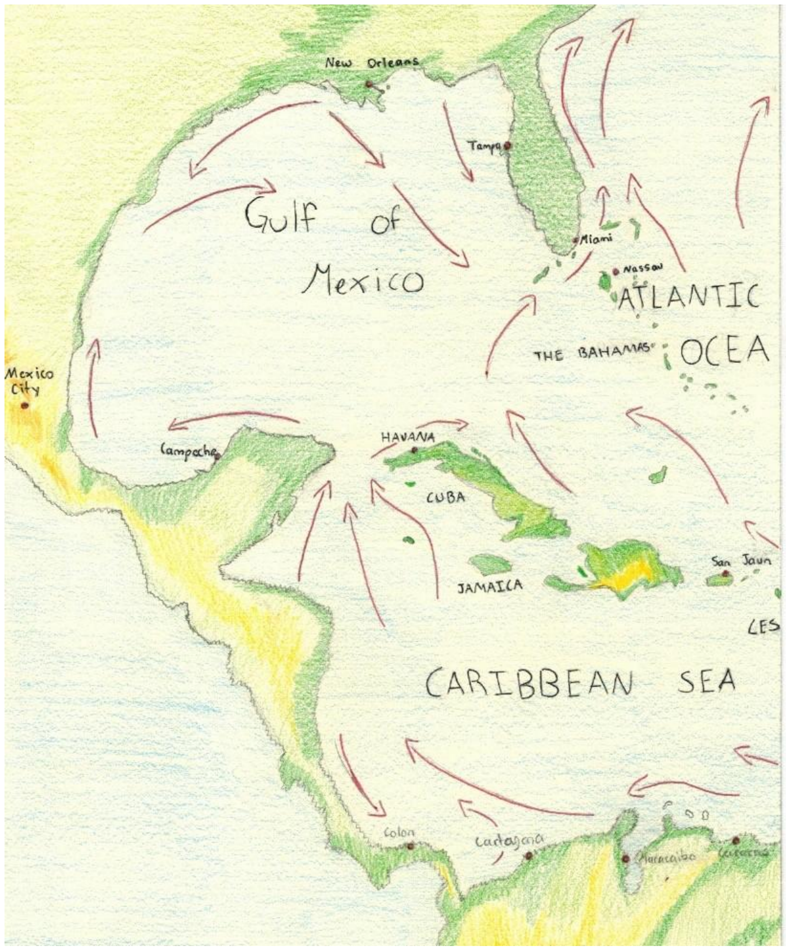


Figure 2: A map of where the ocean currents carry sargasso along the coasts of Caribbean islands

Geographic Boundaries: Where/ Who Does This Problem Affect?

It is obvious to the average person that aquatic debris affects those who live near bodies of water, such as coastal countries, However, there is more to it than what just appears on the surface. Activities such as illegal dumping, pedestrian litter, uncovered truck beds entering/ exiting freeways [16], outdoor events, etc. and even natural causes such as wind and natural disasters, cause non-degradable items to wind up in bodies of water in landlocked places. For example, microplastics, microfibers, microfilms, and micro-fragments have been found in the Colorado Rivers [23]. The river system originates high in the Rocky Mountains, and feeds into 48 other states (excluding Alaska), providing water to millions of acres of farmland and to millions of people. Therefore, the point holds that these non-degradable materials end up in all water systems, and since water is a need for all living organisms, every single person on Earth is affected by this issue. Aquatic debris is such a prominent problem because there are no geographic boundaries. Aquatic debris influences the quality of life for everyone.

Key Stakeholders

Since aquatic debris affects everyone, there have been tremendous efforts to clean up these micro fragments. This allows for a wide range of key stakeholders for this problem statement. From organizations who are funded to build technology to clean the ocean, to private companies that upcycle aquatic debris and sell the product in efforts to keep water clean, most companies have some reach in this area. Other key stakeholders could include: water treatment plants, water quality investigators, clean water movement clubs on the Colorado School of Mines campus, etc. While there are plenty of stakeholders to reach out to, a difficult part of gathering stakeholders for this problem statement is that most of these companies and organizations are coastal. So, the interviews conducted with them must be online, which limits the ability to experience first hand their impact on aquatic debris and water quality.

1.1.4 Existing Solutions

Introduction

The growing presence of ocean trash and non-degradable debris is a concerning consequence of our materialistic society. As we consume more disposable goods and single-use plastics, these materials wind up in our aquatic environments, such as rivers, seas, lakes, and reservoirs, where they have no business being. This pollution poses serious threats to marine life and ecosystems.

Fortunately, a number of organizations and entities have realized these awful impacts of human actions and have proactively taken measures to solve these environmental concerns. Their efforts cover a wide range of techniques designed to address various problems of water pollution. These initiatives include cleanup operations, recycling programs, waste reduction campaigns, and innovative technologies designed to remove and mitigate the impact of plastic and debris in our precious aquatic ecosystems.

Existing Solutions

One of these organizations is addressing the problems of water pollution through promotion and avocation. [25] The *Plastic Odyssey* is a remote field station for scientists, engineers, and researchers. One of its goals is to record effective ways to deal with pollution in addition to doing an on-site technical inventory.[25] A crew of 20 to 30 people, including a media team and technical and scientific experts, operate this 39-meter vessel. The Mobile laboratory acts as a combination of field research and interpersonal advocacy. Multiple compartmentalized subsections include recycling workshops, recycled products display areas, zero plastic cabins, quarters, kitchens and a mechanical analyzing workshop. The boat physically visits extremely contaminated areas in search of remedies to reduce further pollution. Completing stops in 30 of the most polluted regions along the equator. While in each location, 15 different technologies may be tested aboard the ship, which has more than 200m^2 of technical space and a loading capability of about 20 tons of material.[25] It also has a variety of machine tools that may be used to create new parts and improve prototypes. While the vessel primarily operates as a mobile field research laboratory and implementation, *Plastic Odyssey* is also a giant floating billboard. This advocacy serves as a catalyst and invites the press, politicians, local businesspeople, and industrialists to come aboard. With objectives to interconnect these many stakeholders and promote the execution of several local initiatives.[25] All of which surrounds water pollution and contamination of aquatic areas. Plastic Ocean is one underlying project aimed at spreading awareness and solutions to aquatic polluted environments.

On open water, another organization is fighting ocean pollution. In order to remove more substantial pollution from the water, Sea Cleaners is creating and building a logistical open sea vehicle. The *Manta*, a solar- and wind-powered catamaran, is expected to enter the water in 2025 and will include an easy-to-use collection system to look for ocean rubbish.[26] Utilizing conveyor belts from three floating devices extending 33-meters capturing surface garbage. The debris is then contained in two little "mobula" boats, which collect both microplastics and macroplastics. The *Manta* is anticipated to remove 1-3 tons of trash each hour and clear up 10,000 tonnes of garbage annually. The large 5-deck vessel's comparable behavior to that of the *Plastic Odyssey* is another advantage of the suggested method. promoting and putting into practice tactics that can help local communities become involved in sanitizing our waters.[26] The *Manta* poses as an ambassador ship, demonstrating workable and easily replicable techniques for gathering and recycling plastic garbage. The Sea Cleaners group, in contrast to the *Plastic Odyssey*, is putting into place methods to remove marine contaminants right from the sea.

Ocean CleanUp is a similar organization committed to cleaning up oceans and rivers. This group carries out this task in two different ways. Using nets on the open sea and stationary garbage collectors embedded in rivers. While in the ocean, Ocean Cleanup employs a highly efficient method that involves deploying a single large mesh net towed behind two boats. This strategy is carefully planned to efficiently gather floating trash while causing the least amount of harm to tiny aquatic species. This mesh net is made with precisely designed cutouts or gaps that allow tiny aquatic animals like fish and plankton to swim through the netting and escape.[27] This crucial feature ensures that the ecosystem's delicate balance is not disrupted, as smaller marine life continues to thrive and play their essential roles in the food chain. At the same time, the mesh netting efficiently traps heavier trash, such as plastic garbage. The floating waste is collected and trapped by the net as the boats drag it through the water, serving as a barrier that keeps it secure until it is hauled on board for appropriate disposal or recycling.[27] Ocean Cleanup extends its efforts to tackle river pollution with the use of stationary trash collection systems known as *River Interceptors*. These mobile stations are strategically placed within rivers and act as effective barriers. As the river drifts, floating trash and plastic that frequently gathers on the water's surface towards a network of buoys. The gathered debris is directed onto a conveyor belt system by this row of buoys. The aquatic waste is efficiently transferred into covered bins while the conveyor belt travels. This “high-tech solution with solar-powered mechanics, smart processing, and connectivity for easy performance tracking” all works autonomously.[27] In order to stop plastic garbage and other pollutants from entering the ocean, the *River Interceptors* offer a creative and proactive alternative in Indonesia, Malaysia, the Dominican Republic, Vietnam, USA (California). This strategy makes a substantial contribution to the conservation of aquatic ecosystems by reducing the flow of pollutants from rivers to seas.

Sawyer Filters takes a unique approach to tackle aquatic pollution by addressing the micro-level contaminants. They have developed portable filters for use with water from lakes, rivers, and other natural sources. The hazards connected with micro-pollutants in water sources are reduced while promoting personal and community health thanks to these portable filters' rapid availability to clean drinking water. Creating a multidisciplinary series of filtration devices, each one contains thick absolute micron fiber walls that are around 75% stronger than fibers of other typical hollow fiber membranes. As a result, Sawyer filters can be backwashed forcefully and frequently, restoring up to 98% of the initial flow rate within a 100,000 gallon range. [28] Sawyer Filters is significantly influencing water quality by concentrating on the micro-level impurities, guaranteeing safer access to clean drinking water for communities and individuals everywhere.

Clear Creek Cleanup is an opportunity for community involvement where volunteers use their hands to clean the neighborhood. Harnessing human work to physically clean oceans, rivers, and lakes from water contamination presents a tangible and community-driven solution to environmental challenges. Through volunteer efforts and employment programs, pollutants and debris, such as plastic and trash, can be actively removed from aquatic ecosystems. This hands-on approach promotes environmental stewardship, develops awareness of the value of protecting clean water sources, and aids in restoring the natural beauty of these water bodies.[29] Clear Creek Cleanup restores and safeguard Golden’s priceless aquatic habitats for now and future generations by mobilizing human endeavors.

Evaluation

Plastic Odyssey: The operation of a 20-30 manned ship might have significant environmental impacts relating to emissions. A possible source of the carbon emissions is from the energy required from recycling and machine innovation. Other than the obvious carbon missions from the boat’s movements. The massive logistics seem problematic with several moving pieces.The effect of advocating in remote regions on local populations might be considered in the wrong intention and bring forth unintended consequences. One positive outlook is to consider the mass attempt to advocate proper solutions to major issues.

Sea Cleaners: Even with the realistic understanding and undertakings to remove significant volumes of waste from the ocean, the logistics of transporting and gathering such enormous quantities of material is a catalyst of problems.

There are in answer concerns revolving around where and even how the captured ocean garbage will be appropriately disposed or recycled. In regards to mobility, all climates or seasons may hinder the weather-dependent vessel powered by solar and wind energy. The proposed collected goal is unlike the other solutions, and stands in a category of its own.

Ocean Cleanup: Even though Ocean CleanUp uses a mesh net designed to let tiny aquatic animals to escape, there is still a very high probability that other larger marine life may suffer accidental injury. Along with the underlying carbon emission caused by each boat carrying the nets, complications can arise for the waste management system processing the possessed amounts of aquatic debris clean up. However, the autonomous and carbon neutral use of *River Interceptor*s is a similarly efficient way to reduce waste in waterways.

Sawyer FIlters: Although portable filtration devices offer vast access to clean drinking water, the types of contaminants it can effectively remove is limited. As being for personal use, the portable filtration systems only aids in the individual user, rather than a filtration system that can aid the ecosystem. Yet, the focus on microplastics is one perspective that the other solution don't consider

Clear Creek Cleanup: Community engagement in cleanup is beneficial, but it might not be able to stop pollution at its source. Cleaning up after pollution may quickly turn into a repetitive and unsustainable process if there aren't adequate rules and attempts to eliminate it from the source. However, this is a great method to spread awareness and gather real hands-on experience for everyday individuals looking to make a difference.

Report

Each of the existing methods and solutions to aquatic clean up seems a viable option. Whether it is spreading awareness, removing mass amounts of debris from oceans and rivers, filtering micro plastics, or community engagement, every one of these answers the call in their own perspective of water pollution. Yet, every one of these answers have their similar drawbacks. Logiscs, emissions, and community actions are roots to each of these existing methods. As these solutions are based on mainstream companies, each of these examples does not fit within the scope and requirements of our problem statement and definition. On the other hand, if we take smaller components from each of these solutions, our finalized idea could remain in our sights. A device on a manageable small-scale or local apparatus that is carbon neutral, collects majority types of pollution and is autonomous.

1.1.5 Ancillary Issues

Bodies of water throughout the world become polluted due to waste created by humans, the waste collects and can have harmful effects on the environment. Some areas are less affected than others, however it is a recurring issue that should be tried to be limited as much as possible. Trash building up in our lakes, rivers, or oceans do not just create a sore to the eye, but have some harmful environmental effects that if not taken seriously can cause true harm to the world we live in through humans, animals, and our land. According to an article highlighting the effects of water pollution and ways it can be controlled the authors state " As debris accumulates, habitat structure may be modified, light levels may be reduced in underlying waters, and oxygen levels may be depleted. These changes can undermine the ability of open water and benthic (bottom of a body of water) habitats to support aquatic life"[12]. This shows the harm to the aquatic life and the water, but they also describe the harm to humans as stated "In addition to degrading the habitats and ecosystem services that humans use, plastic aquatic debris can directly interfere with navigation, impede commercial and recreational fishing, threaten health and safety, and reduce tourism"[12]. Pollution in bodies of water is something we need to manage better in order to have a safer and healthier environment.

When we clean out the bodies of water of all the pollution, where does the pollution then go? We are focusing on attaining this pollution and instead of it going into another trash pile, it turns into something useful. An issue facing this is if the quality of the product we gather is ruined due to being in water. Water can ruin or alter an object's physical properties if submerged too long, so we need to be able to locate items in which water doesn't ruin its properties so that we can give it another purpose. Another issue we could come across is the cleanliness of an object, if an object is submerged in overly polluted waters, we would need to go through a process to sanitize the object for healthy use.

With the high accumulation of waste in water, an issue can be what exact material or object we want to focus on that is the proper size and isn't broken or unusable with the state it is found in. The process of collecting the objects is another issue, how can we help clean bodies of water, extract our object we want at the same time as not leaving the other trash behind as well.

1.2 Stakeholder Outreach/ Problem Validation

Table 1: Stakeholder Outreach

Analissia Wise	Abi Strait	Martin Vincé	Keegan Dwyer	Robert Davis
> 15 miles off campus interview (5) (yet to be completed) Scholarly Article (1) Interview (3) Email Q&A (1)	> 15 miles off campus interview (5) (yet to be completed) On-site participation in stakeholder daily activities(5) Email Q&A (1) Interview(3)	> 15 miles off campus interview (5) (yet to be completed) Interview(3) Documentary (2) Community Questionnaire (in-person 3) On-site participation in stakeholder daily activities (5) (yet to be completed)	> 15 miles off campus interview (5) (yet to be completed) Interview (3) Phone Interview(2)	> 15 miles off campus interview (5) (yet to be completed) Interview(3) Documentary (2)

1.3 Outreach Findings and Summary

1.3.1 Analissia Wise

1.3.1.1 Stakeholder Engagement

Many bodies of water get polluted, including: oceans, lakes, and rivers. These bodies of water continue to collect pollution through poor habits of humans. People don't always think about where waste will end up, they rather just not deal with it, an article about plastic pollution states "Furthermore, experts estimate that up to 10% of plastic debris produced will enter the sea (Thompson, 2006) and that plastics will outweigh fish in the ocean by 2050 (World Economic Forum, 2016)"[8]. This goes to show that the amount of littering and polluting that happens will build up over time and overtake bodies of water. If plastic alone will outweigh fish by 2050, putting together all the factors of pollution I'd assume will take less time.

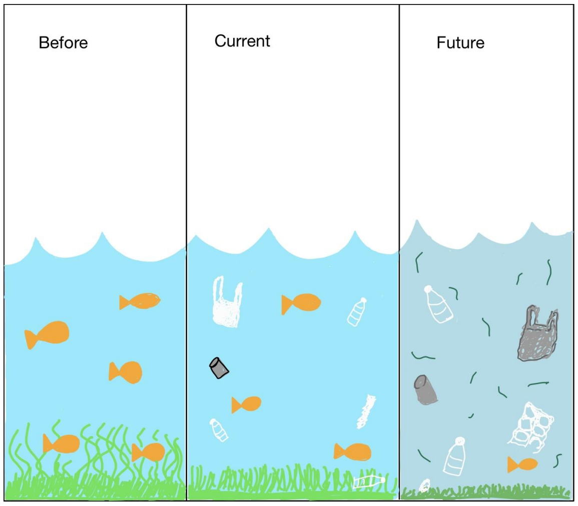


Figure 3: This figure shows the evolution of water pollution and how it affects marine life as well as the quality of the water.

There are also people working hard to clean up the pollution in water, many organizations and companies go out of their way to clean up the waste in the waters caused by others. An organization that dives looking for underwater trash states “We will follow a group of scuba trash divers called Rena Mälaren (Clean Mälaren), who dive for trash in these cold Nordic waters to clean the bottoms while making the waste visible to the general public”[23]. Bringing attention to the amount and type of pollution in waters is important, if people don’t know what it truly looks like or the harm it does it will continue to happen. If we allow it to continue we as humans can bring harm in many different factors.“Thus, even when waste is present and available on beaches or in the water, there is an ongoing discussion on how to address and manage this waste”[23]. This is why we are trying to take this pollution and upcycle, there is no use to collect the pollution for it to once again be taken and have no use after that, this waste will simply continue to collect and collect so we want to upcycle the materials we find in water to give them a more beneficial responsibility.

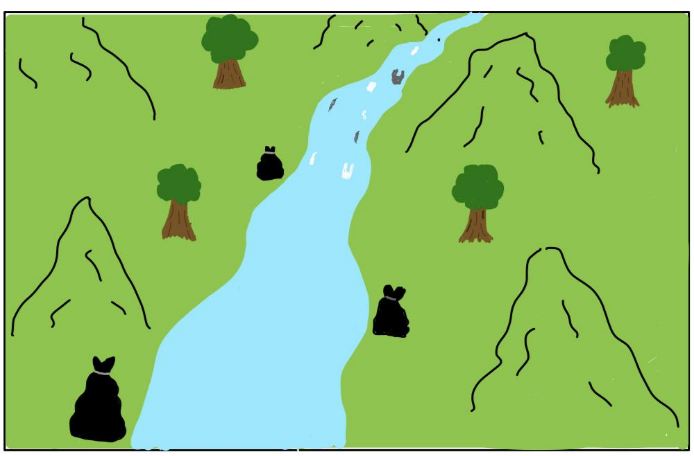


Figure 4: Shows cleaning up rivers do help so that trash doesn’t build up, but the clean up doesn’t stop more trash from coming down the river.

I have gained helpful and useful information from articles including the ones above but I still plan on attending in person interviews as well as phone and email interviews. I am directing my focus on the departments dealing with as well as trying to stop pollution in water. I expect to ask questions about how much waste is in the water, what is usually the most common waste in the water, what they do with the waste after they collect it, and overall if they think upcycling the waste in the water would be a good cause and idea to move forward with. I intend to find out the highest waste factor, so that we can try to build a solution off of that factor. I will have at least 2 in person interviews, one off campus and one with a professor on campus to get more information as well as their perspectives.

1.3.1.2 Remaining Unknowns

I have gained much information from the articles I have read so far and intend to gain much more through the interviews and talks one on one, however there is still much room for knowledge. Our team will need to research much into the materials that are wasted and which materials we can actually use to upcycle, we want to be careful with the material we use and know that the water didn't affect its performance or physical properties. Plastic is a very well known source of pollution in waterways, so if we chose to focus on plastic we need to research the disadvantages and advantages in which it will benefit our solution. No matter what material we use we also need to address the problem of how we will collect the material, will we find our own ways to clean out trash in the waters, or will we locate after it has been cleaned out. I think another issue as well is if we focus on one material too heavily, we shouldn't only focus on pulling that material out of the water we need to try our best to clean the water while gaining our resources.

An obvious unknown is our solution, what will we decide to create when we decide what material we use. Will it be something that benefits the idea of cleaning up the ocean like how the creation came to be or will it focus on something entirely different.

1.3.1.3 Summary

Sadly our waters are greatly polluted and despite efforts they continue to be polluted and even become harmful for the environment. If we try to minimize the pollution as well as clean up as much as we can we can allow the bodies of water to turn into a healthy environment once again. Even then if we only focus on the aftermath of pollution nothing will change, we need to also try and stop the pollution from happening in the first place.

Through research we have gained and will continue to gain new knowledge on pollution in water. We ;know as a whole pollution in water is an issue which is why we decided to try and use the pollution and change it into something beneficial. There are also many possible materials that we can use for our solution and once we dial it down to one or maybe even a couple of different ones, we will be able to research more on the selected ones and create our solution from there.

1.3.2 Abi Strait

1.3.2.1 Stakeholder Engagement

Note: I was focused on contacting organizations that dealt with current aquatic debris clean up, in order to gather further information about existing solutions.

Table 2: Abi's Possible Stakeholders

Possible Stakeholder	Questions	Status
Plastic Odyssey: - Organization that aims to reduce plastic pollution by creating a worldwide network of local recycling initiatives	- What was the original intent of starting your organization? - Why is your organization focused on the cleaning of the ocean rather than fixing the founding problem of using non-degradable materials? - Do you believe that at some	Emailed, has not emailed back

	point in the future there will be no use for ocean clean up because we will have fixed the problem from its origins? - Why is your organization only focused on plastics when there are more materials polluting our bodies of water? - On your website, it only provided a link to partner with you, but not telling who you partner with. Who are you partnered with, and what does partnering with the Plastic Odyssey look like? - In the company's opinion, where should our efforts be focused? Should we be focused on using new materials to prevent non-biodegradables all together, or should we continue focusing on the clean up of these non-biodegradable materials?	
The Ocean Clean Up: - Developing and scaling technologies to rid the world's oceans of plastic - "According to a study conducted in collaboration with Deloitte, yearly economic costs due to marine plastic pollution are estimated to be between $6-19bn USD."	- What was the original intent of starting your organization? - Why is your organization focused on the cleaning of the ocean rather than fixing the founding problem of using non-degradable materials? - Do you believe that at some point in the future there will be no use for ocean clean up because we will have fixed the problem from its origins? - Why is your organization only focused on plastics when there are more materials polluting our bodies of water?	Emailed, has not emailed back

	- In the company's opinion, where should our efforts be focused? Should we be focused on using new materials to prevent non-biodegradables all together, or should we continue focusing on the clean up of these non-biodegradable materials?	
The World Bank: - The Blue Economy - Rather than cleaning the ocean, the blue economy focuses on creating ways to preserve ecosystems by starting at the source. For example, their boat, the PORRIMA, uses only solar, wind and seawater energy. - The Blue economy thinks about good consumption, rather than the sub consequences of bad consumption	- What was the original intent of starting your organization? - Why is your organization focused on the cleaning of the ocean rather than fixing the founding problem of using non-degradable materials? - Do you believe that at some point in the future there will be no use for ocean clean up because we will have fixed the problem from its origins? - What has your organization done to promote the "good consumption" that your website talks about? - In the company's opinion, where should our efforts be focused? Should we be focused on using new materials to prevent non-biodegradables all together, or should we continue focusing on the clean up of these non-biodegradable materials?	Emailed, has not emailed back
Bracenet: - Part of the money brought in from selling bracelets and dog leashes made of fishing nets is donated to environment protection	- What was the original intent of starting your organization? - Why is your organization focused on the cleaning of the ocean rather than fixing the founding problem of	Emailed, has not emailed back

	using non-degradable materials? - Do you believe that at some point in the future there will be no use for ocean clean up because we will have fixed the problem from its origins? - The idea of your company is based on trying to preserve the environment by upcycling fishing nets, and selling them as bracelets. However, is it true that this would only cause a circle because the material of the fishing net never changed, so when somebody is done with their bracelet it could end back where it started? - In the company's opinion, where should our efforts be focused? Should we be focused on using new materials to prevent non-biodegradables all together, or should we continue focusing on the clean up of these non-biodegradable materials?	

