TO: Mark Lamer, PE; Taylor Layland, PE

FROM: Hunter Kassens, Eric Moore, Steven Procaccio, Cole Robertson, Hannah Thelen, Civil Engineering Students

CC: Mark Lamer, PE

DATE: December 7, 2021

SUBJECT: Concrete Canoe Capstone Final Proposal

Hello,

This document contains the Project Understanding, the Scope of Services, and the Project Schedule for the 2021-2022 Concrete Canoe Capstone Team. The Project Understanding includes the Project Purpose, Project Background, Technical Considerations, Potential Challenges, and Stakeholders. The Scope of Services lists out all the major tasks that will have to be completed in order to complete the project as a whole. The Project Schedule is a Gantt chart that exhibits each task start and end date. The schedule also highlights the project critical path, which emphasizes the tasks that can potentially cause delay when working on them in succession with other tasks. The Staffing Matrix includes all the hours for each task completed by each role throughout the project. The Costs Matrix breaks down each of the costs associated with the project. These include the personnel costs, travel costs, lab use costs, and material costs.

If you have any questions or concerns, please reach out. Thank you for your time and consideration.

Respectfully,

Hunter Kassens, Civil Engineering Student

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1.0 Project Understanding

1.1 Project Purpose

The American Society of Civil Engineers (ASCE) Concrete Canoe Competition calls for students from universities across the country to construct a canoe made of concrete that can float. The competition also challenges students to race the canoes against other schools in a friendly competition manner. The goal of the competition is as follows, "The ASCE Concrete Canoe Competition provides students with the unique opportunity to gain hands-on practical experience while testing their skills with mix designs and project management challenges" [1]. The Committee on Concrete Canoe Competitions (C4) releases a Request for Proposals (RFP) each year which describes the guidelines for the construction of the canoe and the overall project competition. The real-world format of the competition structure and submission composition allows students to create professional grade work. Throughout the preparation for the competition, the students are expected to build relationships with their faculty, suppliers, and clients in order to gain a deeper understanding of the practical engineering skills used. There are 21 different conferences across the Nation where schools gather to compete with their concrete canoe. Each Spring, Northern Arizona University competes in the Intermountain Southwest Conference (IMSWC) in order to receive a final score from the conference judges. The final score is composed of five different categories: Project Proposal, Enhanced Focus Area, Technical Presentation, Final Product Prototype and On-Site Race Demonstration. The point breakdown of these categories is shown below in *Table 1*.

Table 1: Point Breakdown by Category [1]

Categories	Maximum Points
Project Proposal	25
Enhanced Focus Area	5
Technical Presentation	20
Final Product Prototype	25
Race Demonstration (5 events)	25
Total Possible	100

1.2 Project Background

Northern Arizona University has been building concrete canoes since 1977. In recent years, NAU's canoe teams have placed as follows: 2020-2021 "Ponderosa" placed 4th overall, 2019-2020 "Agassiz" placed 9th overall, 2018-2019 "VolCanoe" placed 11th overall, and 2017-2018 "Canoopa" placed 9th overall. Each of these rankings was out of a total of 18 schools. Canoopa placed strongly in the categories of both design paper (5^{th}) and final product (6^{th}). On the other hand, VolCanoe placed 13th in design paper and 12th in final product. Ponderosa did well in each aspect: 4^{th} in their design paper, 4^{th} in the final product, and 5^{th} in the oral presentation. NAU typically has challenges with maneuvering the canoe each year, making the maneuverability of the canoe one of this year's major goals. This year's competition will be held at the University of Nevada, Las Vegas in April of 2022.