Current Findings

While there has been little luck of stakeholders getting back to me, the 'about me' section of their websites have given me enough detail to understand what their motives and purpose are. Majority of the organizations/ businesses are oriented towards improving the water quality, and overall quality of life, for living organisms, from humans to marine life. There have been different approaches to how each stakeholder has chosen to take this task on. The more business-like stakeholder upcycled ghost nets (fishing nets lost at sea or deliberately thrown overboard [26]) into bracelets and dog leashes to sell. The other organizations took a more technological approach by innovating ways to solve the problem rather than re-use it. In our team's report, we will find a way to combine these efforts in order to solve the problem statement by making a more efficient use of our materials.

1.3.2.2 Remaining Unknowns

While it might seem that there are little unknowns, since there has been so much research and movements towards cleaning our bodies of water, our group is still facing the question of how to make these methods more efficient. Not only do we not know how we might start to tackle this problem, but there is an additional difficulty of trying to accomplish this task with solely upcycled materials. No matter what solution we choose, there are unknowns and a need for more research to thoroughly complete this assignment. For example, if we choose to replicate a boat like other stakeholders have done, then we must construct it using only trashed materials. This would kill two birds with one stone by utilizing non-degradable items that would potentially end up added to the tally of trash in the ocean to clean up already existing materials. However, there would be an additional need to research how we might run this boat without manning it, how we would build a boat with limited labor and parts. Additionally, there would be a need for additional stakeholders to grant us to use materials for the boat, such as junk yards and lumber yards. In conclusion, there is not much unknown about the existing trash in bodies of water, but there are unknowns when we reach the solution part of this report.

1.3.2.3 Summary

The originating motives for these stakeholders/ organizations are to improve life, both human and marine, by cleaning up the ocean. Whether these organizations employ nets to collect some of the 269,000 tons of trash floating on the surface of bodies of water, or boats to gather the excess sargasso, there is one purpose: preserve Earth. How do we best preserve Earth? Or a better question would be, what is the minimum amount of energy we could use to clean all aquatic debris, or prevent it all together. While our team is attempting to use upcycled materials to rid all bodies of water of aquatic debris, there is still reason to question how to prevent it all together. Should we be funding efforts to find 100% soluble and degradable materials to use for common disposable items? Is there a way to clean non-degradable objects from the ocean so efficiently that it would be worth using? In this paper, we will evaluate multiple solutions to these questions, and we will produce one that we believe will be most effective.

1.3.3 Martin Vincé

1.3.3.1 Stakeholder Engagement

Oceans, lakes, and rivers are just a few of the water bodies that are contaminated. These bodies of water continue to accumulate pollutants as a result of human bad habits. According to Laurent Lebreton, an estimated 1.6 million km^2 contains at least 79 (45–129) thousand tonnes of floating ocean plastic.[24] In addition to this, microscopic water pollutants are seen within all aquatic environments. As humanity's bad habits grow ten-fold, so does the pollution in water. Some solutions have arisen to clean up the open water such as the Plastic Odyssey and Sea Cleaner organization. Similarly smaller scale operations and products have been created to focus in more minute locations.

To combat major ocean pollutants on the sea, two solutions have been developed. The *Plastic Odyssey* mobile field station functions as a cross between field study and interpersonal advocacy and the *Mantra,* an open water logistic vessel aimed to eliminate 10,000 tons of ocean trash annually. [26] The 39-meter-long boat, *Plastic Odyssey* physically travels through places that are extremely polluted in search of solutions to stop additional pollution. Aboard the ship, which has technical and scientific areas with a capacity of 20 tons, different technologies are evaluated, tested, and examined within each environment the *Plastic Odyssey* stops.[25] On the other hand, Sea Cleaners are designing and constructing the *Manta*, an open water logistics vessel. Including an easy-to-use collection mechanism to check for ocean trash, the proposed goal is sailing in 2025. A trapping and conveyor belt system should eliminate 10,000 tonnes of trash annually, or 1-3 tons of trash each hour. [26] The Sea Cleaners organization, in contrast to the *Plastic Odyssey*, is putting techniques into place to remove marine pollutants from the sea directly. However, each of these operations come with their own drawbacks, logistical complications, and possible problematic futures.

To combat minor and more minute scale ocean pollutants, operations and products have been created to focus on this specificity. Sawyer Filters focuses on tackling micro-level pollutants in aquatic pollution by creating portable drinking filters. These filters improve individual and public health by lowering the hazards posed by micropollutants.[28] Along with the previously mentioned large-scale organizations, these filters have their own underlying drawbacks. Toxic, heavy metals and other similar contaminants are not sifted through the filter. Unlike

this individual complication, Sawyer Filters do not address major concerns revolving around the environment and the ecosystem.
Note : I will be conducting an IN-person interview with Prof. Cath, and going to engage in stakeholder precipitation.

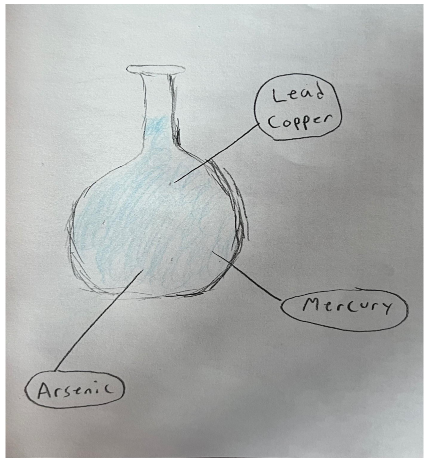


Figure 5: A water filled glass container is complied of microplastics not visible to the naked eye

1.3.3.2 Remaining Unknowns

Despite the highly insightful information we learned from our stakeholders, there are still many unanswered questions regarding our issue and possible remedies. One issue relates to materials. Since there are so many different materials that pollute our oceans, it may be difficult and contentious for our team to choose just one to focus on that is also distinctive, intriguing, and inventive. On the one hand, we have the option to handle macro waste, which is the safest course. The most prevalent sort of marine garbage in our seas and marine environment is larger waste, which can be removed straightforwardly. On the other hand, there is micro containment, such as heavy metals, toxins, which are often ignored in our waters

Second, there is still uncertainty on how to solve the proposed problem statements and further related issues. When brought into marine environments, several types of upcycled waste can cause a variety of environmental problems. These issues arise as a result of the waste's potential for damage and potential incompatibility with the sensitive ecosystems of the ocean. We must take into consideration the viability of our prospective solution in addition to the desire for an original and effective apparatus. We cannot create a solution that is worse for the neighborhood than the contaminants it is intended to address.

1.3.3.3 Summary

Unfortunately, despite all already existing solutions of cleaning and cutting back on marine debris, water pollution is at an all time high, and continues to be each year. This is particularly true for smaller towns that have limited access to preventive and management strategies for marine trash. Populations that are developing are even more at danger because they lack knowledge about the serious threats that marine trash poses to both their own health and the health of the ecosystem. Along with the ability to rectify the damages done from water pollution.

Marco containment issues have received a lot of attention. For the most part high-tech approaches like sailing vessels and autonomous capture machines that can collect tons of debris have been used to solve the problem of marine waste in the present moment. Unfortunately, the solutions we've seen thus far have been expensive, logistically impractical, and beyond of reach for the majority of struggling communities. Smaller towns are skipped in consideration. We aim to address these issues that have been presented and to seek a practical solution for aquatic waste that is effective and functionable.

Figure 6: This drawing on the left depicts waste caught in a river whirlpool from a birds eye view

1.3.4 Robert Davis

1.3.4.1 Stakeholder Engagement

There are several potential solutions addressing the problem that is ocean waste. The most notable example is that of The Ocean Cleanup's *Interceptor*. [19] The Interceptors are aimed to deploy in rivers that have especially large problems with waste. Four designs were deployed in order to meet the needs of a wide variety of circumstances. First is the *Interceptor Original*. [19] The Interceptor Original, which was the first interceptor deployed by The Ocean Cleanup, is a high-tech, smart, solar-paneled easy-to-use river cleaning solution. [19] While it's high-tech and highly effective, the great costs associated with making and deploying these make these only capable of being launched in small numbers with long waiting time periods before the next could be deployed. [19] In addition, the Original Interceptor works best in narrow pathways where waste isn't spread out. [19] To combat this, two more solutions were developed, the Interceptor Barrier and Tender, which work alongside one another to gather large swaths of trash from a greater area. [19] Fortunately, this solution is both more practical in larger areas and more cost effective overall. However, another solution capable of covering wide areas of land as well as preventing the oncoming swarms of waste that come about as a result of disaster waste hadn't yet been implemented. Thus, the Interceptor Barrier was born. [19] The primary purpose of the Interceptor Barrier is halting or slowing the spread of waste throughout a river as opposed to collecting it. As we can see, innovative solutions had to develop as a result of user-demands as circumstances varied. However, none of these solutions are as cost effective as we'd ideally hope. As stated in the background, one of the largest sources of marine waste is underprivileged communities turning to ocean dumping as a means of cost-effectively getting rid of waste. Unfortunately, none of the solutions listed above meet the general requirement of being cost-effective.

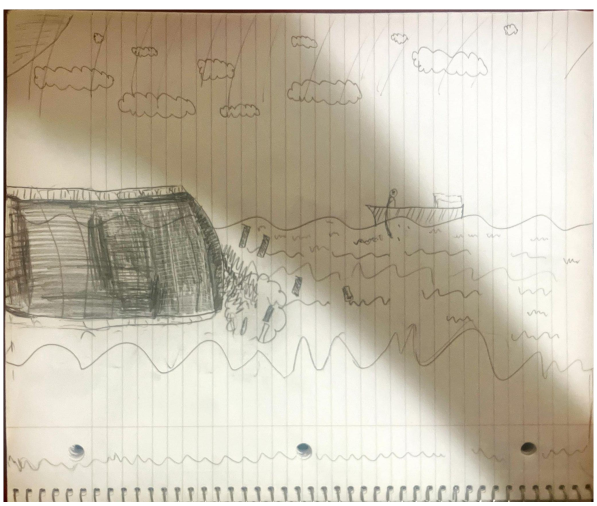


Figure 7: on the left depicts waste in an open sea. Figure 8: on the right depicts waste in a river as would be used in the interceptor barrier and interceptor classic respectively

We can use the Interceptors above as an example of the types of solutions typically found when researching technological solutions to marine waste. [24] Whether its machine learning algorithms capable of detecting trends in marine waste, artificial coral reefs, or artificial coastlines, the general trend seems to be in favor of large, costly constructions. From my research, we then learn about the importance and necessity of designing and constructing a solution that is beneficial to the actual stakeholders we're building our product for. Most communities will not have the resources or knowledge necessary to implement such high-tech solutions. Additionally, we can see from all of these examples that an emphasis has been placed on removing and preventing the spread of waste largely through macroplastics and larger waste rather than microplastics and other chemicals that are harmful to humans. Therefore, it's necessary that we develop a solution to marine waste that not only addresses and considers multiple types of waste, addressing the problem effectively, but is also accessible.

1.3.4.2 Remaining Unknowns

Despite the very insightful knowledge gained from our stakeholders, there are lots of things that remain unknown about both our problem and potential solutions. For one, there's the issue of materials. Unfortunately, there exists a variety of different materials polluting our oceans, and choosing a singular one to address that is both unique, interesting, and innovative, is both challenging and a source of contention within our group. On one hand, we can go the safer route and choose to address plastic waste. Plastic waste has been well-established as the most prominent type of marine waste within our oceans and marine landscape. On the other hand, other types of waste pollute our oceans, waste which is largely going unnoticed such as heavy metals, chemical pollutants, etc.

Secondly, there remains the unknown of addressing our problem and the effectiveness of our potential solutions. It's a bit of a paradox: we want to address our problem from a unique perspective while designing a product that is also effective. However, the most established solutions to ocean waste are also the most effective. In addition to wanting to create a solution to our problem that is both unique and innovative yet also effective, we must contend with both the cost and feasibility of our potential solution. In order to make a product that is truly beneficial to our community, we can't create a solution that is inaccessible to our community, particularly in terms of cost.

1.3.4.3 Summary

Unfortunately, despite the great efforts put into cleaning and reducing marine waste, marine waste only compounds yearly. This is especially true for smaller communities with little access to marine waste management and prevention measures. Underprivileged communities, that are uneducated about the great risks to both their own health and the environment's health marine waste poses, are at an even greater risk. Unfortunately, the solutions derived so far have been greatly lacking in user-empathy.

Great attention has been given to problems surrounding plastics, while little has been done to address the problems surrounding chemical pollutants, heavy metals, fishing equipment, etc. Additionally, solutions to marine waste have typically come in the form of large gatherings of volunteers, or high-tech solutions like autonomous boats capable of collecting tons of waste. Little has been done to address the marine waste problem in our everyday communities; unfortunately, the solutions we've seen thus far have been costly, impractical, and inaccessible to our community at large. We aim to address these issues raised, and seek a practical solution to marine waste that is both accessible and effective–implementing community feedback through shareholders.

1.3.5 Keegan Dwyer

1.3.5.1 Stakeholder Engagement

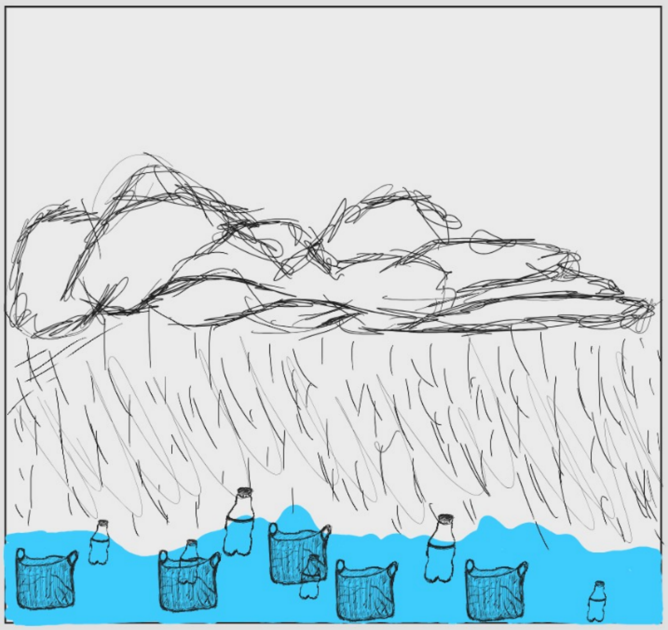
Aquatic life is threatened by pollution. This directly affects the environment as a whole. An article by "Envirotech Online" splits the detrimental effects of water pollution into five categories. The first effect described by the article is known as eutrophication. Eutrophication is a process where algal blooms grow rapidly due to increased levels of ammonia and phosphate in the water. These blooms harm marine life by blocking sunlight and reducing the levels of oxygen in the water. The second effect the article details is plastic ingestion. Marine life mistakes plastic for food and in turn ingests the plastic. This plastic can range anywhere from bags to microplastics. The animals may be able to survive initial ingestion, but their bodies are deprived of necessary nutrients which could lead to eventual starvation. "Envirotech Online " then lists bioaccumulation. Chemicals and toxins can end up in water sources. These chemicals can not only kill marine life, but they also climb the food chain as larger and larger animals eat the smaller toxin ridden marine life. Eventually, the chemicals may come full circle and end up in the foods humans consume. The fourth effect the article explains is the acidification of water bodies. This acidification can alter marine life functions and growth as well as harming helpful corals. The final effect the article lists is the loss of entire species. Species may lose their food source, their ability to reproduce, or their habitat necessary for survival. Ultimately, "Envirotech Online" lists major harmful effects of ocean pollution. If left unchecked, the oceans may lose all ability to sustain life. This not only affects marine life but also other species that depend on marine life for survival. Mankind itself is threatened by Ocean pollution.

Ocean pollution can be fought at the source by reducing consumer products made of plastic. Unfortunately however, reducing plastic products does not remove the plastics and other waste that is already in the oceans. People can also help reduce plastic pollution by recycling as well as cleaning trash by hand. There are still situations where cleaning trash up by hand is not possible. In those situations an alternative method of cleaning is needed.

For my stakeholder engagements, I will begin by attending an interview with Professor Cath which is scheduled for 8:00 A.M. on Thursday September 21st. I will also attend an interview with a stakeholder 15 miles away from campus. Finally, I will conduct an interview over the phone with a relevant stakeholder. Questions I plan to ask relate to Ocean Buster's problem statement "*How can we optimize the removal of aquatic debris through the innovative utilization of upcycled materials?*" I plan to ask about the creation of our device and whether it should be a subversive vehicle or simply a floating vehicle. Furthermore, our stakeholders may provide valuable insight into where we could potentially gather the materials to upcycle for our device. Third, I plan to ask for any resources the stakeholders deem helpful for our project. Fourth, I plan to ask if we should just focus on plastics and solid trash or figure out how to clean up other contaminants such as oil. Furthermore, during the interviews, to learn about said stakeholder's experiences with cleaning up bodies of water as well as how they interact with water professionally.

1.3.5.2 Remaining Unknowns

Our team has gathered necessary information regarding our problem statement. However, we still have an extensive list of unknowns. Primarily, We still do not know how we will build our project. We are unsure about how we can make an effective product using mostly recycled materials. We do not know where we will gather the materials for our project nor do we know precisely what materials we will even need. Second, We are still unsure about what waste to focus our project on specifically. We could focus on plastic waste, but chemical waste is also harmful to our environment. It would not be a terrible idea to attempt to build our product to clean up chemical and liquid wastes such as oil. Our team is also conflicted with the idea of efficiency. We want to make the most productive and efficient product as possible while also remaining innovative. Our team knows that by approaching the project from the point of view of maximizing efficiency that we may end up using ideas and processes that have already been developed.



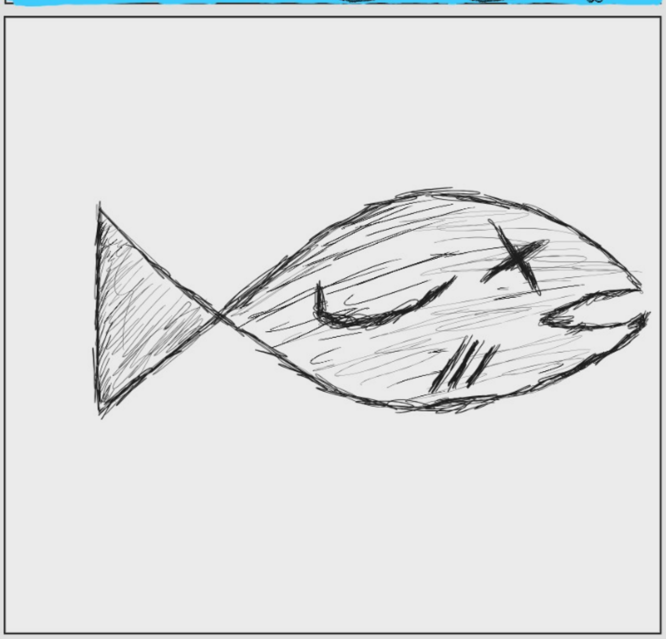


Figure 9 (top): depicts a body of water completely filled with trash that could be easily removed and mitigated in the future.
Figure 10 (bottom): depicts a fish that died due to the effects of pollution

1.3.5.3 Summary

Pollution is especially prominent in our world's bodies of water. This pollution not only harms marine life, but also the environment as well as entities that rely on marine life for survival. While there are efforts to reduce pollution by recycling, engineering biodegradable products, and creating awareness, the pollution that has already been created is still a problem. Our team has decided that it would be beneficial to focus on creating a device that can help clean up currently existing pollution. This is a troublesome and vague dedication however. We aim to create a device using upcycled materials so that it can be produced on a larger scale relatively cheaply. By keeping the design simple and the parts easily accessible, it will be easier to provide our solution to a large consumer base. Through the assistance of stakeholder engagement and further research, we plan to design a cost effective device that will effectively and repeatedly keep our world's bodies of water clean.

2.0 Existing Solutions, Alternatives Reviewed, And Option Selected

2.1 Affected Stakeholders and Existing Solutions

Stakeholders for our design focus on the pollution in water, awareness of pollution, and the act of cleaning water pollution. [37][38][39][40] Our stakeholders focusing on the pollution in the water include Professor Cath and Brynn Goe. [37] Professor Cath informed us on pollution and specific pollutants through waste water treatments and how as an economy we struggle to implement resources to areas with lower incomes which does not overall create a benefit for the environment. [37]We learned that for our design we should make it available for all communities, so that we don't restrict areas from having healthier water. [39] Another stakeholder focusing on pollution is Brynn Goe, she is the superintendent of the Water Treatment Plant in the city of Golden. [39] She informed us of the increase of microplastics in our waterways that accumulate from upstream water treatment plants, this influenced us to not only act on the pollution floating on top of the water but to incorporate a solution for microplastics as well. [40][38] Paul Dearlove, the director of Clean Lakes Alliance, and Rheana Rodgers, the executive admin manager for the city of Golden, focus on both the awareness of water pollution and the cleaning aspect. [38] Dearlove mentions that awareness of the problem and people willing to help is what will eventually lead to the benefit of our water's health. [40] Rheana Rodgers gave a similar perspective to Dr. Dearlove, she believes awareness is an issue with water pollution, she organizes voluntary clean ups of our local creek and stated every week there is more trash on the shore and in the water. Our stakeholders gave us valuable information on the type of pollution our design can help focus on as well as how we should implement our design. Our design is needed to help the problem of pollution in any river despite the income of the area. Our design should also help increase awareness of the issue to help potentially lessen the pollution at the source.

[36] There are already ways to help with water pollution including the Plastic Odyssey Boat, the Ocean CleanUp Interceptor, and voluntary acts. [36][25]The Plastic Odyssey Boat and the Ocean CleanUp Interceptor however focus primarily on the ocean and we want to create a solution for rivers so that it doesn't spread through the environment and potentially end up in the ocean. Voluntary acts aren't always guaranteed and opportunities tend to vary depending on locations. This is why our design will be made available for any area and be made dependable. Our design will run continuously and won't need someone to operate allowing it to clean the river as it flows.

2.2 Requirements, Customer Needs, and Technical Specifications

<u>Design Requirements:</u>

1. **Waterproof/Weatherproof**: The device and all of its components must be fully waterproof and weatherproof. That means the device must be able to withstand a variety of varying weather conditions including rail, sleet, hail, snow, and high-winds.
2. **Reliable/Minimal Maintenance Required:** The device must be engineered to consistently withstand daily operations with a great degree of reliability, and ability to resist any physical damage which might present itself. Furthermore, the device must be designed in such a way necessary repairs can be conducted with a relatively little degree of complexity and effort.
3. **Large Enough to Collect Necessary Types of Waste:** The device must be large enough to collect a reasonably large amount of waste within the area it is intended to serve, while also being able to scale to meet the requirements of the area.

Customer Needs

1. Cost-Effective:
    a. Does not require a large crowd funded efforts.
    b. Cheap, upcycled materials
    c. Gets the job done, doesn't have to be the most aesthetically pleasing

A great many solutions have been proposed to address the problem of marine waste. However, a large reason the problem of marine waste persists despite billions of dollars in funding and decades of labor and research, is because lots of the solutions to marine waste are frankly too expensive to purchase and too costly to maintain. For those reasons, we find it necessary that our solution is cost effective, that means it doesn't require a large amount of crowd funds, it uses cheap, upcycled materials, and doesn't necessarily appeal to the most critical aesthetic eye.

2. Considers A Variety of Needs
    a. Durable and Deployable in a varieties of circumstances:
    b. Disaster Relief
    c. Low-Income Communities
    d. Small streams used for drinking water
    e. Collects Micro Waste which is a great contaminant in sources of drinking water.

Because we plan to deploy the system in a variety of environments, including instances in which natural disasters have occurred, addressing disaster waste, our solution must be both durable and subsequently deployable in a variety of circumstances. In order to address a variety of users, our solution must also be made with the intention of being as affordable as possible, addressing the needs of low-income communities. Lastly, in order to address the type of waste most harmful to humans, microwaste, waste that is naked to the human eye, our solution must address microwastes.

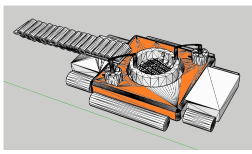
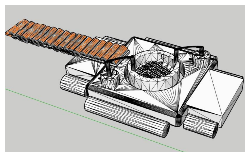
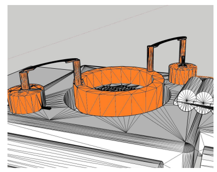
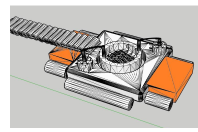
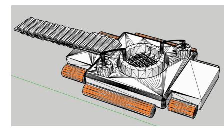
3. Focuses on Smaller Bodies of Water
    a. Rivers
    b. Streams
    c. Dams and other freshwater sources with great concentration of waste

Due to the high volume of marine waste solutions focusing exclusively on larger bodies of water, we feel it necessary to focus on smaller bodies of water such as rivers, streams, dams, and other freshwater sources with a great concentration of marine waste which could potentially harm human health.

Technical Specifications:

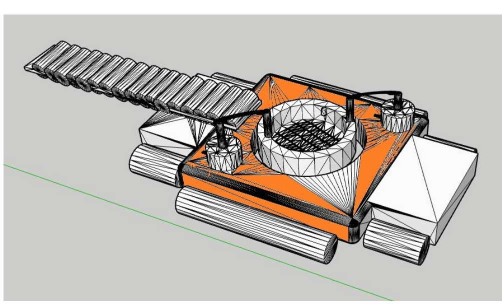
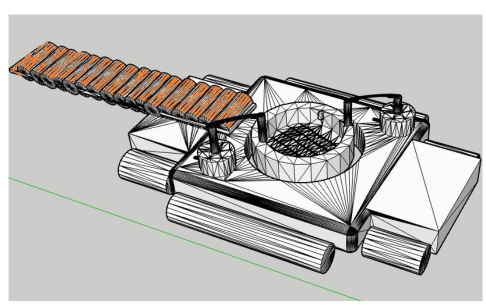
Proposed Upcycled Materials

Table 3: Upcycled Material

Bridge	Conveyor Belt	Pulley System	River Straddle System	Flotation Device
				
Plastic Bottles	**Recycled plastic filament**	**Catgut**	**Metal Wire**	**Styrofoam or Polystyrene Blocks**
Wooden Pallets	**Rubber Mats**	**Plastic or Metal Drums**	**Catgut**	**Inner Tubes or Tires**
Old Tarpaulin or Waterproof Canvas	**Old Bicycle Tires**	**Mesh Bags**	**Fishing Nets or Mesh**	**Old Kayaks or Canoes**
	Cans or empty containers	**Old Nets**	**Wooden Pallets**	**PVC Pipes**

Proposed Non-Recycled Materials

Table 4: Non Upcycled Material

Conveyor Belt	Pulley System
	

Recycled plastic filament	**Ultrasonic Sensor**
Gear Motor (2)	
Waterproofing Material	
Arduino or Raspberry Pi	
Power Supply and various connectors	

2.3 Individual Components of Looks-Like Prototype

2.3.1 Analissia Wise

2.3.1.1 Component Description: Bridge

The bridge is the part of our design that essentially holds everything together and allows everything to work together. The bridge consists of the conveyor belt, collection system, and the river straddle system. The bridge is positioned in the middle of the river. The bridge will be made from non-corrosive materials abundant in the rivers, like plastic. It is also built to distribute weight uniformly, which ensures that it will not topple over (also supported by the floatation devices). In addition, its layout makes it simple to gain access to the component whenever it has to be inspected or maintained, which helps to ensure its durability and reliability.

2.3.1.2 Component Field Sketch

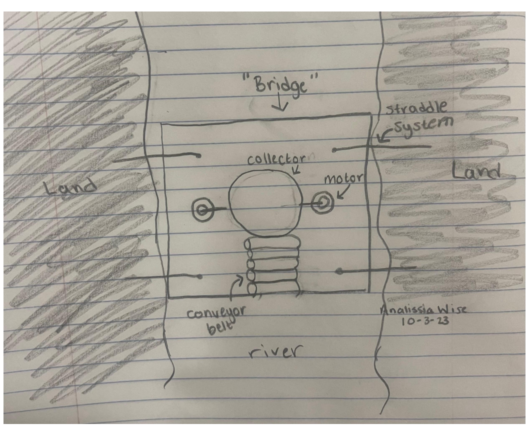


Figure 11: Field Sketch of the bridge and its components

2.3.1.3 Looks-Like Prototype Photo

Figure 12: The bridge component with all its connecting components and how they correlate.

2.3.1.4 Problem Addressed Summary

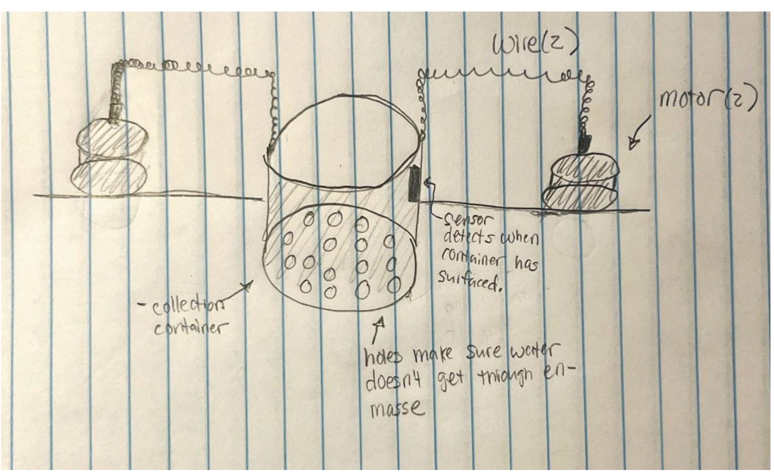
The bridge system will allow our whole design to work collectively. The bridge holds every aspect together and is what allows it to stay afloat without tipping as well as in a stationary position. Without the bridge we wouldn't be allowed multiple aspects to our design. While we want our design to be somewhat proportional to the size of the river, it does not have to span the whole river since we also have wedges to allow the flow of trash to enter our design without the bridge spanning the whole width.

2.3.2 Robert Davis

2.3.2.1 Component Description

The pulley system has three main components (all highlighted): the motor, the wire, and the collection system. The motor will be a tethered motor with an opening for the wires. The motor will turn clockwise, wrapping the wires inward around its teeth. An ultrasonic sensor inside the collection system will detect when the collection system is fully up, stopping the motors and initiating the conveyor belt. It will be made from non-corrosive materials, and it should also be made to be durable against the rush of trash common in disaster debris. To move the waste onto the conveyor belt system, we'll either use a vacuum, a rising floor, or a door system depending on the feasibility of either one.

2.3.2.2 Component Field Sketch



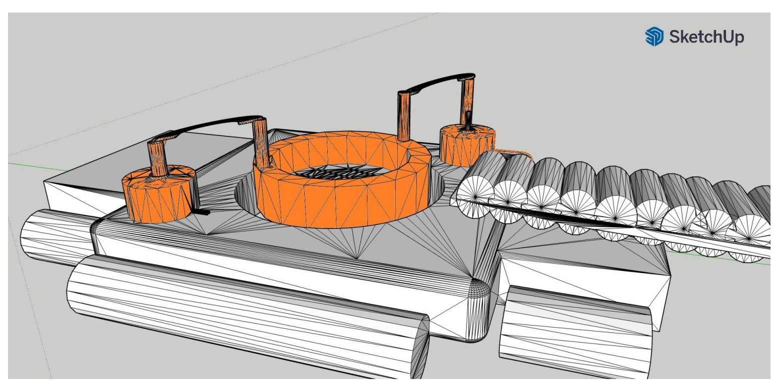


Figure 13 (left): Is a field sketch of our intake system: comprised of two motors, a pullet, and the intake.

Figure 14 (right): Initial CAD Intake Rendition 1, is a CAD model of the intake system (highlighted orange): comprised of two motors, a pullet, and the intake

2.3.2.3 Looks-Like Prototype Photo

Figure 15 (left), Figure 16 (middle), and Figure 17 (right), all depict a looks-like prototype of our intake system.

2.3.2.4 Problem Addressed Summary

The collection system will allow us to effectively and safely store marine waste collected from the river system. The collection system, made from a puncture resistant material, will simultaneously allow for the collection of microplastics underneath the surface, while allowing for the storage of marine waste collected from the conveyor belt system.

2.3.3. Keegan Dwyer

2.3.3.1 Component Description

The construction of our bridge is held up by our flotation mechanism that has been created from materials that are durable and resistant to puncture. It features six chambers, which provide maximum buoyancy stability to the bridge, even when loaded with the substantial weight from the collection system and trash. The flotation device will be robust in order to stop any unintended movement that could be caused by the river currents as collection ensues.

2.3.3.2 Component Field Sketch

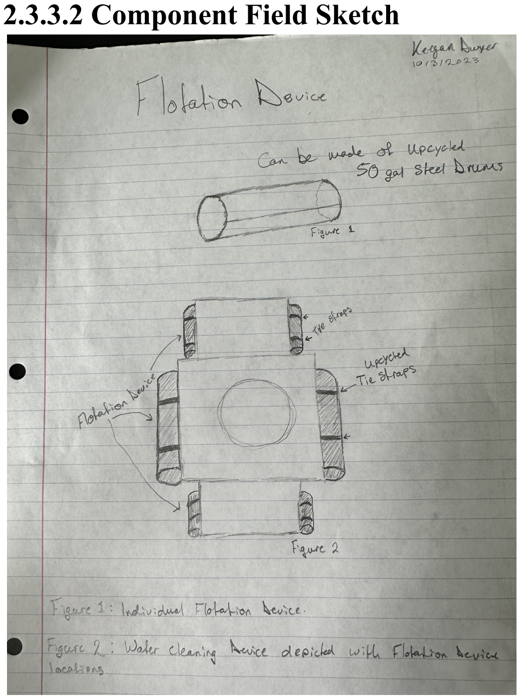


Figure 18: Depicts a field sketch of the flotation device.

2.3.3.3 Looks-Like Prototype Photo

Figure 19: The water bottles on the looks-like prototype act as the flotation devices for the system.

2.3.3.4 Problem Addressed Summary

The flotation device will keep the entire system level with the surface of the river allowing for maximum waste collection by the conveyor belt. The flotation device should be made from an upcycled item (possibly 50 gal. drums). Furthermore, the flotation devices need to be watertight, non-degradable, and durable to effectively keep the system afloat over long periods of time. Without the flotation device, the system would not be able to collect surface level trash.

2.3.4 Abi Strait

2.3.4.1 Component Description

Currently, there are numerous existing solutions that aim to minimize the damage of pollution in the water, such as: large, green energy boats that collect trash on the top of the water; bracelets made from upcycled fishing nets; and reverse osmosis technology to purify water. Majority of these solutions are focused on the biggest bodies of water, the oceans. There are few innovative, cost-effective ideas to minimize damage from aquatic debris in bodies of water in landlocked states, such as ours. Due to this lack of focus, our team has taken on the challenge of reducing the aquatic debris in rivers, creeks, lakes, etc. in landlocked states

2.3.4.2 Component Field Sketch

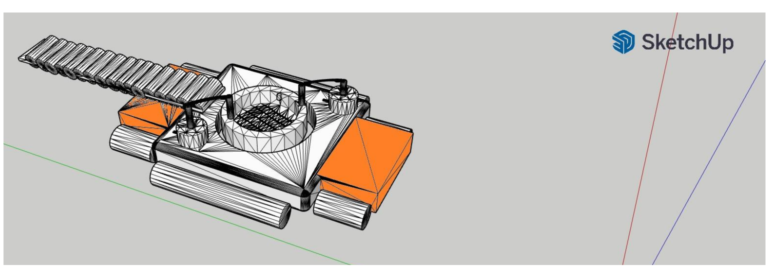


Figure 20: Initial CAD River Straddle System Rendition 1

2.3.4.3 Looks-Like Prototype Photo

Figure 21 (left): River straddle system looks like prototype
Figure 22 (right): River straddle system looks like prototype

2.3.4.4 Problem Addressed Summary

River Straddle component: The River Straddle component is a new innovation that was developed by our team in order to make certain that our system is resilient against the shifting forces of the river. The structure will either be a solid slab or use metal wire (depending on the particular river). The distance between these pillars is precisely calculated based on the width of the river and the predicted weight it's expected to carry in waste. This helps to ensure that there is a balance between the collecting of debris and the preservation of the structure's integrity. In addition to this, we are dedicated to preventing any damage to the natural ecosystem of the river, and the design of our structure is as eco-friendly as possible; we aim for the entire straddle system to be above-water so that the impact on the aquatic ecosystem is negligible.

2.3.5 Martin Vincé

2.3.5.1 Component Description

Conveyor belt component: The subsection regarding the conveyor belt will focus on the majority of macroplastics floating along the water's surface. The prototype conveyor will be attached to the front of the main body. Spanning the majority of the main body, one end of the conveyor will sit underneath a couple inches beneath the river's surface, while the portion of the conveyor will be placed over a collection bin. As such, the conveyor will be angled to an appropriate degree to successfully "grab" non-degrabels from the water, as well as keeping the non-degradable trash stable in motion. The composition is what makes this component stand out against other existing solutions. The belt, which will be constructed from upcycled materials while in combination with certain desired add-on. Unfortunately, the belt prototype will need to be necessary (watersafe 3D printed) componentes to achieve full functionality. The conveyor, which is driven by a belt fed motor, which will entail a simplistic and direct-powered system. This makes the transfer of garbage more straightforward, ensuring complex management, while protecting wildlife from the rotating wheels in an enclosed system. However, the idea of upcycling a motor for proficiency does not equate. As such, the motor will be one of the few items bought new to ensure longevity of the conveyor system. All of the components describe the requirements of the project and water/wildlife safety.

2.3.5.2 Component Field Sketch

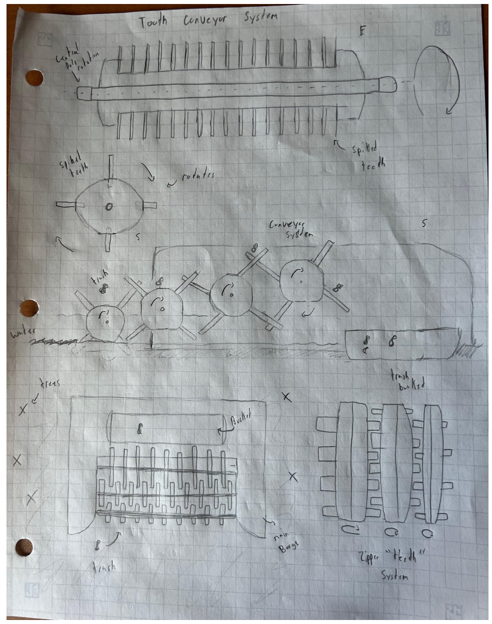


Figure 23: Conveyor system

2.3.5.3 Looks-Like Prototype Photo

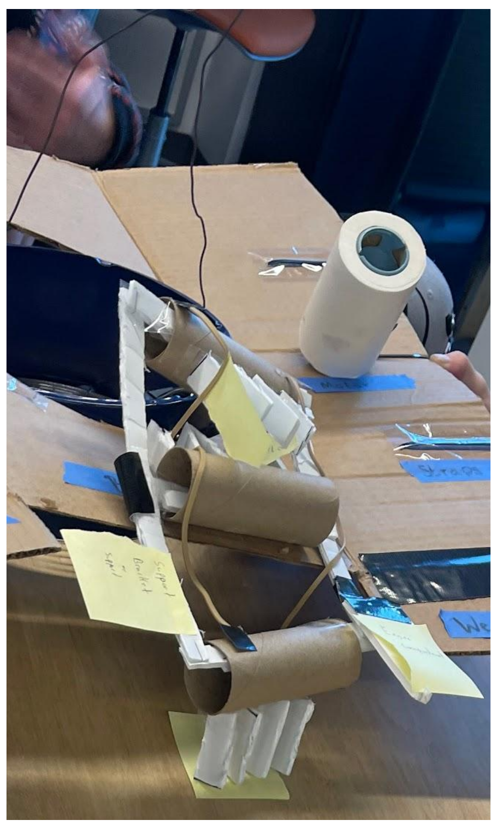


Figure 24: Labeled "looks like" conveyor model

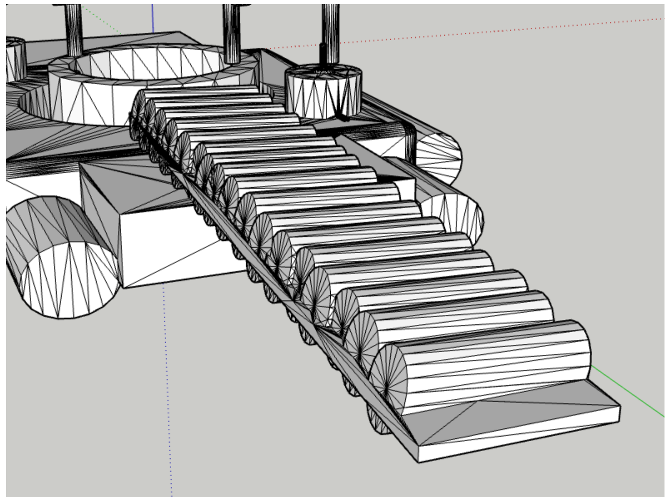


Figure 25: Initial CAD Conveyor Rendition 1

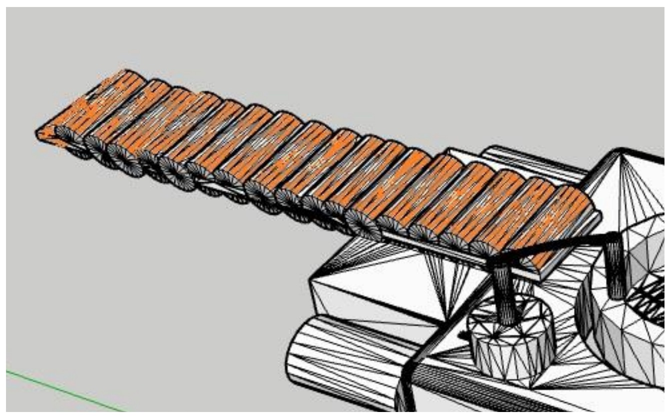


Figure 26: Initial CAD Conveyor Rendition 2

2.3.5.4 Problem Addressed Summary

A conveyor capture system is a method that efficiently removes aquatic debris from water bodies using a conveyor belt or similar mechanism. Without the need of physical effort, this device gathers floating and suspended garbage from the water's surface. Continuous operation prevents buildup and minimizes environmental problems or obstructions to river passage. Debris removal is automated to minimize human interaction, labor expenses, and safety issues. To particularly target particular litter types, such as plastics or organic debris, the system may be customized to solve a particular pollution concern. By doing so, pollution's negative effects on the ecosystem are lessened. Conveyor capture systems may also be scaled up to fit various water regions, from little ponds to enormous rivers or oceans. Their adaptability to different situations is optimized by their scalability. In conclusion, a conveyor system offers an automated, effective, and scalable option for continuous and targeted trash collection, eliminating human work and intervention while lowering environmental impact and minimizing wildlife casualties.

2.4 Decision Analysis Summary

When evaluating the most ideal solution to our problem definition, "*How can we optimize the removal of aquatic debris through the innovative utilization of upcycled materials?*", we wanted to narrow down to a decision that embodied the most prevalent ideas from our stakeholders:

a. Durable and deployable in a varieties of circumstances:
b. Cost-Effective
c. Low-Income Communities
d. Small bodies of water
e. Collects micro waste which is a great contaminant in sources of drinking water.

After additional consideration in our decision-making process, we selected one of the six various alternatives we had narrowed down from our original concepts as the final prototype. Wefirst started with idea generation by writing down our ideas and drawing a mind map where we put notes around different categories, grouping them together as a form of clustering as seen in Figure 27.

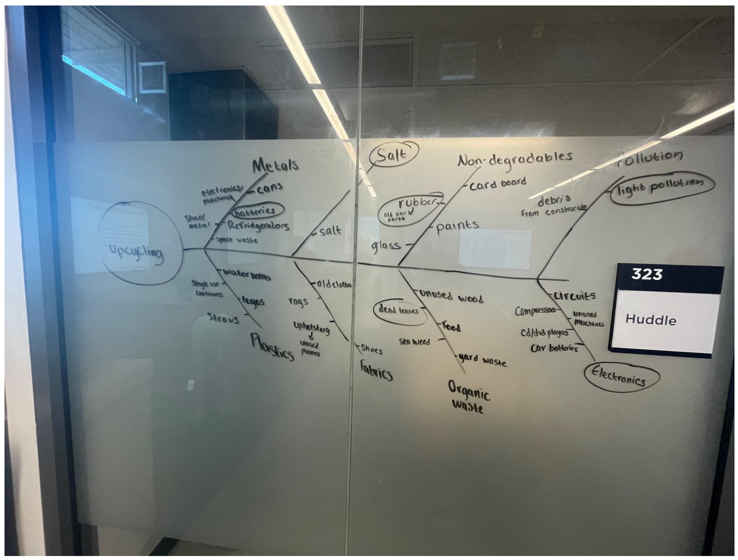


Figure 27: Original Mind Map

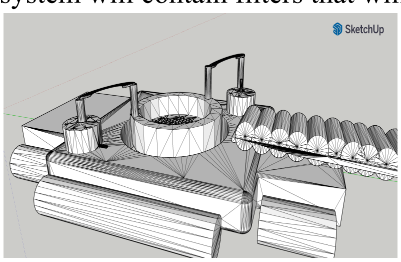
The most significant takeaways from this map were that our strategy needed to be modified for practicality. We found that the non-technical solutions category contained the most ideas since these options had the best possibility of coming to pass. In light of this, the group went on to compile and store online about 75 different concepts. After team consolidation, we discussed and compartmentalized each idea into a grouping. The project criteria were used to further define this classification. As a result, we defined our problem and came up with nine different prototype ideas: the Riverbarge, the Ocean Roomba, the Water Wheel Filter, the Disaster Buoys Capture, the Digitized App, the Biowaste, the Wall-E Ocean Compactor, the Explosive Detonation Removal, and the Glass Dome Protection. Our team developed a choice matrix for the six initial prototypes that emerged from the democracy after taking into account every condition that must be fulfilled for our final design to be successful. We came to the conclusion that the most crucial features of our design must be viability, completeness, attractiveness, sustainability, and practicality. Of these aspects, desirability holds the most weight because our final design must have interest from our key stakeholders, otherwise the other aspects of the design won't matter. A product will fail if we design it in a way that our stakeholders cannot use it. The final design had to be something our team could reasonably develop throughout the course of the remaining semester, given time limits and cost considerations. This was a specific concern. To gain a deeper understanding of each individual category, the team took a deeper look into each of the nine ideas through the use of a decision matrix, as seen in Table 5.We created a design matrix to weigh the different aspects of our five designs. Through this design matrix, we were able to narrow down to three top ideas, River Barge, Ocean Roomba, and Biowaste. Ultimately, after further research and discussion, our group decided to take attributes of each of these three ideas and combine them into a single concept. Keeping in mind our stakeholders, project requirements, and personal opinion, we develop a single design.

Table 5: Design Matrix

	Design Objectives:				
Design Alternative	Viability (cost)	Desirability (enjoyment)	Ability to Finish	Feasibility	Overall Score
Riverbarge	5	4	5	5	4.75
Ocean Roomba	5	5	3	2	3.75
Water Wheel	5	5	5	5	5
Disaster Buoys	5	1	5	5	4
App Idea	5	1	2	5	3.25
Biowaste	5	1	5	5	4.0625
Wall-E	3	5	2	1	2.75
Bomb	0	0	0	0	0
Glass Dome	0	5	2	0	1.75
Scale: 1 to 5; Rate Worst To Best.					