1.3 Technical Considerations

1.3.1 Concrete Mixture

The mix design for NAU's concrete canoe will be governed by rules drafted by the Committee on Concrete Canoe Competitions (C4). These rules control the design of the mix by limiting the materials available to contestants, constraining certain dimensions of the canoe and the number of mixes that can be applied to the canoe. This year the total number of concrete mixtures is limited to a maximum of three. In the mixes, the cementitious materials are required to meet common ASTM standards. At least 30% (by volume) of the total mix is required to be aggregates. A minimum of 50% of these aggregates must be composed of commercially-available lightweight aggregates (meeting ASTM C330) and/or recycled concrete aggregate. The use of bonding adhesives, waste latex paints, and latex emulsions is prohibited. The mix may also contain small reinforcement fibers spread evenly throughout the canoe. The final mix is expected to weigh less than the water the canoe will displace and have a density lower or similar to that of water. This will be achieved by using lightweight aggregates and replacing some of the heavy cement with supplementary cementitious materials (SCM's). Air-trained mixes may also be used to reduce the weight by replacing a portion of the volume of the canoe with air.

1.3.2 Reinforcement

Reinforcement for the canoe is there to ensure the canoe will be able to withstand the loads that could be applied. Reinforcement must be implemented into the canoe in a way that satisfies the rules set by the C4. A couple significant rules that must be followed for this year is that the reinforcement thickness must not exceed 50% of the canoe thickness, reinforcement bars or strands must be less than ½" thick, and the minimum Percent Open Area of any layer of reinforcing material must be at least 40% of the total area. Different reinforcement options will be researched and tested before deciding a final reinforcement material that will be used in the canoe. There will be a few types of reinforcement that will be considered for implementation which will be reinforcing mesh, bearing plates, rebar, and fibers. Research and testing will be performed on the mesh and the fibers that are considered in order to maximize the strength provided to the final project. The mesh will be placed inside the layers of the concrete in order to increase the overall strength of the concrete. The fibers will be mixed in with the concrete mix in order to help prevent cracking in the finished canoe.

1.3.3 Hull Design

The overall design goal of the hull is to increase control for the rowers to maximize the speed the canoe can achieve while staying in control. The categories that will factor into the hull design are efficiency, stability, ability to track well, and compliance with the ASCE Concrete Canoe Rules. The project rules state that the hull must not be greater than 22 feet in length. The initial hull design will be drawn into the software program SolidWorks. This program will be used based on its easy-to-use format and ability to create a 3D model in a short amount of time. Multiple design iterations will be completed in SolidWorks to fully understand the different hull design features that affect the main goal. The multiple design iterations will explore different stems, gunwales, profiles, midspans, bows, and entry lines. After these designs pass the given decision matrix, the designs from SolidWorks will be uploaded into the software program

MaxSurf, a Naval Architecture software. MaxSurf allows for the canoe design to be tested in order to determine drag coefficients and optimize the hull design for maximum efficiency of the canoe. Using this software shows how the canoe will behave in the water before it is actually raced, allowing for the height of the canoe and rowing ability to be optimized before construction of the canoe. The final design will maximize the design challenges.

1.3.4 Structural Calculations

One of the main goals when designing and constructing the canoe is to ensure that it has the required strength to perform in every aspect needed in the competition as well as be able to be picked up and moved without crumbling. The structural calculations will take place in accordance with the rules set by the C4 and will be performed to accommodate the stresses and strains that the canoe will endure. Bending moment is the main type of stress the canoe will endure which can cause it to crack and break in areas. The structural calculations will be performed in accordance with the mix design, hull design, and reinforcement that is selected by the team for the final product. The canoe must be analyzed in a way that ensures the structural aspect of the concrete can support the stresses and strains that will be acting on it.

1.3.5 Construction

The construction of the canoe will start with either a female or male mold. The female mold is an impression of the canoe into a foam mold, and is built from the outside in. A male is developed by forming the inside of the canoe, and the canoe will be poured over to be developed from the inside out. A male mold will have a smoother outside while the female mold will have a smoother inside with the need to for more work to be done on the hull of the canoe. The placement of concrete can be done by hand placement, shotcrete, or injection molding. Mesh fiber inlay will be formed and inserted into the canoe after the first layer of concrete to increase the structural strength of the canoe. Once the canoe is constructed, the concrete will need to be cured for a length of time in a curing chamber. Curing the concrete can be done with humidifying a curing chamber, so that the concrete can cure with a moist environment for a length of time. Curing is the last step in the construction of the canoe. The sanding of the canoe will smooth out the surface of the canoe to help the efficiency and aesthetics of the canoe. This can be done by wet sanding and utilizing different coatings that comply with the competition standards. This coating is used as a sealant for the canoe so that it doesn't allow water to enter the canoe. The sealer can only have two coats, the first coat will be applied before the lettering, and the second layer will be applied at the end.