2.5 Proposed Final Design

Ocean Buster's final design for addressing water waste contains a dual system which will collect surface trash as well as filtering the river underneath. The *RIC* (River Interceptive Collection) system consists of five key components. The "bridge" holds all components together and acts as the base of the system. The "pulley" controls the collection area and allows access to collected waste. The "flotation device" keeps the entire system level with the surface of the river, allowing the "conveyor belt" to collect surface level waste to be stored in the collections system. The "river straddle" system will direct the flow of water and surface waste towards the conveyor belt. Finally, the collections system will contain filters that will remove microwaste from the river as it flows through *RIC*.



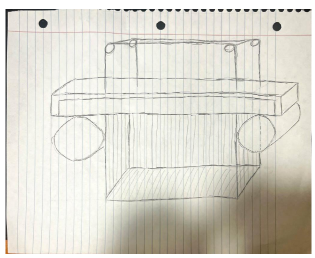


Figure 28: Cad model of RIC (left)
Figure 29 Hand Drawn model of RIC (Middle)
Figure 30: Picture of looks-like prototype (Left)

Table 6: Material and System Requirements

	Materials	System
Requirements	• **Waterproof** • **Non-Corrosive** • **Non-Degradable** • **Durable** • **Upcycled (preferably)**	• **Cost effective** • **Efficient** • **Serviceable** • **Adjustable for river size**

2.6 Module 2 Summary

Throughout our brainstorming process we came up with multiple solutions to address many different parts of our problem solution. A few examples include: An ocean roomba to clean up trash on the surface of the water, but this did not seem feasible for our group who is not near the ocean, and there are many boats that already address this problem; A water wheel that produces hydropower so that it can run itself while it cleans the water using buckets, which was a close second to our main solution, however it didn't address micro-waste or waste under the water's surface; Disaster buoys that would collect trash after a natural disaster, however again was not achievable for our group who has never experienced a natural disaster in Colorado. In the end, we created our design to cater to all of these aspects. *RIC* will be a two part system. One part will collect macro-waste by skimming the surface, and the other will be a collection system under the water to collect micro-materials under the surface. Both parts will be accessible using a pulley system, and the whole design would be built by upcycling old, unused materials, and so they would not cost much, and be accessible to those in lower income areas as well by being cost effective and efficient for the job at hand.

3.0 Subsystem Build and Validation

Analissia Wise

3.1 Subsystem Description: Bridge

The Bridge acts as a connecting system. It connects the river straddle system, the collection system, as well as the floatation system. The bridge is the aspect of our design that will float on the water, due to the floatation systems connected. The collections system will be removable from the bridge in order to allow cleaning. The river straddle system is a multi- purpose system. It will redirect the flow of the trash to our device, but will also keep our device stationary in the river.

3.1.1 Refer to the Scaled-Up Solution

The scaled-up version of the Bridge will vary in size depending on the width of the river. The bridge holds everything together and all the other subsystems rely on the bridge, therefore the bridge needs to be able to support itself as well as all the other systems. The bridge will be made from an upcycled wooden pallet and sealant to protect it from water in the river and weather.

3.1.1.1 Objective of Subsystem

The bridge's primary objective is to allow the device's subsystems to all function and cooperate together. It keeps our device floating and allows our device to achieve its purpose of cleaning the river. The overall objective of our device as a whole is to clean trash out of a river, so the bridge helps keep all the subsystems together in order for all of them to work together to achieve its purpose.

3.1.1.2 How Does the Substem Work

The bridge will be a wooden pallet, with all the subsystems attached. The Bridge will float due to the attachment of the floatation devices. The Bridge will be cut in the middle to allow the collection system to lower into the water when it is needed to collect trash and rise when the collection system needs to be cleaned.

3.1.1.3 Subsystem Inputs

The bridge itself does not need any other inputs to allow it to do its responsibilities, however for our whole design to come together the inputs for the bridge would be the collection system, floatation devices, and river straddle system. These will all connect to the bridge to bring our whole design to life. The bridge will need a sealant to protect it from the water and potentially decaying.[55]

3.1.1.4 Key Subsystem Components

The bridge is only the wooden pallet, so it doesn't have any extra components necessarily. The separate components will be the connection of the subsystems. The Bridge will however include a cut in the front in order to leave a section for the collection system as shown in Figure 31. The cut in the front will allow our collection system to lower into water and when full be able to be pulled back up for cleaning.

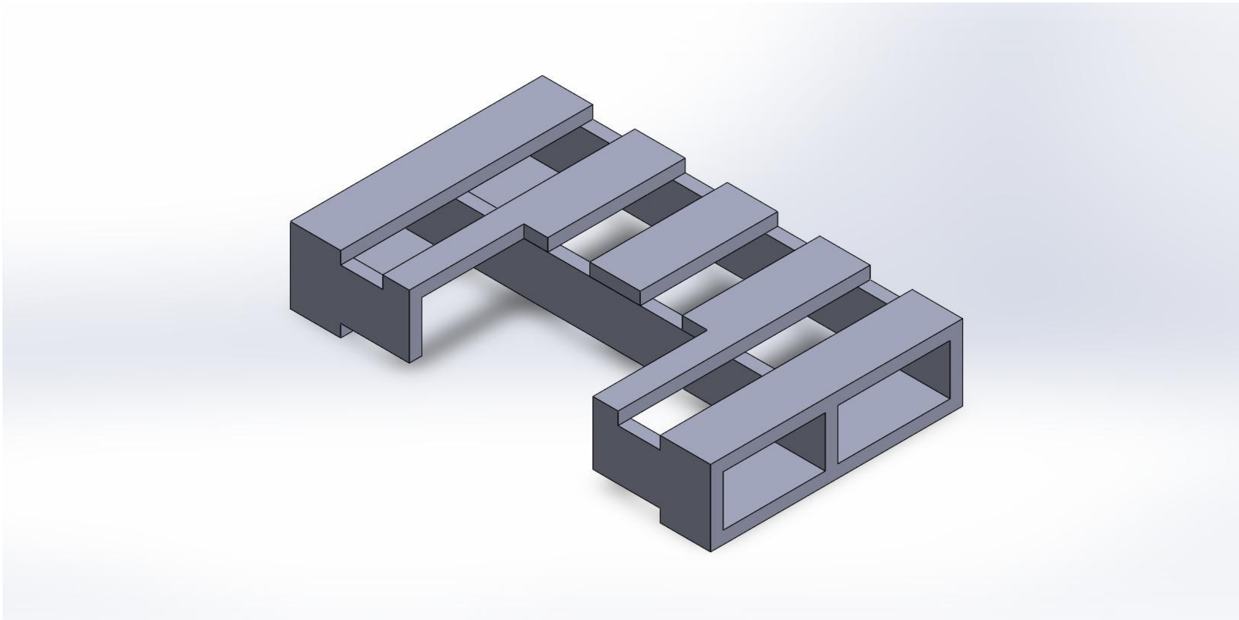


Figure 31: Solidworks model of the bridge design

3.1.1.5 Off-the-Shelf Components

Sealant and screws will be off the shelf components needed for the bridge specifically. Sealant will be needed in order to seal the wooden pallet and make it waterproof so that its condition stays reliable and isn't altered due to absorption of water.[56] We will need nails or screws in order to attach the river straddle system to the wooden pallet.

3.1.2 Physical Properties of the Subsystem

The bridge will be a wooden pallet and the dimensions can vary depending on the width of the river, we will currently use an average size wooden pallet being 48''x40''. Our wooden pallet will then be cut in the front for a spot for our collection system. As shown in figure 32. The wooden pallet would have no other modifications to its original design other than the front cut. The other subsystems will be attached via rope or by screws.

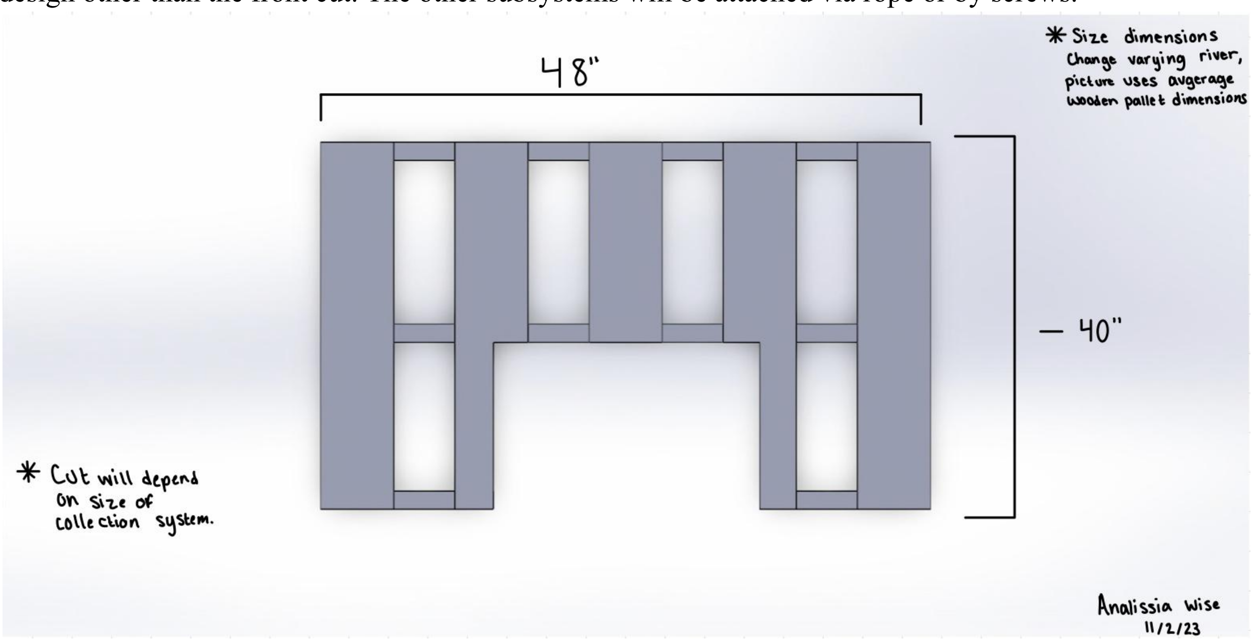


Figure 32 : Solidworks model with an average wooden pallet size

3.2 Idea Generation and Decision Making

Initially the bridge was going to be the same object and fully connected to the collection system, but it was decided that it should be separate in order to allow removal for cleaning. The bridge also was discussed to be fully buoyant itself, so we didn't need floatation devices, however it would interfere with the collection system and cause more difficulties. The other materials we came across were factored out based on the decision matrix. Plastic and plastic pallets were an idea and could have been upcycled however wooden pallets aren't as risky and don't offer the same benefits as wood.[57] The wooden pallet was overall the best decision because it allowed for things to be separate, it was able to be upcycled, and it made it easy to connect with other subsystems without disturbing them. When deciding on the object we will use we realized with the fluctuation of river sizes, we will need an object which can be altered size wise without its properties being disturbed which ultimately helped us decide on the wooden pallet being the best option. There are also around 500 million new pallets made every year due to them being one of the basic building blocks of supply chains, meaning that there are plenty to upcycle and give new purposes to.[58]

Table 7: Bridge Decision Matrix

Ideas	Time Commitment	Availability (Is it easily upcycled)	Interference with other subsystems	Easiness to connect other subsystems	Size	Total
Wooden Pallet	8	10	9	8	10	9
Tote Bin	6	4	2	4	6	4.4
Plastic	6	6	3	3	3	5

3.3 Validation of Subsystem

3.3.1 Test Results

The bridge testing is important. We need to make sure that the bridge's structural integrity is strong enough to withstand the river's current while having to hold the other subsystems as well.

To test the bridge we will test multiple times, first we will test it with the floatation devices and river straddle system to make sure they are able to keep the bridge afloat and stationary. Next we will test it with the conveyor system and collection system to see if the bridge is able to hold everything in the correct position to collect trash while staying afloat and stationary.

3.3.2 Analysis and Calculations

Analysis and Calculations are dependent on the size of the river. Calculations will depend on the width and depth of the river. There is no designated size the bridge will need to be for each river, however we will make sure that the bridge is not occupying too much or too little of the river.

3.3.3 Secondary Research

Research will be conducted for the type of sealant needed to best protect the wooden pallet. We will research and approve the sealant, in order to have our bridge be protected from the river and weather conditions. The bridge needs to be strong enough to support the other subsystems, so strength of the bridge is important which is why we need to research and take precautions when protecting the condition of the bridge. We also researched about the bridge and what would be the best upcycled material, we decided wooden pallets because they are more environmentally friendly than other material and have strength that could withstand the force put on it by the devices.[59]

3.3.4 Stakeholder and Expert Feedback

Communication will be done with stakeholders to validate the material decision. We will use the advice from our stakeholders to keep our wooden pallet with sealant or if we will need to take additional precautions in order to allow our system to work as intended with no set backs.

Keegan Dwyer

3.1 Subsystem Description: Floatation System

The flotation system is responsible for keeping the entire device afloat. The system will be made of a durable, watertight material, and will be attached directly to the bridge of the device. The flotation system will need to be buoyant enough to hold the entire weight of the device level with the surface of the river. The flotation device will be two 5-gallon water containers sealed to be water tight, and secured to the bridge of the water cleaning system.

3.1.1 Refer to the Scaled-Up Solution

The scaled-up solution depends on the size of the river. The larger the span of the river, the larger the cleaning device should be. Regardless of the size of the cleaning device, the flotation system will still need to support the weight of the device. The larger the device, the larger the flotation system will need to be. For smaller rivers, 5-gallon water containers will suffice, but for larger rivers, the flotation system may need to be 50-gallon drums.

3.1.1.1 Objective of Subsystem

The objective of the flotation device is to keep the river filtration device level with the surface of the river.

3.1.1.2 How Does the Substem Work

The subsystem will be secured to the bridge of the river filtration system to keep the entire device afloat.

3.1.1.3 Subsystem Inputs

The subsystem will interact with the river and the bridge. As the river flows, the flotation device will keep the device level with the surface of the river.

3.1.1.4 Key Subsystem Components

The flotation subsystem will consist of two separate, water-tight, and durable 5-gallon water containers.

3.1.1.5 Off-the-Shelf Components

There will be no off-the-shelf components. Both of the 5-gallon water containers will be collected from family members who no longer need them and recycled.

3.1.2 Physical Properties of the Subsystem

- Water Tight
- Durable
- Non-Degradable
- Large enough to sustain the weight of the river filtration system

3.2 Idea Generation and Decision Making

Originally, the team believed that a 50-gallon tank would work perfectly as a flotation system for the river filtration device. After careful consideration, using the 50-gallon drum as a flotation system began to make less sense as it would be too large to bring into the classroom. The team’s second idea for a flotation system was to use 2-liter bottles. These are the right size for the works-like prototype, and are easily available, however, the plastic is flimsy and would be prone to damage from the current of the river. Ultimately, a 5-gallon water container makes the most sense to use for a flotation system as it is easily available, durable, and the correct size to attach to the river filtration system.

Table 8: Flotation Subsystem design matrix.

Ideas	Time commitment	Availability	Interference with other subsystems	Easiness to connect other subsystems	Size	Material	Total
2-liter water bottles	9	10	9	8	7	7	50
5-Gallon Water container	9	10	9	9	10	10	57
50-gallon Drum	6	6	7	4	2	10	35

3.3 Validation of Subsystem

3.3.1 Test Results

The flotation device will be tested to ensure durability and buoyancy. The device should be submerged in water to prove it is watertight and capable of holding up the weight of the river pollution collection system.

3.3.2 Analysis and Calculations

The calculations for the flotation device depends on the size of the river filtration device. The larger the filtration device, the larger and more buoyant the flotation subsystem will need to be. The flotation subsystem will need to be buoyant enough to support the weight of the device, keeping it afloat.

3.3.3 Secondary Research

There should be no need for secondary research. As long as the flotation system is durable, water-tight, and buoyant enough to support the weight of the river filtration device, then no further research will be required.

3.3.4 Stakeholder and Expert Feedback

After meeting with stakeholders, primarily Professor Cath, the team decided that the flotation device should not only be buoyant, but also be non degradable. It would be unwise for the team's device to pollute the same water that the device should be cleaning.

Abi Strait

3.1 Subsystem Description: River Straddle System

River Straddle System Pt. 1: Funnel Walls

The primary purpose of the river straddle system is to funnel the trash on the surface of the water into the converybelt so that it can be pulled into the collection system with the rest of the aquatic debris. Required inputs for this part of the river straddle system is the trash and the energy from the water current, in order to output cleaned water. The river straddle system will be two symmetrical pallets that will be wider on the end connected to the bridge, than on the end farther from the bridge. It will look much like a trapezoid. As mentioned before, the wider part of each wall will be attached to the bridge, which connects all parts of our design. The walls will be vertical to the water, and diagonal to the current, in order to maximize the amount of surface trash that we bring into the collection system via the funnel system.

While creating the funnel system, our team first thought of using wooden pallets for the walls; however, this was an expensive, and not very appealing idea due to the walls blocking the view of the body of water. Then, our team moved to the idea of using a buoy type system, much like local pools use to separate different parts of the pool. Although this fixed our money and visual appeal problems, it posed an issue of efficiency, because it was possible that the trash would roll under the buoys and defeat the whole purpose of the funnel system. After much consideration, our team agreed upon an inexpensive, reliable material that would accomplish the goal of the funnel system: pool noodles. Pool noodles are often thrown out after only a few uses, which makes them an ideal material to upcycle.

On our works-like model, the pool noodles will simply be hot glued together for stability, but for the real version of our river barge, the noodle noodles will need more reinforcement to fare against the current, which might include sewing them together, or creating multiple layers for more support. Additionally, our works-like model will only be about three feet long (actual dimensions are listed below), but the actual dimensions of our design are intended to change for each body of water, so that the river barge can fit across the whole mouth of the body of water. For our works-like model, the river straddle system will be composed of pool noodles laid on top of each other and hot glued together, then screwed to the edge of the bridge. The walls will rest slightly below the surface of the water, which the buoyancy of the pool noodles is intended to help with. The hope for the river straddle system is that as macro-waste - large pieces of aquatic debris - float down the river with the current, they will hit the walls of the river straddle system and be funneled into the conveyor belt portion of the river barge, in hopes that the trash will eventually end up in the collection system where it can be cleaned out.

River Straddle System Pt. 2: Rope Connector

The secondary purpose of the river straddle system is to connect the river barge to the land around it so that it can stay in place against the current, and so that it can withstand effects from nature, such as strong winds. Inputs for this part of the river straddle system include the weather, in order to output stability for our design. The rope will be made from paracord due to its reputation to withstand strong forces (paracord is often the top choice for outdoor activities such as rock climbing), and since the rope will ground our whole design, it is imperative that it is strong enough. While paracord is the ideal rope solution for the rope connector, it's strong physical properties make it a material that withstands almost anything, and can be reused many many times, so consequently, it is not thrown out very often. This means that for our works-like prototype, and most likely for the real sized version, the paracord used for the rope connector will be bought instead of upcycled. The other material used for the rope connector will be tent stakes, to attach the paracord to the ground, but these are thrown out often enough to be upcycled. The rope will be screwed to the top of the bridge, and attached to the ground with the tent hooks to keep the river bridge secure in place.

3.2 Idea Generation and Decision Making

Table 9: River Straddle Decision Matrix

Ideas	Time Commitment	Availability (Is it easily	Interference with other	Easiness to connect other	Size	Avg

		upcycled)	subsystems	subsystems		
Pool Noodles	8	10	9	8	10	9
Wooden Pallet	6	4	2	4	6	4.4
Pool Buoys	6	5	3	3	3	5

3.3 Validation of Subsystem

3.3.1 Test Results

There will be three distinct tests for the river straddle system that will all take place in Clear Creek to test the subsystem and complete design against real simulations. The first test will be of the river straddle subsystem by itself to make sure it floats and holds up against the hardships of nature, such as wind. This first test will be making sure the structural integrity of the individual subsystem won't let the whole system down. The second test will be of the river straddle subsystem with the bridge, to make sure that both of those subsystems will hold up together, since that will be the subsystem that the river straddle system will be attached to. The third and final test will be of the whole system together, to make sure that all subsystems work together, and no subsystem interferes with the function of another. While there are three distinct tests, if any of these tests fail, we will regroup, reconstruct the failed subsystem(s), and test them again until we succeed.

3.3.2 Analysis and Calculations

The analysis and calculations of the river straddle system will be based on two factors. The first factor is the width of the mouth of the individual rivers/ bodies of water, since this will affect how big the design will be. The second factor will be how big our team makes the bridge, which will be determined after we get our wooden pallet this Sunday.

3.3.3 Secondary Research

Our team did research on each type of material for the river straddle system to see which one would be the best pick. Out of the research for the ropes, paracord was the most reputable for withstanding bad weather, and although it is expensive and would not be upcycled, it is important that the rope we use has strong physical properties since it will be holding our design together. For the funnel systems, pool noodles were the most optimal material because of their light physical properties and buoyancy without rotating.

3.3.4 Stakeholder and Expert Feedback

Stakeholders will be contacted about each of the design's subsystems to see if each one will work without affecting anything in the environment. Pool noodles and paracord will most likely not have any problems since both are used in aquatic settings already.

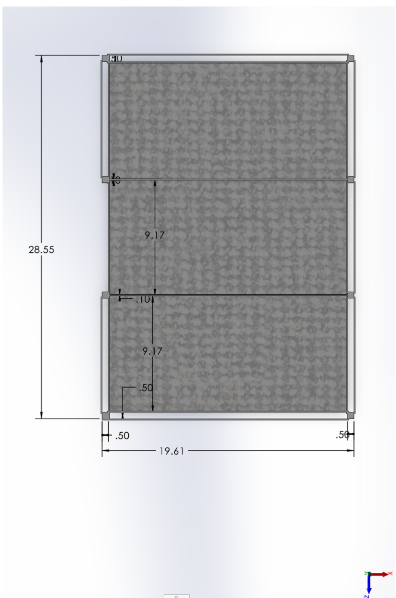
Robert Davis

3.1 Subsystem Description: Micro Waste Collection System and Sensors

The underwater collection system is a component of the river collection system for collecting micro waste. It consists of a metal wire-barrier supported by PVC pipes and a metal mesh grating to capture waste. A frame is constructed to attach the mesh to the collection unit. The ultrasonic sensor (HC-SR04) is paired with an ESP32S microcontroller. The sensor is responsible for detecting the level of waste collected in the system by measuring the distance from the sensor to the waste surface.

3.1.1 Overall Objective of The Subsystem

Under the bridge, the micro waste collection system will be composed of four pvc-pipes supporting a metal wire-barrier which would ensure no micro plastics escape the enclosure. Situated perpendicular to the collection system's walls, which are parallel to the river, a metal mesh grating serves the purpose of collecting micro waste coming into contact with the collection system. To connect the mesh to the greater collection system, a frame the exact dimensions of the micro waste containment unit is constructed.