1.3.6 Aesthetics

The final design and aesthetics of the canoe will reflect Northern Arizona University and the ASCE student chapter. The aesthetics of the canoe is judged at the competition and can be used to gain significant points in the competition as a whole. The main goals of the aesthetics are to provide a mix that can be applied uniformly across the mold. This uniform application will help with the consistency of the concrete, will provide a smooth finish throughout the canoe, and minimize voids in the concrete. The overall theme of the canoe and aesthetics is drawn from the great and mighty Ponderosa Pinecone. The Ponderosa Pinecone can be found throughout Northern Arizona and is a staple in the ecosystem. The Ponderosa Pinecone was chosen and will be used for its inspiration, strength, and beauty. Lastly, the Ponderosa Pinecone image will be used throughout the design to improve the overall aesthetics of the final design for the canoe.

1.4 Potential Challenges

1.4.1 Mix-Design

Mix design is the first important challenge that the team will encounter as it sets the base for the project. The challenge that goes along with mix design is creating a lightweight but durable mix. The mix must generate enough compressive/tensile strength while maintaining an exceptional streamline in the water. Through the process of trial and error, several mix designs will be created and tested for compressive strength, slump, and workability to determine the final mix design.

1.4.2 Concrete Application

The application of concrete is the second key challenge that the team must overcome. The team has two options for the application process; by hand or with Shotcrete. Each process has unique challenges that must be addressed and mitigated. Each of the applications requires a different type of concrete mix. A challenge that is similar to both processes is the reinforcement moving while the concrete is being placed. This issue will be addressed by using smaller sections of reinforcement if placed by hand. If placed using Shotcrete, the advantage is that the different application style and mix design will allow the concrete to be applied with minimal movement in the reinforcement.

1.4.2a Placement by Hand

While applying the concrete, it is important to have an even distribution of aggregate throughout the canoe. This issue could be solved by having mentees and team members constantly spread and smooth the concrete as it is being placed.

1.4.2b Shotcrete Application

The challenge with Shotcrete is confirming the lifts applied are even and consistent. The most efficient way to limit the error is to have a singular team member in charge of the Shotcrete application sprayer. Then, trowels will be used to smooth the applied concrete which will assist in assuring the concrete is evenly placed around the mold.

1.4.3 Mentee Involvement

Mentees are students not yet involved in a capstone project who contribute their time to help the canoe team successfully finish the project. Involving mentees in the design process will also help to prepare them for what they may do for their capstone project. A strong mentee program will ensure the sustainability of NAU's concrete canoe involvement for years to come.

1.4.4 COVID-19

COVID-19 has posed a large issue for the project's completion for the last two canoe teams. This year's conference is slated to be in person, after teams in the past two years participated remotely- with last year's team not constructing a physical canoe. The team will be preparing for a physical conference by preparing a canoe and making accommodations for travel and transportation. The canoe team is prepared for any potential last-minute changes, including a possible switch over to a virtual conference depending on the climate of the matter in the spring of 2022. The team is also abiding to any current restrictions that may affect how in person collaboration and client interactions take place to ensure the safety of everyone involved on the project.

1.5 Stakeholders

There are five stakeholders in this project: Northern Arizona University, Northern Arizona University's College of Engineering, Informatics, and Applied Science (NAU CEIAS), NAU ASCE student chapter, the client (Mark Lamer, PE), and team sponsors. The university and the NAU CEIAS department are stakeholders in this project as the reputation of the college is at risk depending of the team's performance at the Intermountain Southwest Student Conference. If the team receives a good place at the conference, it will reflect positively on the university and the CEIAS department. The ASCE student chapter at NAU is considered a stakeholder because all team members are also members of ASCE, the ASCE chapter also contributes funds to the project and is therefore seen as a stakeholder. Success at conference could increase attendance at club meetings and more fundraising opportunities. The success of the project at the end of the day relies on the satisfaction of the client which makes the client a major stakeholder. The monetary donations and material supplies provided by the team sponsors gives them stake in the project. If the team performs well and places high at conference the sponsors will get positive attention.