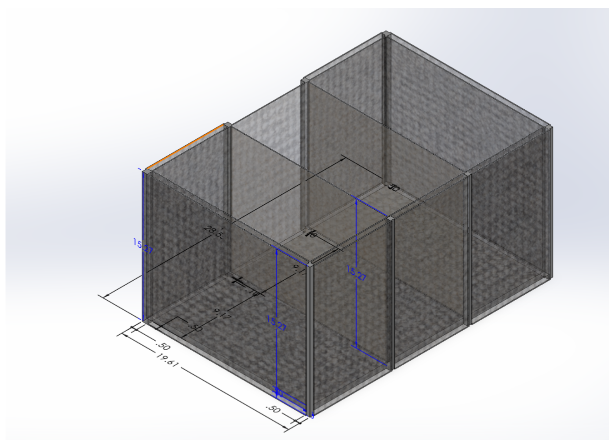
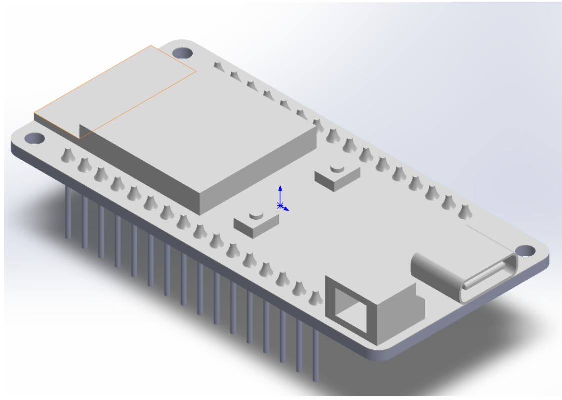
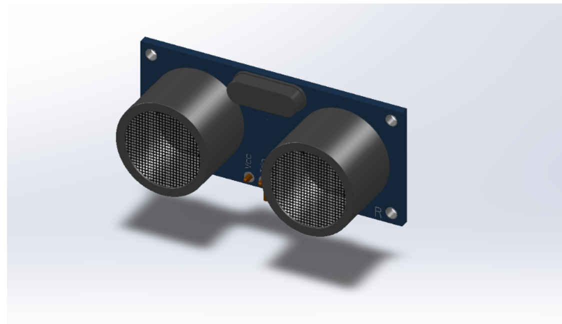


Figure 33: depicts top view of microplastic collection system (left)
Figure 34: depicts isometric view of microplastic collection system (right)

Within the above ground waste collection system, an HC-SR04 ultrasonic sensor connected to a ESP32S microcontroller and breadboard circuit lie within the inner casing of the collection system, measuring the distance from the top of the container the waste has accumulated. Powering the circuit, a 5000maH battery is also connected to the waste collection system. To waterproof the circuit, the circuit will sit within a junction box of similar dimensions. The ESP32S's built in radio will be leveraged to send a notification to the user via the Blynk cloud computing system, detailing the battery of the circuit as well as the how full the collection system currently is.





[49] Figure 35: depicts EPS32 (right)
[50] Figure 36: depicts ultrasonic sensor (left)

3.1.2 How The Subsystem Works

The micro waste collection system works by trapping underwater waste within an underwater containment unit. The micro waste collection system is supported by eight pvc-pipes (four on each side) serving as the posts for the chicken-wire grating which is to be wrapped around the perimeter of the contraption. Once miro waste makes its way through the chicken wire, the mesh system (seen in between the pvc pipes) traps the underwater waste using 0.3mm mesh screens coated with a polyurethane adhesive. By using a mesh, water may flow through, however, the unintended consequence is smaller pieces of microwaste, some invisible to the human eye which oftentimes contaminates drinking water, flow through the mesh and never get caught, therefore, a smaller 0.15mm mesh will be situated behind the 0.3mm mesh. The reason we won't use the 0.15mm mesh to begin with is because of concerns of crowding. The micro waste will accumulate on the surface of the mesh screen. Having two mesh screens, one for larger debris, and one for smaller debris, allows us to tackle two problems in one: overcrowding and too small debris seeping through the cracks of the larger mesh screen which will be reserved for larger pieces to reduce crowding.

Once the above ground waste units have been filled, an ultrasonic sensor will allow us to detect the distance from the sensor itself (which will be situated at the top of the waste collection system) to the level where waste has accumulated. The sensor will be a ESP32S microcontroller connected to a soldered breadboard and HC-SR04 ultrasonic sensor. The ESP32S is compatible with the arduino IDE, even having its own dedicated library. The ultrasonic sensor will be operated on a timed interval, detecting distance periodically, how often depends on our testing, how frequently should the ultrasonic sensor operate to ensure maximum battery life? The circuit will use a 5000 mah usb battery which is compatible with the ESP32S board we've chosen. To ensure protection from water which might splash onto the sensors, we will use a junction box to protect the circuit, ensuring imperviousness. The ESP32S microcontroller has a built in radio, which through cloud computing software Blynk, can send an email to the operator to service the above ground waste collection system. The cost to use Blynk is trivial, as it's based on how often messages are sent, which for our purposes will be very infrequent. The Blynk software is also compatible with C++, which will be used in the arduino microcontroller.

3.1.1.3 Required inputs

Required inputs for the micro waste collection system include microwaste and human-operated users periodically cleaning the system. Because the entire collection system, including the under and above water portion, is removable, the cleaning system then means re-coating the mesh in the polyurethane adhesive and removing the already accumulated waste. Once the mesh system has become too worn, the mesh can be replaced by simply removing the frame, removing the old mesh, and inserting a new one.

Inputs for the sensor include power, provided by the power supply. Inputs for the microcontroller include data from the ultrasonic sensor and power from the power supply connected to the breadboard, connected to both the ultrasonic sensor and microcontroller. Inputs from the user operator include the message from Blynk cloud computing software used to communicate the status of how full the above-ground collection system is.

3.1.4 Key subsystems

Key subsystems of the micro waste collection system include the increasingly smaller screens and the larger containment unit which acts as a housing for the mesh screens. Ket systems of our sensors include the microcontroller, the ultrasonic sensor itself, the breadboard, the jumper cables connecting the components, the waterproof junction box housing the components, and the battery powering all the components.

3.1.5 Off-The-Shelf Components

Off The Shelf Components Include**:**

- *Microcontroller (*ESP32S*) ($13)*
- *Battery ($13)*
- *Usb to usb cable ($7)*
- *Ultrasonic Sensor ($6)*
- *Casing for microcontroller and ultrasonic sensor ($9)*
- *Breadboard (x2) ($14)*
- *Electrical Glue ($8)*
- *Mesh Screen ($15)*

3.2 Idea generation

Initially, we didn't plan on focusing on microwaste, we wanted to focus exclusively on macro waste. However, our stakeholders expressed deep interest in a solution to smaller pieces of waste which oftentimes go undressed. The solution was obvious, we would have some sort of underwater collection system for non-buoyant types of micro waste which wouldn't be collected by the above ground portion. We initially had three very good ideas about how to implement this. First, was the "large open container" idea, which was an idea to have a sort of dam created underneath our contraption. However, this was flawed because it would disturb water movement, and micro waste could flow out again. The idea to use a mesh system to trap the waste within this containment unit was also suggested, however, this didn't address the problem of obstructed water movement and if microwaste was small enough to flow in, they're small enough to flow right back out. Then, Martin Vince proposed the idea of using a mesh screen coated in a waterproof adhesive. However, the obvious problem was the mesh screen being filled. At least in the "large open container" solution, we didn't really have to worry about the volume being filled since the waste was so small. So, the idea was proposed to use two mesh screens, one large and one small to maximize space (if we had more resources to spend, we could use more, each being increasingly smaller than the last).

Table 9: River Straddle Decision Matrix

	Doesn't Disrupt Water	Effectively Traps Micro Waste	Effective Area/Volume
Large Open Container	✖	✖	✔
Large Open Container + Mesh	✖	✖	✔
Increasingly Smaller Mesh Screens + Adhesive	✔	✔	✔

The reason we used pvc pipes and a chicken-wire perimeter was to ensure that the micro waste collection system met the same dimensions as our above water collection system while having a variable length according to how deep the river is.

To tell when it was time to collect the above ground waste, we considered three solutions, using a human operator, a camera, and an ultrasonic sensor. With a human operator constantly checking the system, it involves going to the location, roping in the device, and deconstructing it to tell when the trash level is full. If we were to use a sensor, which sensor we'd use was a matter of debate. We could use a camera operated by a human operator, however, that'd be too cost and power intensive sending video wirelessly. We could use a camera using computer vision, however, this was far too complex. We'd have to train our algorithm to detect trash, which would take lots of time, and machine learning is, well, difficult. The most obvious solution is using an ultrasonic sensor, however, ultrasonic sensors are notoriously unreliable. However, of the three, it seems to be the most realistic solution.

Table 10: Sensor Decision Matrix

Key: 1(Worst)-5(Best)

	Cost/Feasibility (x1)	Effectiveness(x1)	Complexity(x1)	Total
Human Operator	1	5	2	8
Camera (using a machine vision)	3	4	1	7
Camera (using human operator)	1	5	2	8
Ultrasonic Sensor	5	3	3	11

3.3 Validation of Novel and Unique Design Aspect

3.3.1 Test Results

Micro Waste Collection System

The micro waste collection system should be structurally sound, enough so to withstand non-trivial bad weather conditions. Testing should include simulated effects due to bad weather events. Furthermore, testing should include medium-term corrosive effects which might occur.

Table 11: Depicts test type, test objective, and testing method

Test Type	Objective	Method
Visual Inspection	To identify obvious structural defects.	Examine all visible parts of the device for cracks, corrosion, or other signs of wear.
Load Testing	To simulate weight and pressure.	Apply weights or force to components to simulate the stress from debris and water during a storm.
Flexibility	To check component connections.	Manually manipulate connections to ensure they have the necessary range of movement and can withstand weather forces.
Debris Simulation	To understand debris impact.	Manually throw or float various types of debris at the system to see how it collects and affects the structure.
Vibration Monitoring	To measure resistance to shaking.	Vigorously and violently shake the micro waste collection system

Sensors

- Works Test: Test whether the ultrasonic sensor detects the waste level when full.
- Projecticles: Throw projectiles at our sensors
- Unexpected Waste: Sharp and abnormally heavy objects are types of unexpected waste we might encounter, we should test if the system can withstand these forces.
- Waterproofing test: Spray and submerge system

3.3.2 Analysis and Calculations

Micro Waste Collection System

Design Requirements

Table 12: Micro Waste Collection System Design Requirements.

• Maximizes available space to store microwaste
• Traps micro waste of varying sizes
• Structurally integral
• Doesn't allow waste to escape
• User serviceable

Table 13: Micro Waste Collection System Dimensions.

Outer Dimensions		Mesh Dimensions	
Length	28.55 in	Width	18.6 in
Width	19.6 in	Height (dependent on outer dimensions)	~15.27 in
Height (variable)	~15.27 in	Area (variable as a function of height)	~284 in^2
Volume (variable as a function of height)	~27 gallons	First Mesh Hole Diameter	0.15 mm
Mesh outer hole diameter	51 mm	Second Mesh Hole Diameter	0.30 mm

Table 14: Micro Waste Collection System Materials.

Material Type	
Inner Mesh	Stainless Steel
Outer Mesh	Galvanized Steel
Poles	polyvinyl chloride (pvc pipes)

Table 15: Micro Waste Collection System Weight.

Weight/Construction

Inner Mesh	n/a
Outer Mesh	n/a
Poles	~0.45 lb/1ft^3

Sensors

Design Requirements

Table 16: Sensor Design Requirements

- Moderate degree of accuracy
- Weatherproof
- Durable
- Reliable

Dimensions (Length*Width*Height)

Table 17: Sensor Dimensions

EPS 32	4.45 x 4.13 x 0.79 inches
Ultrasonic Sensor	4.92 x 3.35 x 1.73 inches
Junction Box	n/a (container will scale to the size of construction once finished)
Breadboard	2.17 x 3.31 x 0.35 inches
Battery	3.66 x 2.4 x 0.55 inches

3.3.3 Stakeholder and expert feedback

Once the subsystem has been constructed, there are numerous stakeholders I plan to involve in the feedback process. [45][47] The EPA and WM (Waste management) to learn how we can effectively manage collected waste, as well as ocean cleanup as to the effectiveness of our microplastic collection solution. [48] Furthermore, we plan to consult the Transfer Station and Recycling Center for Clear Creek County. Lastly, we plan to consult the Golden CO Congressional District in implementing our solutions in local water sources.

Martin Vince

3.1 Subsystem Description: Conveyor System

3.1.1 Refer to the Scaled-Up Solution

The collection system within the RIC is an essential tool for managing and accumulating macro and micro trash in rivers. Within the center of the bridge, the collection system is broken down into two smaller subsections. The surface-level collection and the underwater collection The following information pertains to the surface-level collection subsystem. Within the surface collection system will be the portion of our RIC that collects macro waste floating on the surface level of the river. The macro trash collection system will consist of an upcycled tub that is connected to the bridge. Its excellent efficacy in eliminating garbage stems from its strategic placement near the middle of the bridge, which covers a significant percentage of the available river's surface. The system's efficiency is further increased by changes to its walls. This altercation includes the removal of the front wall perpendicular to the river's flow and the replacement of the back wall with a thin mesh structure. The RIC's surface-level collection system will effectively manage and regulate macro-waste in rivers. Its design integrates advanced filtration systems with structural elements to provide efficient waste removal and protection.

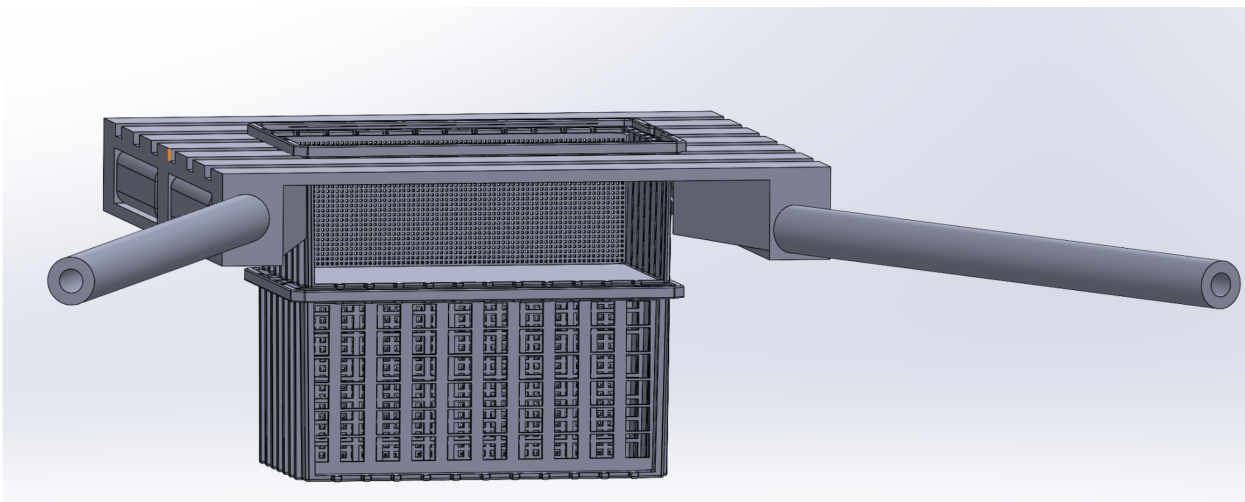


Figure 37: SolidWorks Rendition of *RIC*

3.1.1.1 Objective of Subsystem

Within the surface collection system will be the portion of our RIC where there is a subsystem that collects macro waste floating on the surface level of the river. The solution employs a repurposed polyethylene plastic tub as a bucket and is incorporated into the bridge framework. Acting as a bucket, the subsystem's front wall—which is angled perpendicular to the river's flow—is removed. Along this line, the rear wall, which is angled perpendicular to the river's flow, will be replaced with mesh. The subsystem walls' design captures and confines macroplastics and other non-biodegradable waste products, ensuring the passive buildup of big waste materials. The surface-level water collection system will passively collect large amounts of non-degradable waste floating into the collection system's opening and capture the macroplastics within the subsystem's walls. The system will also allow easier removal of the entire collection system through a set of handles located on either side of the system.

3.1.1.2 How Does the Substem Work

The water surface subsystem within the overall collection system works to efficiently capture and accumulate floating macro waste by utilizing a repurposed polyethylene plastic tub, acting as a bucket. Integrated into the bridge framework, several renditions are completed to effectively meet the required purpose.

- <u>Upcycled Polyethylene Plastic Tub</u>: The repurposed polyethylene plastic tub is situated perpendicular to the bridge walls, which are parallel to the river; the tub will act as a bucket. It ensures structural integrity and acts as a garbage container in addition to being the main component for collecting waste.

- Front Wall Removal: To ensure smooth waste material intake, the front wall of the subsystem is purposefully removed to allow unrestricted macroplastic flow into the collecting system. This wall is perpendicular to the river's flow.
- Rear Wall Replacement: To reduce water turbulence and facilitate waste capture, the rear wall of the subsystem will be replaced with a mesh structure. While efficiently trapping macroplastics and non-biodegradable waste items, the mesh structure allows water to pass through.
- Passive Waste Collection: Macro, non-degradable waste items are directed into the subsystem's opening by passive energy. Relying on the natural river flow, the subsystem's walls and mesh will capture and contain macroplastics and other non-biodegradable waste items that float on the river's surface and follow the current.

By utilizing these design elements, the subsystem will effectively and sustainably collect macrotrash, resulting in reducing surface-level river pollution.

3.1.1.3 Subsystem Inputs

Regarding the surface-level collection subsystem, some inputs required for functionality are periodic human involvement and cleaning, component replacement, and passive energy utilization.

- Human Operation: Frequent human involvement is an essential component of the system's functionality. This included periodic cleaning and maintenance of the subsystem. An example of this is the further removal of gathered macro trash from the collection system. This allows the system to operate smoothly without any blockages.
- Component Replacement: If needed, periodic component replacements would need to occur. In particular, the rear mesh component would need replacement if it became too worn out for functionality. This includes replacing the outdated mesh inside the system's frame with a new one in order to keep it effective at collecting trash.
- Passive Energy Utilization: One of the main concepts revolving around the surface-level collection subsystem is the utilization and involvement of the river's current. As the river's current naturally flows downhill, the subsystem takes advantage of this energy to function efficiently. The system operates passively, collecting floating macro trash that flows down the river.

3.1.1.4 Key Subsystem Components

Within the surface collection system will be the portion of our *RIC* there is a subsystem which collects macro waste floating on the surface level of the river. For the surface level subsection of our collection system, there are several key components needed to accomplish the intended purpose.

- Upcycled Polyethylene Plastic Tub: This is a container constructed from polyethylene plastic. Polyethylene is a type of plastic that is tough, chemical resistant, and adaptable. This tube will include handle cut-outs, designed for easier removal and cleansing of the entire collection system. [49]
- Mesh Component: In order to catch macroplastics and non-biodegradable garbage while allowing water to flow, a mesh structure is essential to waste collecting and filter systems. Its strong construction, precise opening size, and structural integrity are all features. Its functioning is ensured by routine cleaning and maintenance.

3.1.1.5 Off-the-Shelf Components

Off The Shelf Components Include**:**

- Mesh Screen Component ($10-15): Described above.

3.1.2 Physical Properties of the Subsystem

The following figures are the dimensioned sketches of the three portions of the housing subsystem. Refer to previous figures 47 and 48 for isometric models of each component of the subsystem. The tables have all other values for the individual components of the housing subsystem.

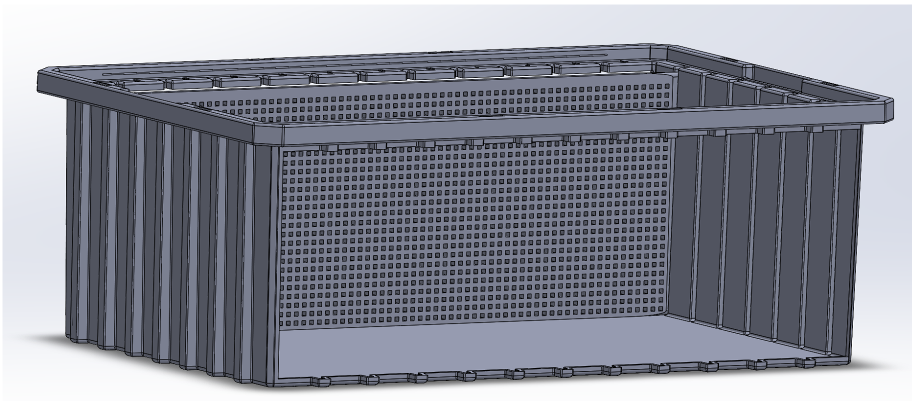


Figure 38: Front Isometric View of SolidWorks Surface Level Subsystem

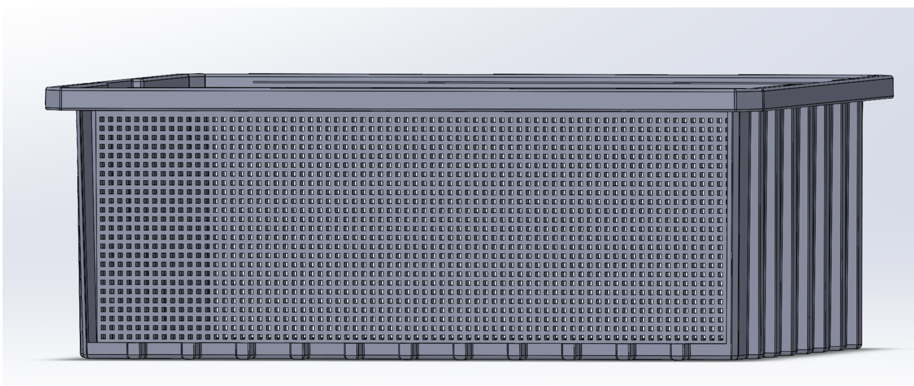


Figure 39: Back Isometric View of SolidWorks Surface Level Subsystem

Table 18: Collection System Specifications

Material Type	Polyethylene Plastic
Construction	Upcycled PP Tub with Side Cutouts (from appropriate tool)
Weight	1.52 pounds (0.69 Kilograms)
Dimensions	28.55" L x 19.61" W x 15.27" H (72.4 cm x 49.8 cm x 38.8 cm)
Thickness	¼ Inch (0.635 cm)
Volume	27 Gallons (102 Liters)

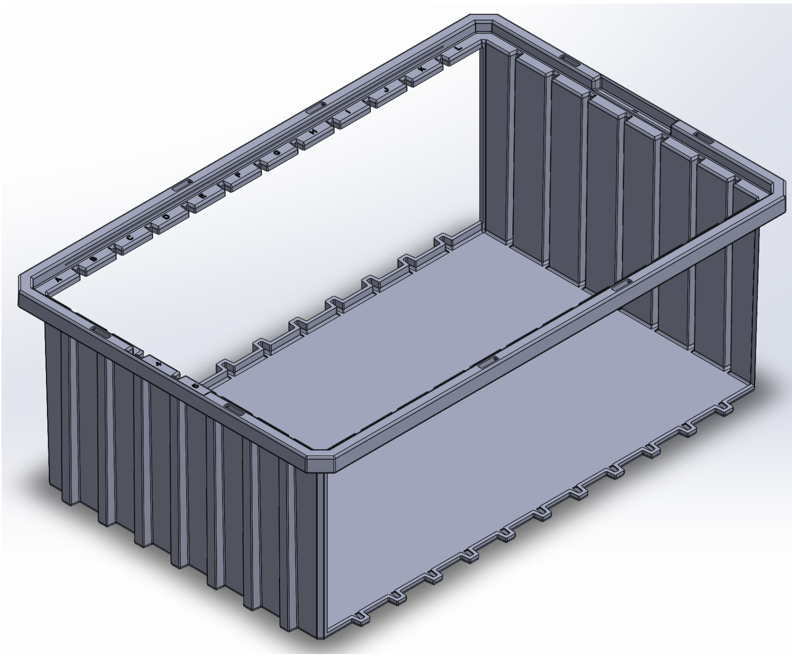


Figure 40: Isometric View of SolidWorks Surface Level Subsystem - Plastic Tub

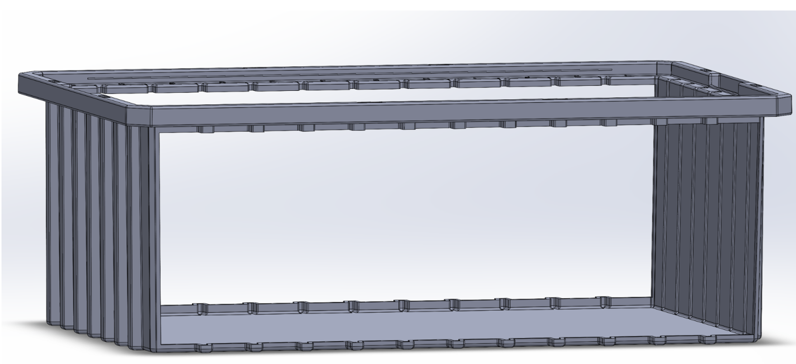


Figure 41: Front View of SolidWorks Surface Level Subsystem - Plastic Tub

Table 19: Surface Level Subsystem Specifications

Material Type	Fiberglass
Construction	Fitted/Cut (off the shelf item)
Weight	0.24 pounds (0.3.88 Ounces)
Dimensions	28" L x 1/10" W x 15" H (71.12 cm x 0.254 cm x 38.1)

Thickness	1/10 Inch

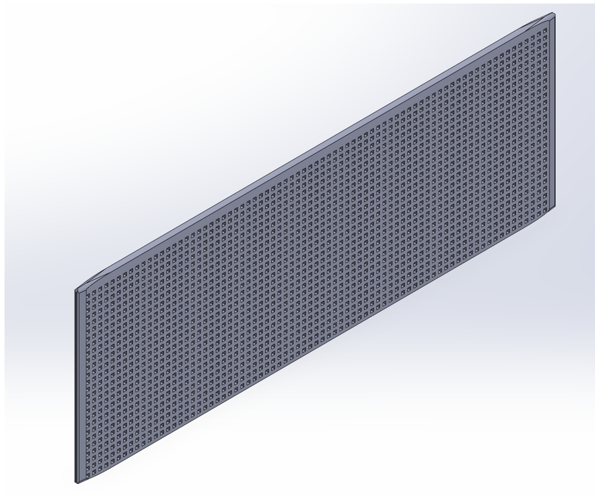


Figure 42: Isometric View of SolidWorks Surface Level Subsystem - Mesh Component

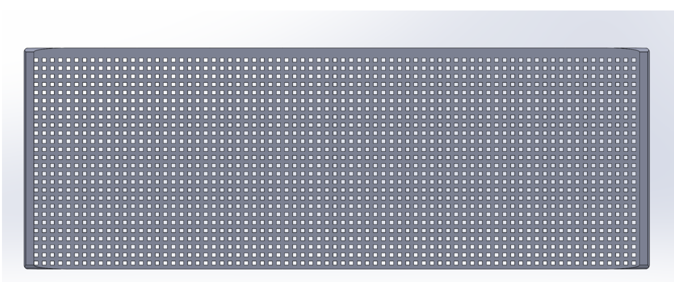


Figure 43: Front View of SolidWorks Surface Level Subsystem - Mesh Component

3.2 Idea Generation and Decision Making

The idea generation for the housing subsystem was modeled off of the idea generation steps that were conducted in Section 2.4. The initial ideas were generated with quantity in mind. The ideas were filtered to just a few of the highest quality, and then those were put to a vote and weighted on a decision matrix, Figure 11 The multipliers were given to each category based on their importance and final impact on the overall design. The individual values were assigned based on both real-world experience that we have as a team as well as feedback from the Cornerstone professor [43].The numerical values assigned to each category represent a scale: 10 (worst), 1 (best).