2.0 SCOPE OF SERVICES

2.1 Task 1: Enhanced Focus Areas

An area of enhanced focus will guide work done by the 2021 concrete canoe team. To choose a focus area that best enhances the work completed by the team, a design matrix will be designed and utilized as a decision process. There are examples of potential enhanced focus area topics in the Request for Proposal. The chosen enhanced focus area will decide the succeeding tasks.

2.2 Task 2: Mix Design

The team will create a mix design based on parameters put forth in the 2022 ASCE Canoe Guidelines. The mix will be formulated in accordance with the requirements that ASCE creates. The mix historically varies from year to year.

2.2.1 Task 2.1: Mix Design Research

2.2.1.1 Task 2.1.1: Cementitious Materials

The team will research past mix designs used for NAU's concrete canoe teams and at other schools in order to develop a starting point for ratios in the mix design. From there, the team will focus on the ratios of cement to other cementitious materials used in the final design. All materials will be analyzed and re-evaluated for the initial and final mix designs. The proportions of cementitious materials within the mix design will affect the overall combined strength and weight of the final product as well as must be within competition specs and rules.

2.2.1.2 Task 2.1.2: Aggregates

The team will research different types of super-lightweight non-microsphere and microsphere aggregates that are in accordance with the 2022 competition rules. The controlling factor of aggregates in our mix design, according to the 2022 rules, will be that aggregates must be at least 30% of the total volume of the final mix design. In addition, a minimum of 50% of the aggregates utilized in the mix design will either be C330 compliant or recycled concrete aggregate (RCA). Research will be conducted through contacting material suppliers and past teams to receive expert consultation as well as competition and field knowledge. Aggregates occupy a majority of the volume of the mix and will determine the density and strength of the mix.

2.2.1.3 Task 2.1.3: Admixtures

The team will communicate with suppliers and the team technical advisor to receive expert guidance regarding the permitted admixtures per the 2022 rules [2]. Proportions of these admixtures may change from the initial mix design to the final mix design. Admixtures are performance-driven additions to the mix design that accomplish a specific goal such as water weight reduction or cure times.

2.2.2 Task 2.2 Develop an Initial Mix

Given the research conducted for the cementitious materials, aggregates, and admixtures, an initial mix shall be created. This mix should try to fulfill the desired properties that the team has set forth. Once the mix is completed, modifications can be made to future mixes in order to achieve the best concrete mix possible.

2.2.3 Task 2.3: Mix Design Testing

2.2.3.1 Task 2.3.1: Slump Test

For each mix design, slump tests will be conducted following ASTM C143 standards. This test involves placing wet concrete into a cone. The cone is taken off and the concrete will "slump". The height that the concrete has gone down will be the slump measured. The slump value describes how viscous the mix is and its workability.

2.2.3.2 Task 2.3.2: Unit Weight of Mix

Prior to compressive and tensile strength tests, the unit weight will be calculated from the cylinders. This will follow ASTM C138 standards. Unit weight will provide the necessary information to calculate specific gravity, providing the team with the buoyancy of the concrete. This is done by using the unit weights of the materials and volume that each material occupies.

2.2.3.3 Task 2.3.3: Compressive Strength

Compressive strength tests will be conducted at the 14-day and 28-day marks in full accordance with the ASTM C39 testing standard. The compressive strength test results will be used in structural calculations and mix design comparisons.

2.2.3.4 Task 2.3.4: Tensile Strength

Tensile strength tests will be conducted at the 14-day and 28-day marks in full accordance with the ASTM C496 testing standard. The tensile strength test results will be used in structural calculations and mix design comparisons.

2.2.4 Task 2.4: Final Mix Design

Once the team has developed multiple mix design options or initial mix designs as well as completed the necessary testing for each, the final mix design will be chosen based on the desired characteristics of density, workability, and compressive/tensile strength. This final mix will be considered in the hull design and reinforcement options and will be used for structural calculations. The final mix design table which outlines all materials included in the mix, the volumes of each, the percent of the total mix volume, and specific unit weights of each material and the mix design, will be included in the final report and conference technical proposal.

2.3 Task 3: Hull Design

2.3.1 Task 3.1: Hull Design Research

The team will research geometric options for the hull design while following the dimensional limits set within the Request for Proposal that was released by C4. The shape chosen for the hull design affects the performance of the canoe in order to best optimize the trade-offs between speed and maneuverability.

2.3.2 Task 3.2 Software Modeling

2.3.2.1 Task 2.3.1: SolidWorks

SolidWorks is a computer-aided drafting program that is compatible with other analysis programs such as MaxSurf. SolidWorks will be used for the design component of hull design. The chosen geometric shape will be implemented within the program.

2.3.2.2 Task 2.3.2: MaxSurf

MaxSurf will be used to optimize the SolidWorks design through simulation. MaxSurf is a program that analyzes the hydrodynamics of vessels. This will help the team to predict the canoe's performance in water.

2.3.3 Task 3.3: Structural Analysis

The team will perform the structural calculations in accordance with the rules set by C4. These calculations will ensure the structural integrity of the canoe in different loading situations such as a 2-man load versus a 4-man load. The calculations will be done in an excel sheet so that the variables can be easily edited. The results from the reinforcement testing and the mix design testing will be included within these calculations. Final calculations will be checked by an expert before finalizing the design.

2.3.4 Task 3.4: Final Hull Design

Once the team has completed the mix design research utilized both SolidWorks and MaxSurf, the hull design will be finalized. This final hull design will have been analyzed for structural strength and hydrodynamics in order to optimize the speed and durability of the canoe design.

2.4 Task 4: Reinforcement

2.4.1 Task 4.1: Research

The final canoe design will include both a primary reinforcement (mesh) and a secondary reinforcement (fibers), and reinforcement bars. Research on mesh reinforcement that has been used in the past will be conducted along with exploring other innovative options. Research will be done for several types of fiber reinforcement. The research will indicate the predicted strength of both the mesh and the fibers.

2.4.2 Task 4.2: Analysis and Testing

Analysis comparing the researched options of mesh reinforcement will be conducted through a decision matrix that utilizes the material properties provided from the suppliers. The strength of the fibers will be analyzed through tensile testing. The analysis for primary and secondary reinforcement will provide values necessary to complete the structural calculations which will inform structural and reinforcement designs.

2.4.3 Task 4.3: Final Reinforcement Design

Once the team has performed the necessary research and testing for both fiber and mesh reinforcement, the final reinforcement for each will be decided. The strengths of these reinforcements will be included in the structural calculations and in both the final report and the conference technical proposal.

2.5 Task 5: Construction

2.5.1 Task 5.1: Mold Procurement

The mold that will be used as a basis for the canoe to be created from. The final mix design will be applied into or onto the final mold to create the canoe. The team at this time has not decided on whether to use a female or male mold as each have their advantages and disadvantages. The team is looking into buying a fiberglass or high-density polyethylene (HDPE) reusable mold. If reusable molds are deemed too expensive or inefficient, the team will investigate CNC cut Styrofoam molds as used by previous teams.

2.5.2 Task 5.2: Cure Chamber Procurement

A cure chamber will be constructed in order to keep the canoe in a humid environment to ensure the concrete keeps a suitable moisture content during the 28 days of curing. Flagstaff has a notoriously dry environment, with humidity levels lower than typical regions. Therefore, extra caution must be exercised to ensure that the concrete cures correctly to minimize the risk of detrimental cracking. Once a chamber is constructed to keep the canoe in a cool, dark environment, a humidifier will be utilized to keep the chamber humid.

2.5.3 Task 5.3: Reinforcement Placement

Reinforcement placement will be considered after the most effective reinforcement material is decided amongst plastic, rubber, and steel reinforcement options. Proper placement of reinforcement will minimize the effects of cracks in the concrete mix and maximize the strength of the canoe. Using the universal testing machine, the concrete mix and different reinforcement options can be strength tested and compared. Using the outcomes of this test, the best reinforcement option can be chosen, along with placement recommendations based on the shear force diagram generated by the testing. This can ensure that the weak spots of the concrete are accounted for and protected.