Table 20: Surface Level Collection Decision Matrix

Ideas	Time Constraint	Availability (Is it easily upcycled)	Interference with other subsystems	Functionality with other subsystems	Complexity	Size	Total
Screw Conveyor	7	8	8	6	8	8	9
Belt Conveyor	9	9	8	6	9	6	9.4
Passive Intake	4	2	5	3	4	4	5.2

The passive intake collecting system was selected as the final design choice over the screw conveyor and belt conveyor because of its lower complexity, minimum interaction with other subsystems, and better performance in terms of time efficiency. Out of the three options, the passive intake system had the lowest overall score, thus being the most advantageous. The decision matrix took into account the subsystem's availability, complexity, size, interaction with other subsystems, and time limitation. Compared to screw and belt conveyors, the passive intake system needed less time for installation and maintenance, making it a better option for achieving project deadlines. Because this system could be upcycled more, it was optionally considered through project requirements. The passive intake system's capacity to function more harmoniously within the current framework was also indicated by its lower interference with other subsystem scores. The passive intake system was selected in spite of its higher ratings in several categories because of its better time efficiency, less interaction with other subsystems, and simpler design. Upcycling potential may not have been as important in this project as meeting deadlines and making sure garbage collection actually functions smoothly. After taking these factors into account, the decision matrix determined that the passive intake system was the best option.

3.3 Validation of Subsystem

3.3.1 Test Results

The surface-level collecting subsystem will be put through three different tests. The "flow simulation" add-in for SolidWorks is needed for the first test. I will do a simulated mock-up of how the surface-level collection will respond to water flowing through the subsystem using this complex software. By utilizing SolidWorks for water flow analysis, the team can predict and maybe refine their findings prior to doing more testing. I'll carry out a similar examination for the full *RIC* after this initial batch of simulations. Clear Creek will host the following three tests. This is to make a comparison between the preliminary findings from the "flow simulation" in SolidWorks and the real outcome. The surface-level collecting subsystem by itself will be the subject of the first Clear Creek test. This is intended to ensure that it is resistant against natural adversities like erosion and is effectively developed. This test will ensure that the subsystems' individual structural integrity won't fail the system as a whole. The surface-level collecting subsystem with the bridge and river straddling subsystems will be tested again in Clear Creek. We are able to comprehend how each subsystem functions and holds together as a consequence of this examination. To ensure that no subsystem interferes with the operation of another and that all subsystems operate together, the system as a whole will be tested for the third and final time. Even if there are several tests, if any of them are unsuccessful, we will get together, rebuild the failing subsystem or subsystems, and test them once again until we are successful.

3.3.2 Analysis and Calculations

Two major aspects affect the success of the surface-level collection subsystem: how well it collects non-biodegradable macro garbage and how it affects the environment. The first component evaluates the subsystem's capacity to gather, hold, and remove macro waste from the water's surface in order to fulfill its primary function of cleaning and purifying the water body. Important factors to take into account include the intake mechanism's design, how well the mesh structure captures debris, and how frequently and effectively waste is removed. The second aspect explores the subsystem's operation's wider ramifications and effects, such as water displacement, wildlife conservation, and public opinion.

- Water Displacement: The subsystem's functioning may have an impact on water displacement and flow, thus it's important to make sure it doesn't interfere with the river's natural flow and may have unexpected downstream effects.
- Wildlife Conservation: In order to safeguard and maintain the natural ecosystem, wildlife conservation procedures have to be implemented.
- Public Opinion: Human opinion is also very important, as the success and sustainability of environmental initiatives depend on how the local community and other stakeholders view the subsystem and how the public accepts it.

3.3.3 Secondary Research

n/a

3.3.4 Stakeholder and Expert Feedback

Stakeholders will be contacted about each of the design's subsystems to understand their opinion on functionality, user and system interface, and possible environment modification.
Stakeholders in the development of projects include:

- Recognizing Stakeholder Perspectives: A thorough grasp of the requirements and interests of each stakeholder is necessary since project stakeholders can take many different forms. By including stakeholders, a collaborative approach is fostered and their interests are balanced in the project's design and execution.
- Functionality Assessment: Stakeholders comment on the subsystems' usability and point out areas for improvement.
- Legal and Regulations: Interacting with stakeholders may be necessary under certain legal or regulatory frameworks to avoid future legal disputes or delays in project implementation
- User and System Interface: Based on feedback from stakeholders, the subsystems' interface design and user-friendliness are assessed.
- Environmental Impact and Modification: By offering information about possible environmental effects of the system, stakeholders support reduction efforts.[39]

3.4 Subsystem Interfaces

Our design consists of the bridge, the floatation devices, the collection system, and the river straddle system. Thes floatation devices, bridge, and river straddle system all are what supports the collection system which is essentially the entire purpose of our design. The center of our interfaces is the bridge, which every other subsystem is connected to. The collection systems can be lifted and lowered onto and off of the bridge, which allows for easy access to clean these two subsystems. The bridge itself will be supported and connected by the floatation devices via paracord rope to stay afloat, and the river straddle system will keep the design stationary in the middle of the river by tying paracord the bridge then staking the other sides to the shore. The river straddle system also facilitates the collection of the surface trash into the top collection system by funneling the floating macro-waste into the top collection system, and so these two systems will be connected via paracord as well.

Table 21: Subsystem Table

Subsystem	Subsystem Interfaces	Relevant Interface
Bridge	1. Floatation Devices 2. River Straddle System 3. Collection Device	1. Connects To the underneath of the bridge to allow the bridge to stay afloat. 2. The River Straddle System allows the bridge to stay stationary. 3. Collection device is supported by the bridge in order to collect trash.
Floatation devices	1. Bridge	1. Is connected to insure the bridge stays a float so that the collection system is able to collect the trash floating on and under the water.
River Straddle System	1. Bridge	1. Connect the bridge to the ground in order to stay stationary and not move downstream. 2. Although it is not physically attached to the collection device it funnels floating trash to the collection system as well.
Collection Device	1. Bridge 2. Consists of two different collection systems	1. It uses the bridge as a support system to stay in place as well allow it to collect floating trash and trash underneath the water 2. There is a top and bottom collection system; they both rely on the bridge, however the top collection system is mainly focused on floating trash, while the lower collection system is focused on the trash underneath the water.

3.6.1 Description of Interfaces

The interfaces for each part of our design include:

- The bridge connects everything together, and so is physically connected to each subsystem, including: floatation devices, the collection system, and the river straddle system.
- The river straddle system grounds our design to the land via rope inside of the pool noodles.
- The floatation device gives our design buoyancy to float, but only connects to the bridge.
- The collection system will be brought to shore by the river straddle system, then by hand each part of the collection system will be removed and cleaned.

3.6.2 Subsystem Interface Diagrams

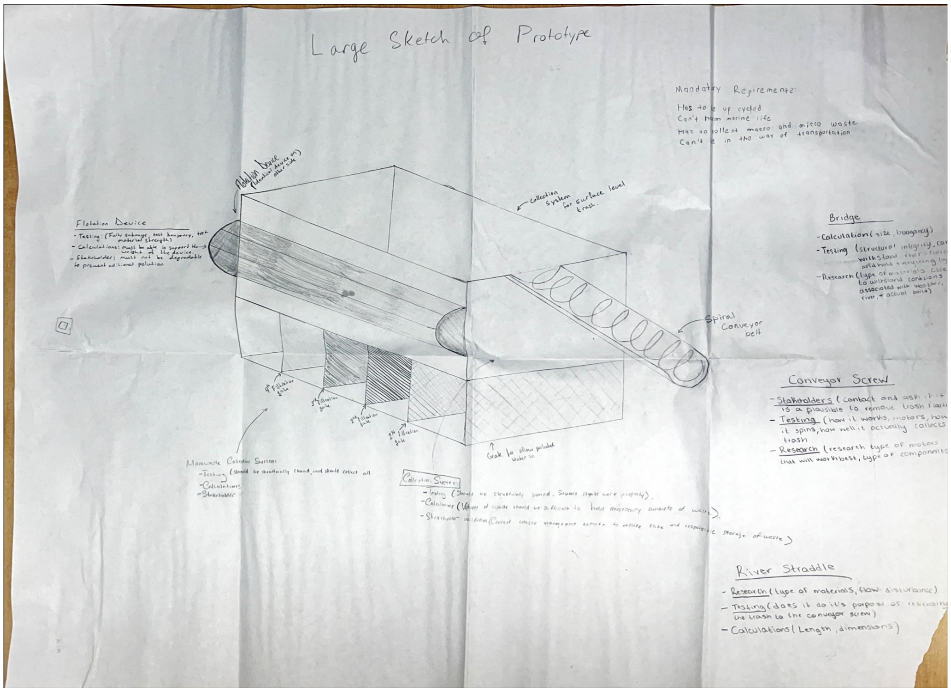


Figure 43: Initial large sketch rendition or prototype, along with validation statements

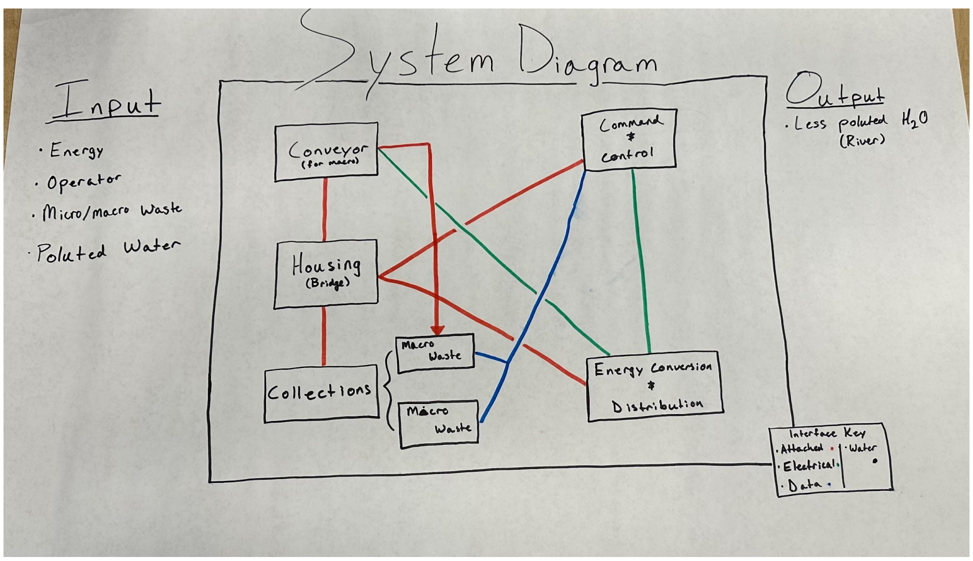


Figure 44: System Diagram Sketch with Inputs and Outputs

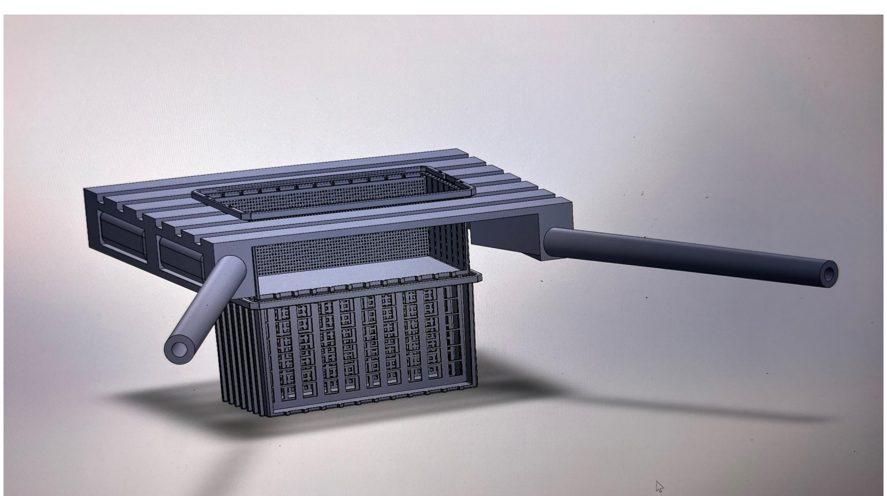


Figure 45: Front Isometric View SolidWorks Rendition of *RIC*

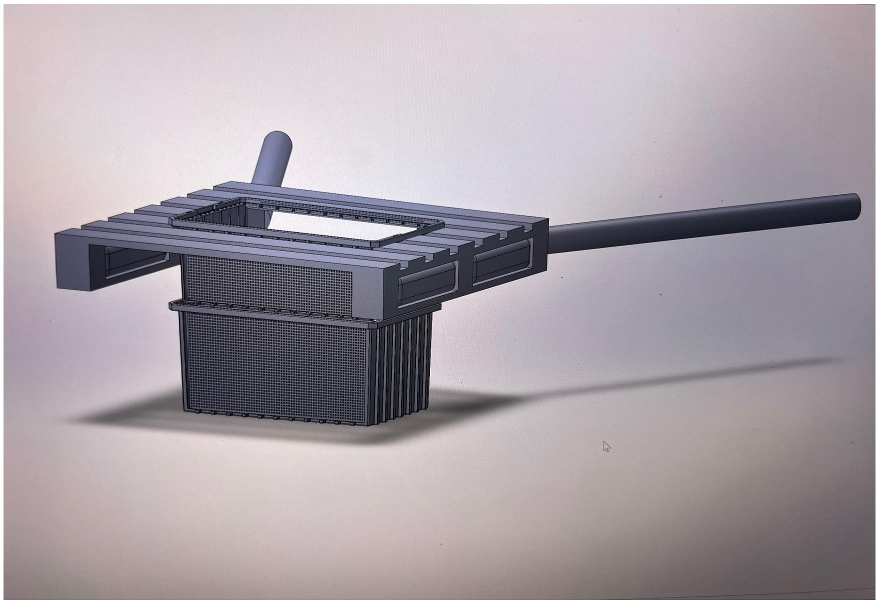


Figure 46: Back Isometric View SolidWorks Rendition of *RIC*

3.6.3 Interface Data Transfer

The bridge should act as the point of convergence between all subsystems including the micro waste collection system, the sensors, the flotation devices, the river straddle system, and the macro waste collection system. Connected to the flanges of the bridge, the river straddle system should connect directly to the shore, enabling the device to remain stationary. Underneath the bridge sits both the micro and macro waste collection systems. The micro waste collection system will collect underwater micro-waste, while the macro waste collects waste above water funneled to it by the river straddle system. Within the macro waste collection system sits the sensors, detecting the distance from the top the waste resides. Once the waste has reached a certain threshold, the ultrasonic sensors should then interact with the EPS32 board to send a signal via the Blynk cloud system to the user. Connected directly underneath the bridge, the floatation devices ensure the bridge and all connected components remain on top of the water. Lastly the human operator, the user, should rope in the entirety of the system, and clean it out, methods of cleaning are specified in each respective part above.

Section 4. Team Value Proposition and Risk Report (BRIEF)

4.1 Solution Value Proposition, Costs, and Benefits

4.1.1 Full-Scale Solution Criteria

The overall design goal of the system is to collect macro and micro-materials in landlocked bodies of water, notably rivers. The prototype indicates the possibility of concentrating water-clean-up efforts on landlocked bodies of water and is relatively affordable to build. We were given $100 to develop the prototype at the start of this project, and our prototype came in under budget at $71. Having such a low-cost prototype will justify the expenditure because it will serve as a testing prototype model for the full-scale solution. Because water is a human necessity, *RIC* will improve water quality, which will improve overall human well-being. According to the Centers for Disease Control and Prevention (CDC), poor water quality can and will lead to a drop in human health [60]. The approach *RIC* takes will improve human health by removing aquatic debris from rivers and purifying the water. To fit the mouth of rivers, which according to the National Library of Medicine are on average less than 150 meters [3], the final product will usually be much larger than the prototype. Materials that are not upcycled, such as PVC pipes, will also need to be larger in quantity, which raises the price. However, unlike most finished goods, which require higher-quality, more expensive materials, the majority of our solution's final design is still based on upcycled components, which are frequently free. This allows us to keep our final product at no more than triple the price of our prototype, or roughly $150-$200. Furthermore, testing the finished product would be free because the Colorado School of Mines has access to a river, Clear Creek, which is less than a five-minute walk from campus. The only problematic component of testing the final product is that the size of the product is designed to accommodate the breadth of the river, so it would have to be tested when there are few people at Clear Creek. However, this testing is the most significant design criterion for addressing the specific user wants that our design team would not be able to properly work solely on calculations and forecasts.

Because our technology is different from existing options, it will challenge competitors whose goals are also water cleanup activities. The majority of existing solutions are based on the assumption that the majority of rubbish ends up in the ocean; however, Our World in Data reports that "70% to 80% is... transported from land to sea via rivers and coastlines." [63] Not to mention that, according to the CDC, the majority of tap water in the United States comes from sources such as rivers [60], and over 40 million people get their drinking water from the Colorado rivers [61], making the approach our design takes on water clean-up efforts more critical than ocean clean-up efforts because the water our final solution attempts to clean directly impacts humans.

4.1.2 Prototype Solution Materials and Costs

Table 22: Prototype Materials and Costs

Product	Unit Cost	Quantity	Total Cost
Sensor System	$25	1	$25
Battery	$13	1	$13
Silicone Waterproof Sealant	$11	1	$11
PVC Pipes (3ft)	$0	1	$0
Plastic Tub	$0	1	$0
Bridge (Wooden Pallet)	$0	1	$0
Flotation Subsystem (2x 5-gallon containers)	$0	2	$0
Tent Pegs	$5	2	$10
Pool Noodles (River Straddle)	$0	1	$0
Mesh Screen	$0	2	$0
Underwater Glue	$12	1	$12

Total Cost:			$71

4.1.3 Full-Scale Solution Materials and Costs

Table 23: Full-scale Solution Materials and Costs

Product	Unit Cost	Quantity	Total Cost
Sensor System	$25	1	$25
Battery (Lead Acid)	$150	1	$150
Industrial Strength Sealing Products	$10	1	$10 *Multiple products can be created from one purchase*
PVC Pipes (10ft)	$10-$20	1	$20
Plastic Tub	$0	1	$0
Bridge (Wooden Pallet)	$0	1	$0
Flotation Subsystem (2x 50-gallon containers)	$0	2	$40
Tent Pegs	$5	2	$10
Pool Noodles (River Straddle)	$0 (upcycled)	Varies due to length of river	$0
Mesh Screen	$0 (upcycled)	Varies due to size of river	$0
Underwater Glue	$12	1-2	$24
Total Cost			$150-200

4.1.4 Design Benefits

Manufacturing this design would reduce diseases and improve human health not only across our country for landlocked states, but for everyone who relies on rivers for drinking water. Furthermore, regular cleaning of *RIC* would give scientists information on whether or not the water from the source is contaminated. Recently, contaminated drinking water in Jackson, Mississippi caused up to 10% absenteeism rates in local schools in April 2023 [64]. The ultimate device would not only prevent many scenarios like these by removing harmful toxins from source water, but it would also prevent diseases caused by toxins in water from spreading swiftly owing to the *RIC'*s regular monitoring and cleaning.

While other inventive solutions exist, such as the RiverCleanup [65] river skimmer, our team's design maximizes the benefits of river cleaning technology by maximizing the area that the technology can clean while decreasing the cost required to manufacture the equipment. Increased population, according to Penn. State University [66] and Swarthmore College [67], have a positive, linear link with water pollution, which negatively affects human well-being. If we do not find a more beneficial conscious solution to water pollution for source water soon, our generation and all future generations will suffer more.

4.2 Risk and Mitigation

4.2.1 Full-Scale Solution Risks and Mitigations

When evaluating the final solution for our design, we must analyze all potential risks so that our product may achieve its goal without negatively impacting other factors. These dangers are depicted in the table as well as mentioned below. The bulk of these risks are of "low" or "moderate" magnitude, however, flooding-related risks are of "major" size because the runoff from the mountain poses a danger to *RIC*. Most of the hazards for our full-scale design have been considered, except for flooding, which we have no control over and may result in our product being a seasonally applied technology. The prototype's construction has resulted in the most mitigation of our concept and the most altered area of the full-scale solution. For example, our design team originally intended for the top subsystems to link to the bottom subsystems using waterproof adhesive; but, due to the weight of the lower subsystems, this has proven challenging. To address this issue, our team devised a novel method of attaching the subsystems that involves drilling the subsystems into each other rather than using adhesive. These minor design adjustments made during the prototype stage will be scaled up and incorporated into the full-scale solution to avoid any additional risks that may prove to impede our full-scale solution and its goal. These risks will be minimized by increasing whole product testing and individual subsystem testing of the prototype, as well as changing calculations to account for design changes.

4.2.2 Risk Analysis Matrix and Breakdown

Table 24: Risk Analysis

Risks	Likelihood to Occur	Impact of Risks
A: Frozen River	Unlikely	Low
B: Large Debris Obstructs Collection System	Unlikely	Major
C: Environmental Disruption	Likely	Moderate
D: Vandalism	Likely	Low
E: Debris Overload	Unlikely	Moderate
F: Maintenance and Mechanical Challenges	Very Likely	Major
G: Flooding	Likely	Moderate

A. Frozen River (seasonal)
- During the winter season, frozen rivers pose the risk of obstructing our product.

B. Large debris obstructs collection system
- Driftwood and other large debris may obstruct the collections system and result in a buildup of waste that cannot be properly collected.

C. Environmental Disruption
- The Device may obstruct the flow of the river making it difficult for fish to swim past. Environmental Disruption

D. Vandalism
- The impacts of vandalism can disrupt and destroy certain key components of the *RIC,* contributing to a decrease in waste collection.

E. Debris Overload

- If the collection system is not emptied regularly and or the amount of waste collected is larger than predicted, then the collection system may overflow and cease work as intended.