2.5.4 Task 5.4: Concrete Pours

The concrete placement and pour for the canoe are a vital process for the project as our project transitions from the design to physical phase during the concrete pouring process. The team will use the selected final mix design, reinforcement technique and locations, and the selected mold to place the concrete into or onto the mold in order to create our canoe.

2.5.5 Task 5.5: Curing and Removal from Mold

The curing of the concrete canoe while in the mold is crucial to minimizing the amount of cracking and ensuring the highest compressive strength possible. The curing of the concrete in the mold will likely take 14-days to 28-days to achieve max strength before removal of the mold. The team will apply water and any other needed curing agents to ensure the characteristics mentioned above during the curing process. Removing the canoe from the mold will be done by adding a removing liquid that doesn't allow the concrete to bond to the mold. The team will reach out to our technical advisor closer to the pour date for specific recommendations as Taylor Layland, Technical Advisor, gave multiple suggestions during our preliminary meeting.

2.5.6 Task 5.6: Apply Aesthetics

The aesthetics of the canoe constitute the evenness the concrete pour, the smoothness of the surface of the canoe, and the paint job. Precautions will be taken in order to ensure a good concrete pour. Sanding will be done in order to have a smooth surface to the canoe. The paint job of the canoe will reflect the theme of the project - the ponderosa pinecone.

2.5.7 Task 5.7: Create Stand

The stand is necessary for the display of the canoe at the conference. The stand will reflect our team's theme and complement the aesthetics of the canoe. The stand will likely be made from wood because wood is relatively cheap and easy to work with.

2.6 Task 6: Conference Deliverables

2.6.1 Task 6.1: Complete Conference Preliminary Information

The Conference Preliminary Information is the acknowledgement of the Request of Proposal. This gives the C4 a rough schedule of our project, the intent for our technical proposal, and some prequalification forms. This task needs to be completed in order to enter the 2022 ASCE Concrete Canoe Competition.

2.6.2 Task 6.2: Complete Conference Technical Proposal

A technical proposal will be submitted for points toward the overall competition score. The technical proposal will follow the provided outline given in the Request for Proposal released by C4 [2]. The proposal will be judged based on the overall design components along with the success of the project management.

2.6.3 Task 6.3: Complete Enhanced Focus Areas Report

The team will submit a report justifying and presenting the chosen enhanced focus areas for this year's canoe. This report will follow the guidelines set in the Request for Proposal released by C4 [2]. The enhanced focus area report will be judged based on the selection process along with overall summaries of the enhanced focus areas. It will also be judged based on the problem statement, technical solution, results, and team collaboration for each of the enhanced focus areas. The final item the report is judged on is the overall presentation of the report.

2.6.4 Task 6.4: Give Conference Presentation

The team will create a presentation to be presented live to a panel of judges for part of the overall competition score. The presentation will be given either virtually or in-person if permitted. The presentation will challenge the team to enhance their competence and knowledge of the project.

2.6.5 Task 6.5: Transport Canoe

The transportation of the canoe to the IMSWC conference in Las Vegas will be necessary and critical to the project and conference competition. Finding safe transportation of the canoe will be difficult as the canoe will likely be above 20 feet in length.

2.6.6 Task 6.6: Race Canoe

There are 5 different races that the canoe will have to perform in. These races are a 4-man co-ed sprint, a women's 2-man sprint, a men's 2-man sprint, a women's 2-man slalom, and a men's 2-man slalom. The races are of varying lengths, all slalom races are 200 meters in length. Practice will be necessary in weeks prior to the conference in order to optimize performance.

2.7 Task 7: Deliverables for CENE 486

2.7.1 Task 7.1: Complete 30% Submittal

A 30% report and presentation will be submitted to the grading instructor by the deadline. The 30% report will be the first rough draft submission to ensure the team is on track for the final report. Along with the submission of the 30%, mix design and hull design are to be complete by this stage.