F. Maintenance and Mechanical Challenges

- If any of the systems fail, the entire device's effectiveness may be compromised.
- The device will need to be routinely checked to ensure proper functionality.
- Buoyancy of the device is integral to proper functioning and will need to be checked routinely.

G. Flooding

- Weather may affect the flow of the river. If rain increases drastically then there is potential for flooding and disruption of the flow of the river. However, relating to buoyancy, there is minimal risk as the entire system will rise and fall with the water level.

4.2.3 Mitigation Plan

When evaluating the final solution for our design, it is critical that we analyze all potential risks so that our product may achieve its goal without negatively impacting any other elements. These dangers are depicted in the table and mentioned below it. The bulk of these risks are "low" or "medium" in size, however weather-related risks are "high" in magnitude since water changes state during colder seasons. The majority of the hazards for our full-scale design have been considered, with the exception of weather, which we have no control over and may result in our product being a seasonally applied technology. The creation of the prototype itself has resulted in the most mitigation of our design and the most altered region of the full-scale solution. For example, our design team intended for the upper subsystems to attach to the bottom subsystems using waterproof adhesive; however, due to the weight of the lower subsystems, this has proven impossible. To address this issue, our team devised a novel method of attaching the subsystems that comprises drilling the subsystems into each other rather than using adhesive. These minor design adjustments made during the prototype stage will be scaled up and included into the full-scale solution to avoid any further risks that may stand in the way of our full-scale solution achieving its goal. These risks will be minimized through expanded entire product testing and individual subsystem testing of the prototype, as well as revised calculations to account for design modifications.

5.0 Final Full Scale Design & Deliverables

5.1 Design Description

This semester, we were tasked with solving a current world problem using upcycled materials. The prompt left us with the challenge of deciding to make something out of upcycled materials or making something useful out of upcycled materials. We decided to do both. We incorporated upcycling into both our design and solution. The problem we chose to address was the increase in aquatic debris in our rivers, which has disastrous impacts on our health, ecosystem, and economy. As a result, we decided to focus on the question, "How can we optimize the removal of aquatic debris through the innovative use of upcycled materials?" Our River Interceptor Collection System, or *RIC*, spans the width of any river and collects trash brought down by the current in two parts. The first component is the above-water collection system, which consists of an upcycled solid tote with a mesh backing made of upcycled window screening that sits half in and half out of the water to collect surface or macro-waste. The underwater collection system is made from upcycled window screens wrapped around lines of PVC and works to filter micro-materials out of the water from the holes of the window screens decreasing in size as the water pushes deeper into the system. Both of these components are held together by an upcycled wooden pallet, and they are kept afloat by sufficiently sized gallon water containers attached to either side of the bridge with paracord rope. The straddle system, which is a paracord rope threaded through upcycled pool noodles and attached to the bridge in two places, is the final component of RIC. One end of the rope is tied to the bridge, while the other end is staked to the shore with tent stakes. The remaining pool noodles are attached to the above-water collection system at an angle with waterproof adhesive to funnel surface waste into the system.

The system's overall design goal is to collect both macro and micro waste in narrow, landlocked bodies of water, particularly rivers. Our design suggests the possibility of focusing water-clean-up efforts on landlocked bodies of water and is relatively inexpensive to construct. Because water is a human necessity, RIC will improve water quality, thereby improving human well-being overall. Poor water quality, according to the Centers for Disease Control and Prevention (CDC), can and will lead to a decline in human health [60]. By removing aquatic debris from rivers and purifying the water, RIC's approach will improve human health. The final product will be much larger than the prototype, large enough to span most of the width of the river, which according to the National Library of Medicine are on average less than 150 meters [3]. Materials that are not upcycled, such as electronics, will be purchased in large quantities, reducing the price. However, unlike most finished goods, which require higher-quality, more expensive materials, the majority of our solution's final design is still based on free, upcycled materials. This allows us to keep our final product at no more than three times the cost of our prototype, or around $150-$200. Furthermore, because the Colorado School of Mines is in close proximity to Clear Creek, which is less than a five-minute walk from campus, testing the finished product is free. The only issue with testing the final product is that its size is designed to accommodate the width of the river, so it would have to be tested when there are few people at Clear Creek. However, because this testing is the most important design criterion for addressing specific user desires, our design team would be unable to work properly solely on calculations and forecasts.

Because our technology is distinct from existing alternatives, it will pose a challenge to competitors also seeking clean rivers. The majority of existing solutions are based on the assumption that the majority of trash ends up in the ocean; however, according to Our World in Data, "70% to 80% of trash is... transported from land to sea via rivers and coastlines [63]." Not to mention that, according to the CDC, the majority of tap water in the United States comes from rivers [60], and over 40 million people get their drinking water from Colorado rivers [61], making our approach to water clean-up efforts more critical than ocean clean-up efforts because the water our final solution attempts to clean directly impacts humans.

5.1.1 CAD Models

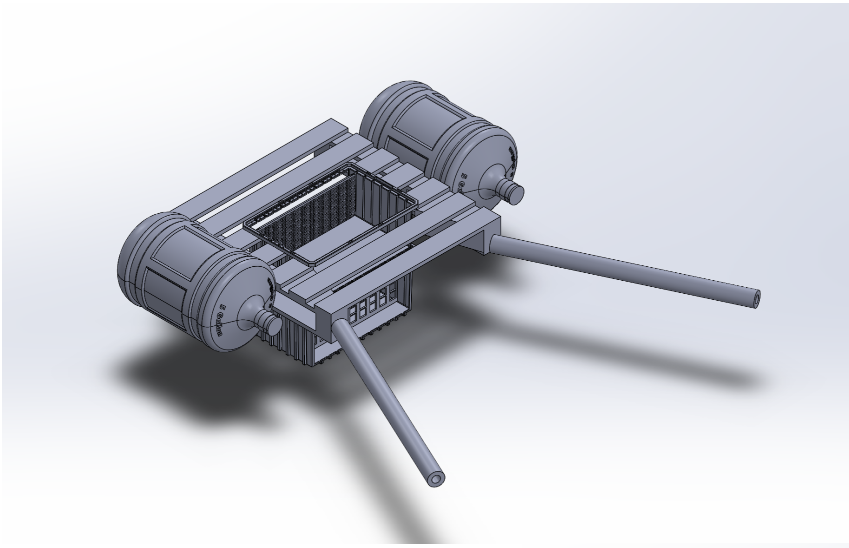
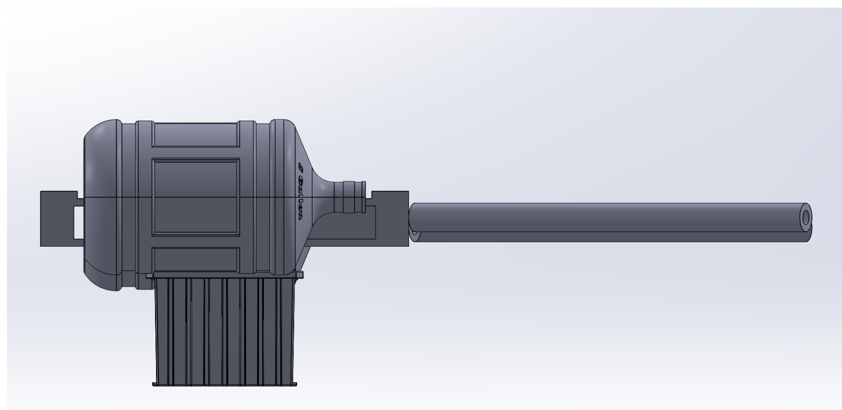


Figure 47: Front Isometric View SolidWorks Final Rendition of *RIC*

Figure 48: Side View SolidWorks Final Rendition of *RIC*



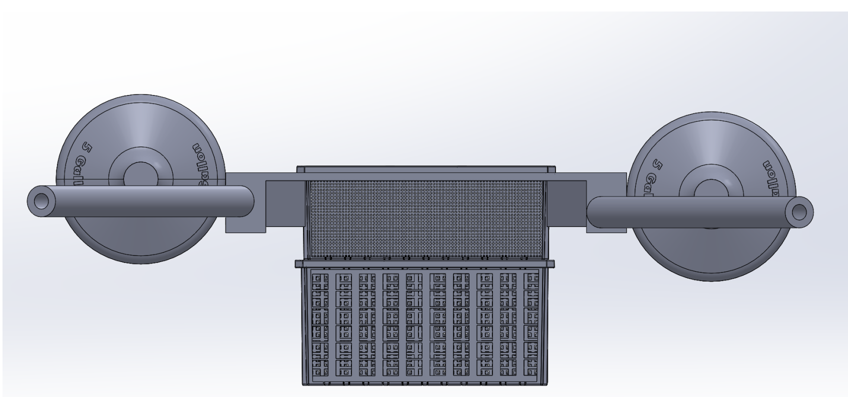
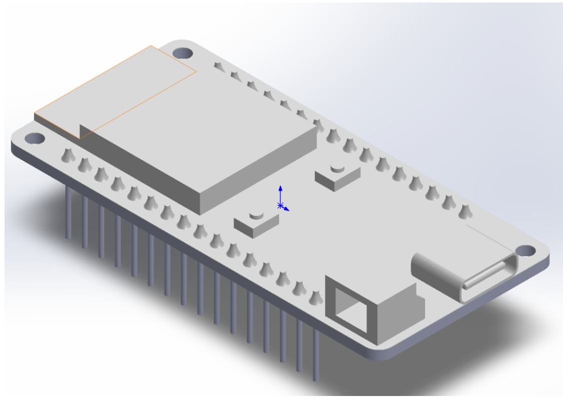


Figure 49: Front Isometric View SolidWorks Final Rendition of *RIC*



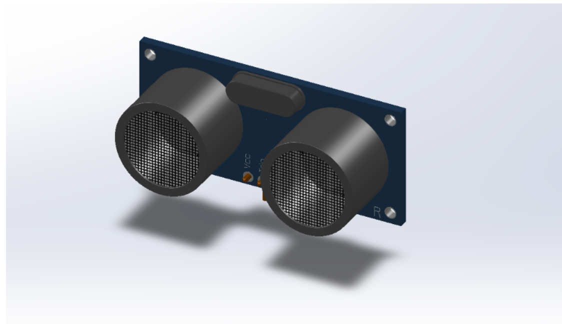


Figure 35: depicts EPS32 (right) [47]
Figure 36: depicts ultrasonic sensor (left) [48]

5.2 Design Components and Physical Properties

5.2.1 Updated Design Product Specification Table

Table 25: Updated Design Product Specification Table

Key Component	Material Type/ Cost	Physical Properties	Probable Functionality
Sensor System	$25, ESP 32 Wifi and Bluetooth Board. UC-SR04 Ultrasonic sensor. Plastic junction box.	Held in a waterproof container, attached to the lid of the top collection system, weighs less than 5 pounds, and is less than 10 inches on each side.	The sensor is functional, and measures the difference between the height of the trash collecting in the top collection system, and the lid. As the difference nears zero, it tells the user it is time to clean out the collection system.
Bridge	Upcycled wooden pallet of any wood type	On average five feet in width and two feet in length, but the top of the pallet is cut to fit the size of the tote for the top collection system. The pallet is also, on average, about six inches tall in order to sit on the water without disrupting the naturalistic view.	The bridge is functional and holds the design together well, but will need a wood sealant to withstand long durations in the water.
Above-Water Collection System	$0 Upcycled plastic tote, with the front and back cut out in order for water to flow through, but an upcycled chicken wire or window screen is attached to the back cut out in order to trap macro-materials in the system.	On average three feet in width and one foot in length, since it has to be small enough to fit in the bridge. While the width and length dimensions will probably not change, the height of the tote will depend on the depth of each river.	The top collection system is functional and requires no mitigation for future use.
Underwater Collection System	$10, made out of PVC pipes from Home Depot, and upcycled window screening with different sized holes to filter different sized micro-materials submerged in the river	Since this component of *RIC* is submerged in the river, the dimensions will be determined by the depth and width of the river.	This part is functional for short durations, however this component requires the most mitigation to try to secure the PVC pipes to the tote while holding the weight of the trash without falling apart.
Straddle System	$15, this component will be created using paracord from Home Depot since it needs to be strong enough to secure *RIC* in a stationary position, with upcycled pool noodles surrounding it to ensure it's buoyant enough to rest on top of the water.	The Straddle System is the most dependent on the width of the river, since the length of the rope and pool noodles being used must span the width of the entire river, so there is no set dimension for this component.	This part is functional, and does not require much, if any, mitigation or regular maintenance.
Floatation Devices	$0 - $30, the floatation devices will be made of same sized water jugs attached to the bridge via paracord in order to keep the design afloat in the river	Buoyancy Calculations Prototype: Our prototype is 40 pounds, and the two, five gallon water jugs displace 40 gallons of water each, so they must be attached to the side to keep the design afloat when the collection system is full, but also not too buoyant to cause the top collection system to be too close the surface of the water. Most full-scale sized *RIC*s will use two, five gallon jugs, but this could change based on how big *RIC* must be for that specific river.	This part is functional, and there are further buoyancy calculations below in the *5.3.4 Analysis and Calculations* portion of this report.
Total Cost:			$71

5.2.2 Drawing/ CAD References

The exploded view of the CAD model for *RIC* visually shows the key components described in table ?.

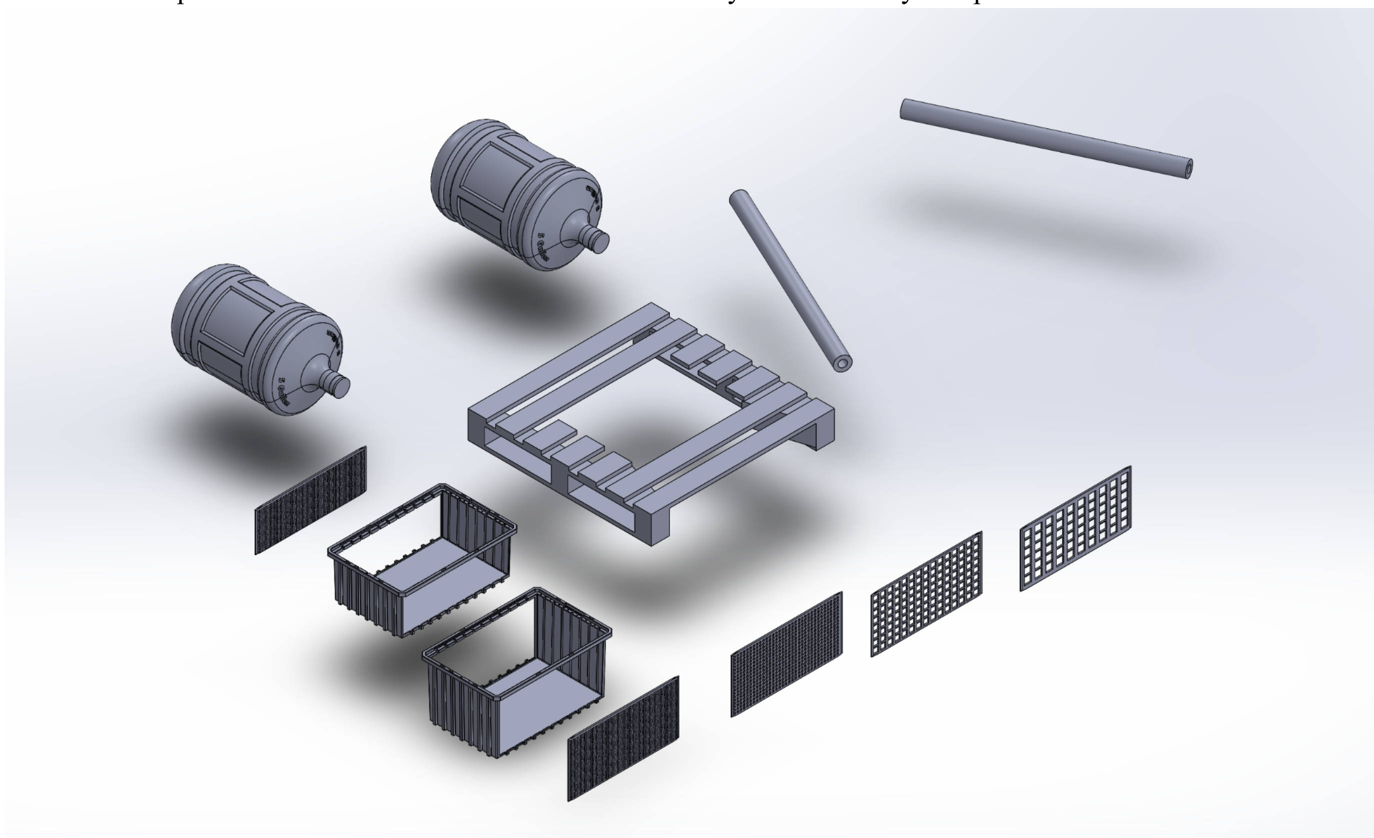


Figure 50 : Exploded view of our design

Figure 1: is a cartoon depicting the problem statement that our design addresses aquatic debris.

5.2.3 User Interfaces

The bridge, floatation device, collection systems, sensors, and river straddle system are all components within our design. The collection system is essentially the entire purpose of our design, supported by the floatation devices, bridge, and river straddle system. The bridge serves as the hub of our interfaces, to which every other subsystem is linked. The collection systems can be both lifted and lowered onto and off of the bridge, making cleaning these two subsystems simple. To stay afloat, the bridge will be supported and connected by floatation devices via paracord rope, and the river straddle system will keep the design stationary in the middle of the river by tying paracord the bridge and staking the other sides to the shore. The river straddle system also aids in the collection of surface trash into the top collection system by funneling floating macro-waste into the top collection system, and thus these two systems will be linked by paracord.

5.3 Updated Concept Validation

5.3.1 Updated Design Requirements

Table 29: Updated Design Requirements

Requirements	Reasoning
Must Collect Micro-Waste	Stakeholder Professor Cath impressed upon us the severity of micro waste in water supplies. Therefore, our novel solution should address this issue.
Using Upcycled Materials	Due to both the project requirements, and to ensure environmental responsibility, we will use all upcycled materials within our final design.
Waterproof	In order to service the water, our design must be fully waterproof to ensure reliability and operability.
Durable	Because our solution will be in rivers and must withstand natural occurrences and disasters so as to not further pollute the river, we must ensure our design is durable.
Maintainable/Low-Maintenance	Another issue expressed by lots of stakeholders was the necessity of having something that is low-maintenance so as to not be a financial and time burden on consumers.
Cost-Effective	One of the largest issues found within our research was that existing solutions addressing river-waste were very high-tech and cost ineffective, making it out of reach for communities needing this issue addressed the most, impoverished communities.
Concerned Exclusively With Rivers and Similar Bodies	Many of the solutions researched are focused on ocean waste, and while this is a noble cause, most of our drinking water comes from freshwater sources like rivers and similar bodies; therefore, we felt this should be our primary area of focus.
Aesthetically Pleasing	A primary reason we chose to tackle river waste is not just because of the potential health impacts waste in freshwater poses for humans, but also because millions in revenue is lost from a loss of tourism [11] due to marine waste, largely because tourists see this as attractive. To ensure we can address this issue, our design must not only be effective at cleaning river waste, but also aesthetic.

5.3.2 Updated Design Decision Matrices

Table 28: Updated Surface Level Collection Decision Matrix (lower is worse)

Ideas	Time Constraint	Availability (Is it easily upcycled)	Interference with other subsystems	Complexity	Effectiveness	Size	Total
Screw Conveyor	3	3	2	3	10	8	4.83
Belt Conveyor	3	2	2	1	8	8	4
Passive Intake	3	10	9	10	4	2	6.33

Table 8: Flotation Subsystem design matrix.

Ideas	Time commitment	Availability	Interference with other subsystems	Easiness to connect other subsystems	Size	Material	Total
2-liter water bottles	9	10	9	8	7	7	50
5-Gallon Water container	9	10	9	9	10	10	57
50-gallon Drum	6	6	7	4	2	10	35

Table 9: River Straddle Decision Matrix

Ideas	Time Commitment	Availability (Is it easily upcycled)	Interference with other subsystems	Easiness to connect other subsystems	Size	Avg
Pool Noodles	8	10	9	8	10	9
Wooden Pallet	6	4	2	4	6	4.4
Pool Buoys	6	5	3	3	3	5

Table 10: Micro Waste collection system decision matrix

	Doesn't Disrupt Water	Effectively Traps Micro Waste	Effective Area/Volume
Large Open Container	✖	✖	✔
Large Open Container + Mesh	✖	✖	✔
Increasingly Smaller Mesh Screens + Adhesive	✔	✔	✔

5.3.3 Scholarly and Authoritative Research

Our team's references aided us in two ways. One way was in determining which problem statement appeared to be the most relevant to address, and the second way was in determining which materials were best suited to address our problem statement. The majority of our initial research focused on the problems that extra materials caused in our world. The negative effects of aquatic debris on living organisms, the ecosystem, human health, and the economy were explicitly and repeatedly mentioned throughout our sources. While this appeared to be an appropriate problem for our team to design a solution for, we repeatedly ran into the issue of our solution being too costly, extensive, and prevailing for us and our limited experience and knowledge to solve. How were we going to build something to clean up the ocean if we didn't have access to it? When so many people require access to clean water, how would we build something large enough to provide a solution for the majority of people? So, the next phase of our research focused on existing solutions, and we discovered that the majority of water cleanup efforts focused specifically on non-landlocked bodies of water. Once we were able to identify stakeholders, people who get their drinking water from sources such as rivers, it was time to investigate what materials and solutions would be most effective in addressing this issue.

5.3.4 Stakeholder Interviews/ Feedback

While stakeholder engagement was useful in determining which problem statement our team would address, the feedback from these interviews was more useful in guiding the purpose and design of our solution. Everyone we spoke with had different ideas about what our design could do for landlocked bodies of water. Professor Tzaahi Cath, the head of the W3ST water treatment group here on Mines campus, was eager to explain how water treatment plants operate, and he was enthusiastic about how we could improve these water treatment facilities. This interview provided us with our first insight into how critical it is for source water to be as clean as possible before becoming drinking water. Other stakeholders agreed that water pollution and aquatic debris were serious issues that needed to be addressed, but they had different ideas for how to do so, such as making sellable products out of aquatic debris or developing a drone that could detect and pick up aquatic debris. After all of our stakeholder meetings, our team could design a feasible and low-cost solution to the problem statement: RIC.

5.3.5 Analysis and Calculations

While the RIC appeared to be a simple design, just connecting five key components at the time, it proved difficult and required more time than anticipated during the construction process. Initially, our group planned to use two upcycled totes, one for the above water collection system and one for the below water collection system, but there weren't any smaller plastic totes available that spanned the exact bottom-side width of our larger tote, so we had to improvise. We determined that we could use PVC pipes wrapped in upcycled window screening, but testing revealed another issue, the structure's integrity (discussed below). The bridge and straddle systems worked flawlessly, and the sensor proved as a useful component to meet the requirement of the "technical in nature" aspect of our design. The floatation devices worked, but when the collection systems were empty, they were too buoyant for our design, so we had to perform buoyancy calculations and reposition the water jugs. Because water weighs 8 lbs per gallon, each 5-gallon jug can hold 40 lbs of water. The RIC weighs 21.88 lbs, and the two 5-gallon Jugs hold a total of 80 lbs of water. The flotation system, when combined, can support the entire RIC system and raise 72.7% of the device above water. The opening in the macro waste collection system will be at a more appropriate height in relation to the surface of the river if the flotation system is moved to the side of the device rather than under the device.

5.3.6 Testing

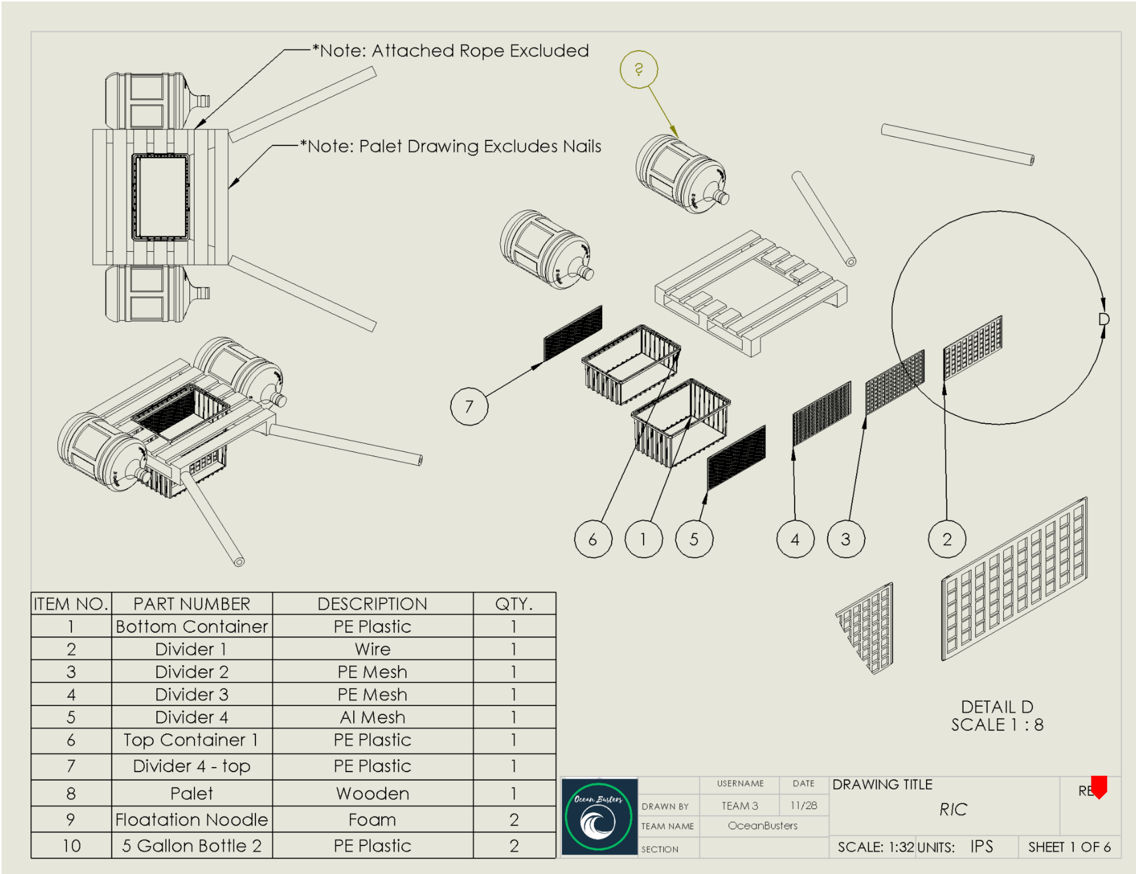
We went to Clear Creek to test the RIC after it had been completed. While it was too cold to get in the water and hold the RIC in the middle of the river, we tested it against a less intense, and shallow, side current and it worked! Both pieces of macro-materials we threw into Clear Creek were collected by RIC. There was no way to test whether RIC could collect micro-materials under water, but according to our scholarly and authoritative research, filtration systems with descending sized holes are effective at collecting micro-materials. While testing RIC was successful for a short period of time, the bottom collection system of the design soon fell apart due to not being attached well enough during the construction stage. So we returned to the Digger Space to rebuild RIC with more precisely placed adhesive and stronger attachment methods. Consider 5.5.3 for full testing procedures and results.

5.4 Conclusion

The RIC is a novel solution since it is a low-cost way to address the issue of aquatic debris in source water and provide clean drinking water to millions of people. RIC is the optimal solution for cleaning aquatic debris from source water in order to improve human health, allow ecosystems to flourish, and boost our economy by developing a self-sufficient technology that relies on the current of the river to clean macro and micro-materials from drinking water.

5.5 Appendix

5.5.1 Working Drawings



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Bottom Container	PE Plastic	1
2	Divider 1	Wire	1
3	Divider 2	PE Mesh	1
4	Divider 3	PE Mesh	1
5	Divider 4	Al Mesh	1
6	Top Container 1	PE Plastic	1
7	Divider 4 - top	PE Plastic	1
8	Palet	Wooden	1
9	Floatation Noodle	Foam	2
10	5 Gallon Bottle 2	PE Plastic	2

Figure 51: Working drawing showing all components.

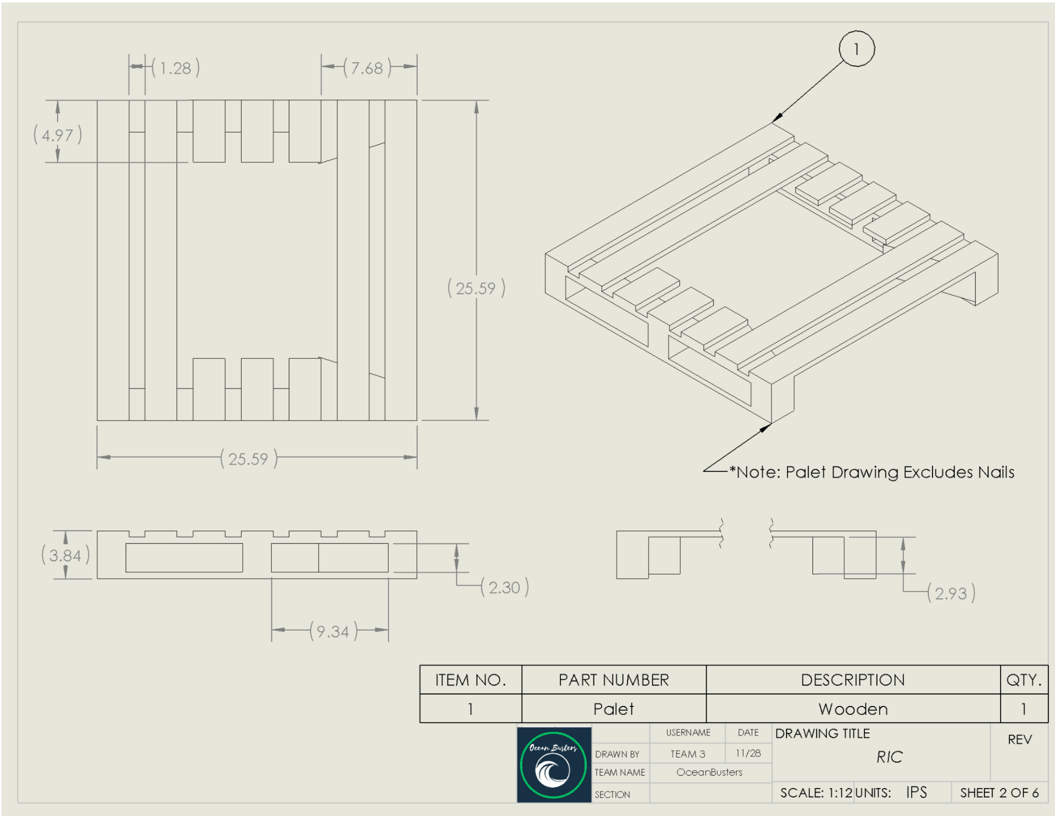


Figure 52: Working drawing of bridge

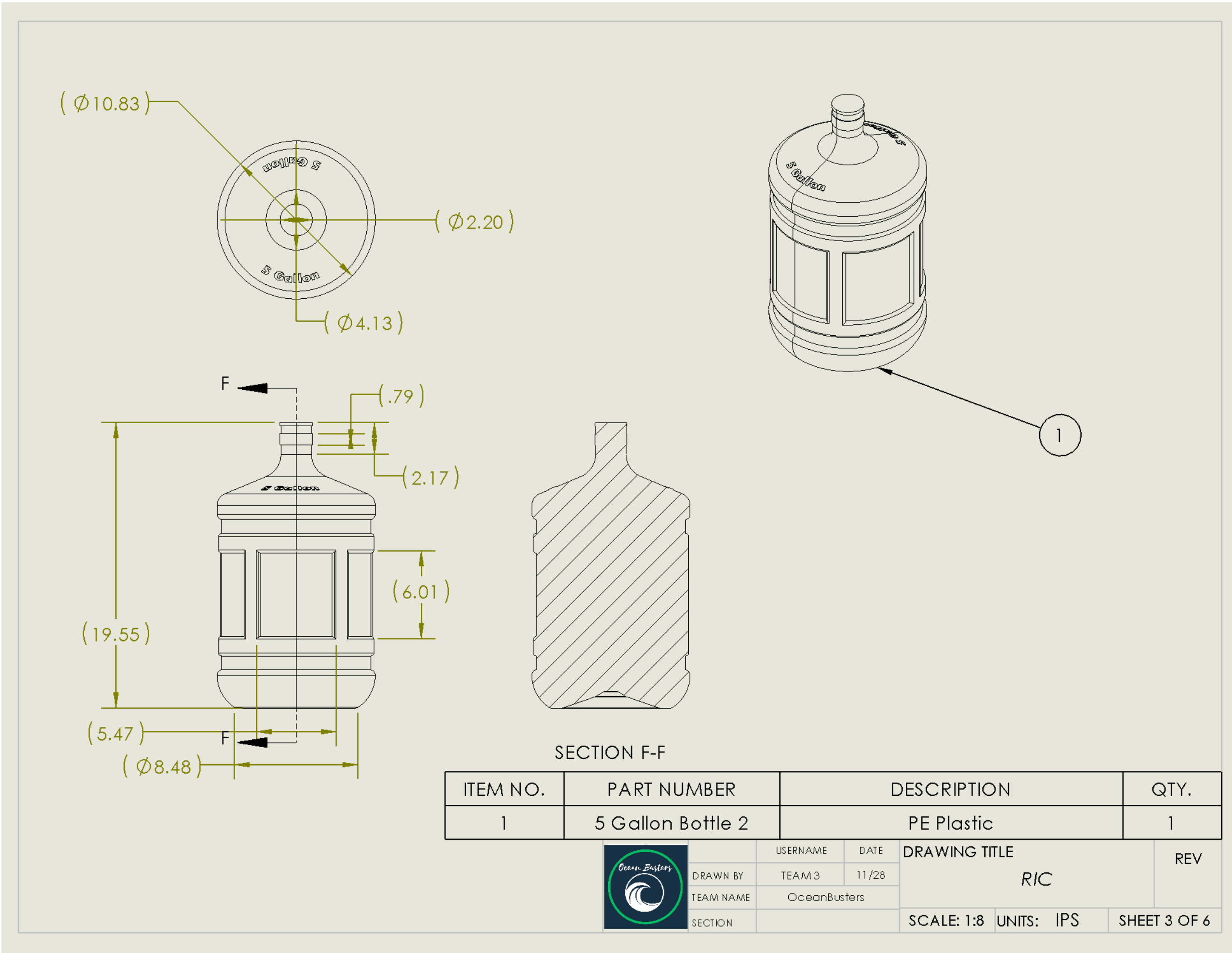


Figure 53: Working drawing of the flotation system.

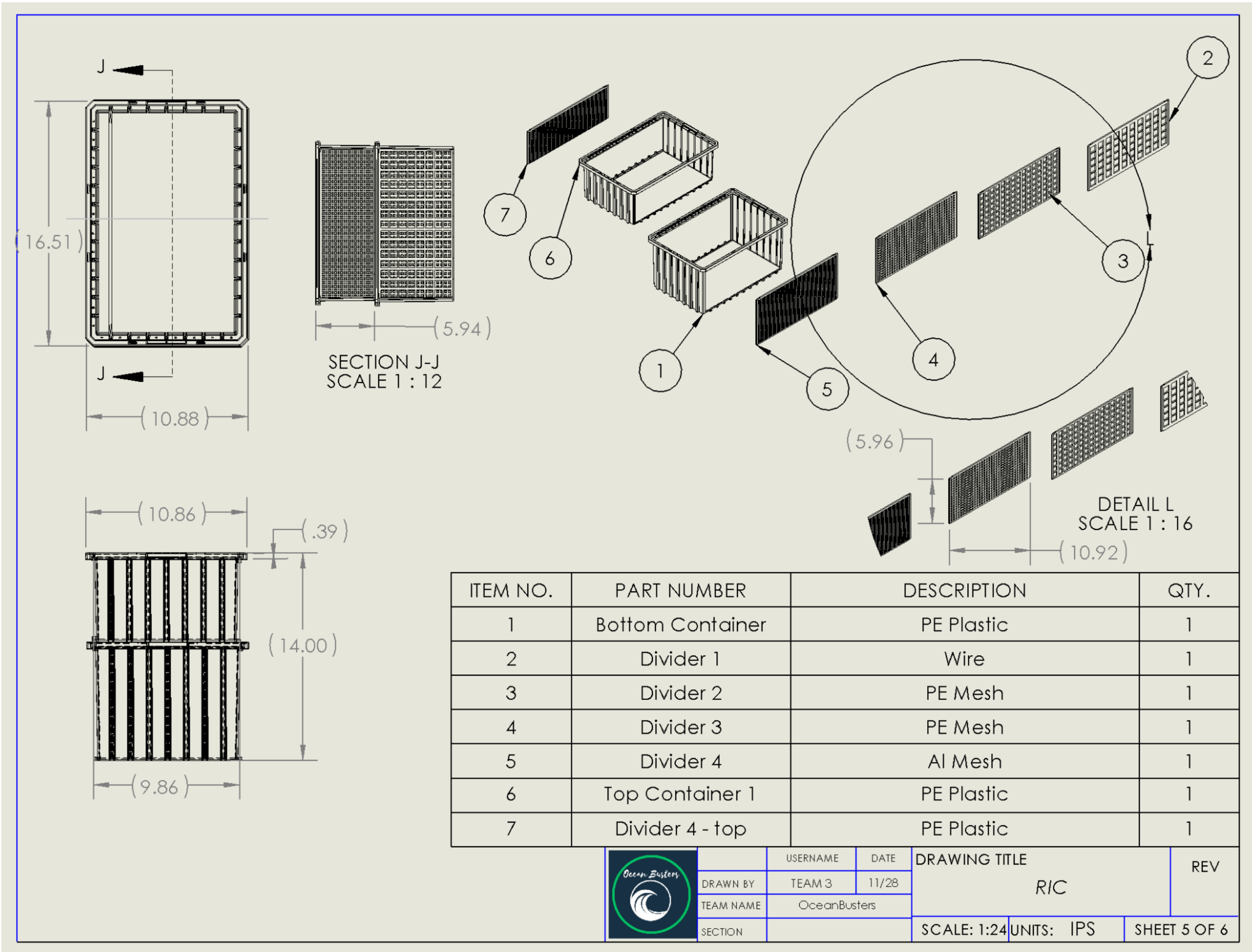


Figure 54: Working drawing of macro-waste collection system

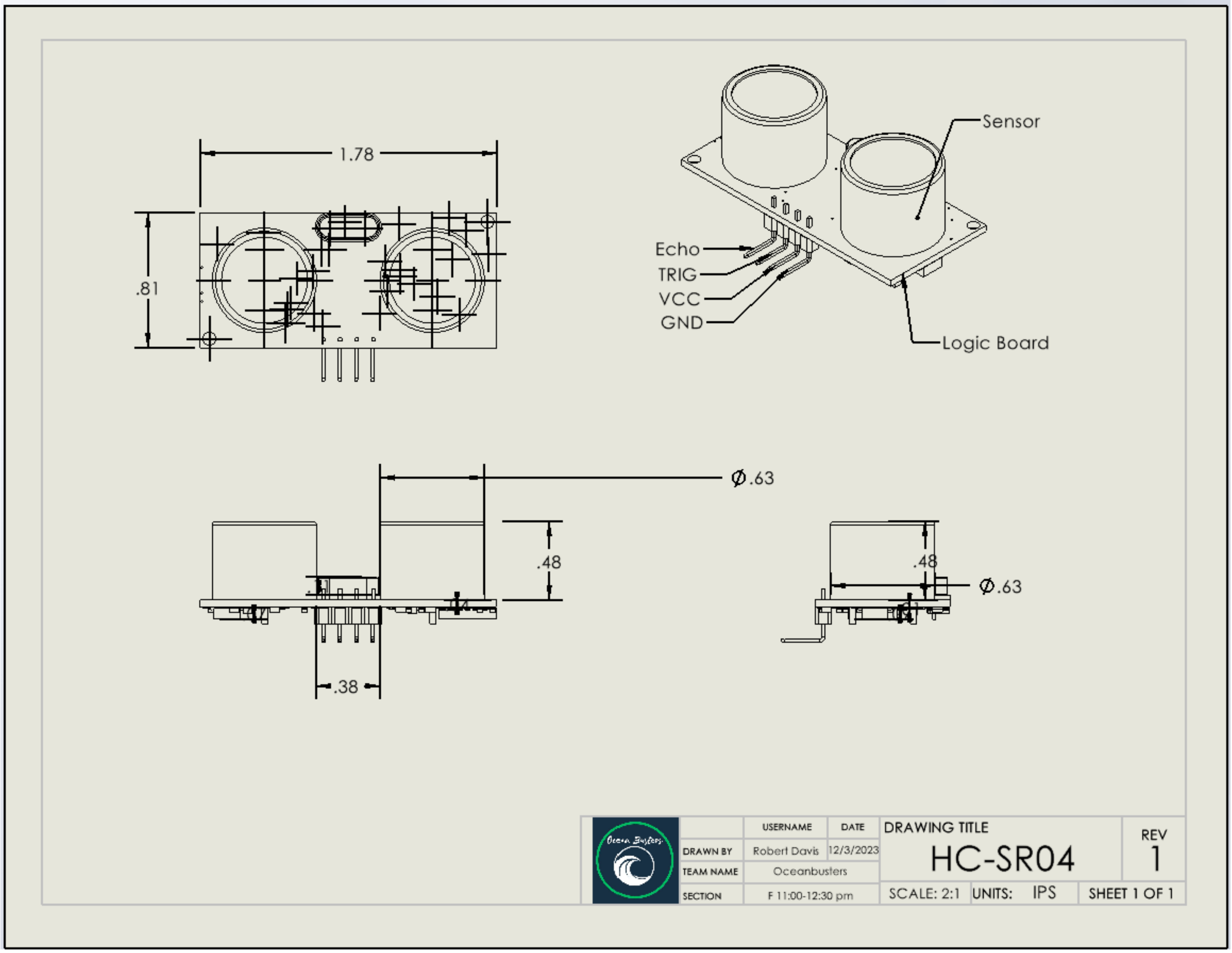


Figure 55: Working drawing of ultrasonic sensor, HC-SR04 (bill of materials omitted, copyrighted) [48].

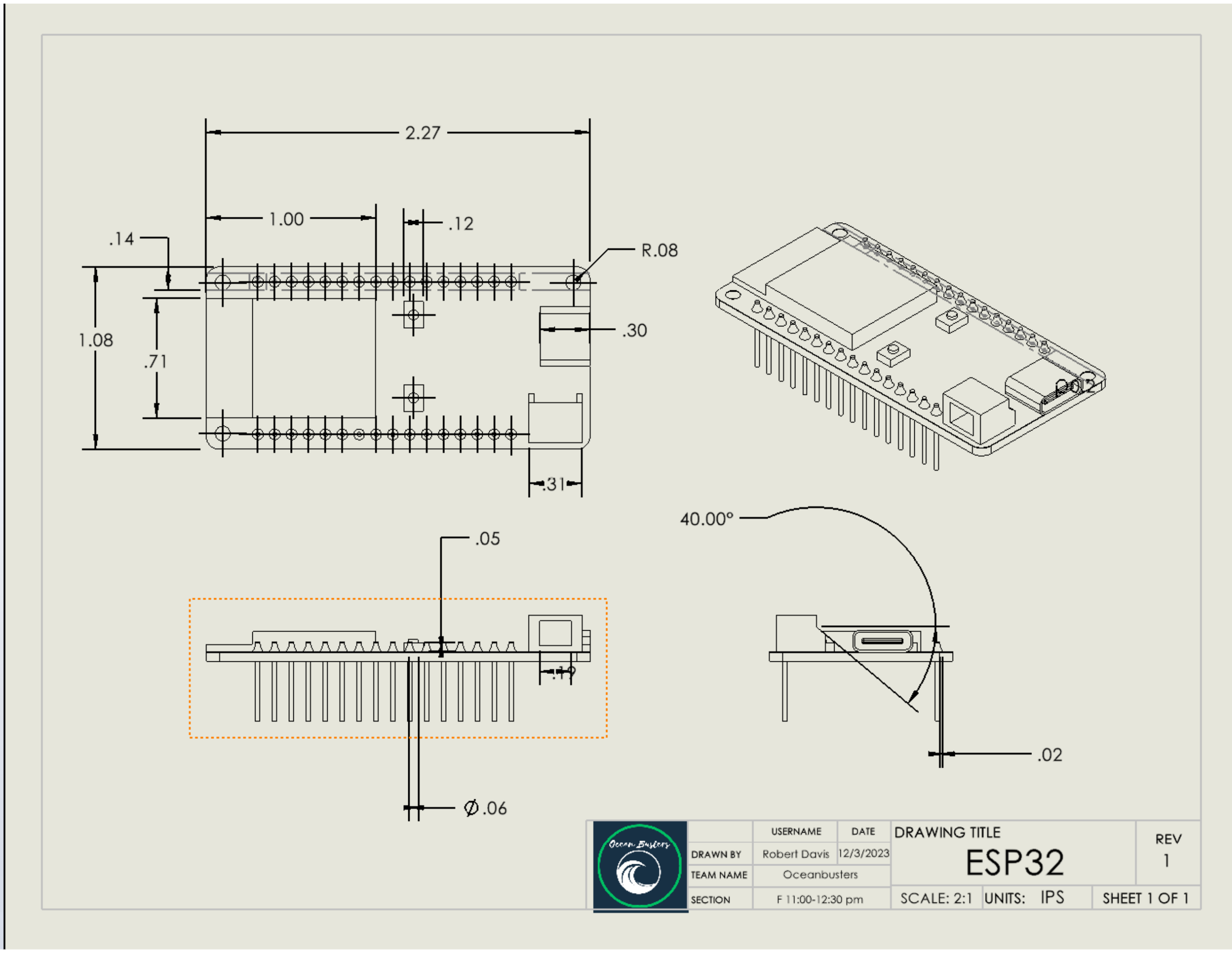


Figure 56: Working drawing of ESP32 board (bill of materials omitted, copyrighted) [47].

5.5.2 Bill of Materials

Table 26: Bill of Materials

Subsystem	Material 1	Material 2	Material 3	Material 4
Bridge	Pine Wood (Pallet)	Steel Nails (coated in silicone)		
Above-Water Collection System	Polypropylene Plastic (Tote)	Rubber (Mat)	Silicone Sealant/Adhesive	Aluminum Mesh (Window Screen)
Under-Water Collection System	Aluminum Mesh (Window Screen)	Steel (Chicken Wire) (coated in silicone)	Polyvinyl Chloride (PVP pipes)	Steel Screws (coated in silicone)
River Straddle System	Nylon Rope	Polyethylene Foam (Pool Noodles)	ABS Plastic (tent stakes)	
Flotation Device	Polyethylene Terephthalate (PET) (water jugs)			
Sensors	ESP 32 Sensor (undisclosed materials)	Lithium-Ion Battery	HC-SR04 Ultrasonic Sensor (undisclosed materials)	Polyethylene terephthalate (junction box)

5.5.3 Test Results

Table 27: Test Results

Test Type	Method	Results & Notes
Visual Inspection	Examine all visible parts of the device for cracks, corrosion, or other signs of wear.	Passed. Ensure further structural integrity by ensuring all components are securely fastened.
Load Testing	Apply weights or force to components to simulate the stress from debris and water during a storm.	Passed. Underwater collection system structurally compromised by forces >6400 N (force of a kick). Shouldn't be an issue considering the small impact of microwaste.
Flexibility	Manually manipulate connections to ensure they have the necessary range of movement and can withstand weather forces.	Passed. High degree of flexibility about joints. Underwater collection system potentially compromised. Joints cannot flex >15 deg due to adhesive used.
Debris Simulation	Manually throw or float various types of debris at the system to see how it collects and affects the structure.	Passed. Mesh on backside of above-water collection system potential weak-point. Withstood rocks at high-velocity.
Vibration Monitoring	Vigorously and violently shake the micro waste collection system	Passed. No potential issues found.

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