2.7.2 Task 7.2: Complete 60% Submittal

A 60% report and presentation will be submitted to the grading Instructor by the deadline. The 60% report will be the second rough draft submission to ensure the team is on track for the final report. Along with the submission of the 60%, reinforcement design will have been complete, and the canoe will be cast.

2.7.3 Task 7.3: Complete 90% Submittal

A 90% report will be submitted to the Grading Instructor by the deadline. A practice final presentation will be given in order to receive feedback before the final presentation. The 90% report will be the last draft submission prior to the final report. This submission will include all completed sections of the report with the expectation of receiving redlines. At this stage, the canoe has been completed to entirety and conference deliverables are complete.

2.7.4 Task 7.4: Complete Final Report

The final report will be submitted to the Grading Instructor by the deadline. The final report will document the overall design and performance of the team's work throughout the course of the project.

2.7.5 Task 7.5: Complete Final Website

The team will put together a website that includes all team contact information along with the deliverables listed above. By the end of this project, this website will outline the work done throughout the project. Creating a website will allow for an electronic documentation method that can be used by future engineering students.

2.7.6 Task 7.6: Give Final Presentation

The team will give a final presentation to the instructors of CENE 486. This presentation will be judged based on the overall organization and professionalism, technical approach, scope, schedule, fees, health and safety, quality control and quality assurance, sustainability, construction drawings and specifications, project schedule, mix materials and proportions, structural calculations, and innovation. The final presentation will encompass the overall progress of the team throughout the course of the project.

2.8 Task 8: Project Management

2.8.1 Task 8.1: Project Meetings

2.8.1.1 Task 8.1.1: Team Meetings

Team meetings are to be help on a weekly basis, location and time to be determined. Within the team meetings, a thorough discussion of action items and upcoming tasks are to be had. As a group, feedback will be analyzed and discussed in order to ensure progress of project is positively trending.

2.8.1.2 Task 8.1.2: Grading Instructor/Technical Advisor Meetings

Meetings with the Grading Instructor/Technical Advisor are to be held at least 4 times throughout this semester, or roughly every 3-4 weeks. These meetings are organized to gain greater insight into project, and to ensure work is completed to the highest quality while following all given criteria.

2.8.1.3 Task 8.1.3: Client Meetings

Client meetings will be organized to be held on a monthly basis in order to relay updates and information to client. The progression of the project will be discussed in these meetings, and client will be able to comment and give new information that may be critical to the project.

2.8.2 Task 8.2: Budget Management

A budget analysis will be conducted by the team before the project work begins to ensure that the necessary funds are met to complete the project. Fundraising is necessary for this project in order to purchase materials for the mix design, construction preparation, and transportation. Fundraising will be conducted to meet the budget demands.

2.8.3 Task 8.3: Schedule Management

A schedule will be created in order to keep the team progressing throughout the project. A Gantt chart will be utilized to visually represent the schedule. The schedule will likely have small changes throughout the course of the project in order to compensate for tasks taking longer or shorter amounts of time to complete.

2.8.4 Task 8.4: Fundraising

Fundraising will be done in order to satisfy the costs of materials primarily. Fundraising will be supplied by both monetary and material donations. Likely sponsors will be material suppliers, construction or engineering firms, friends, and family members.

2.9 Impacts

2.9.1 Task 9.1: Social

The social impacts of the project will be analyzed over the course of the project. The social effects are likely to affect the ASCE chapter at NAU, the public perception of NAU, and it could even change the lives of the students involved in the project

2.9.2 Task 9.2: Economic

The economic impacts of the project will be analyzed at the conclusion of the project. The success or failure of fundraising for the project will play a large part of this. There will also be the impact that the sponsors of the team will have on our project.

2.9.3 Task 9.3: Environmental

The environmental impacts of the project will be analyzed at the conclusion of the project as well. There are many ways in which the completion of the project will have on the environment.

2.10 Exclusions

There are no exclusions within the project scope. All aspects of the project are outlined in order to achieve the deliverables from both CENE 486 and the Request for Proposal from C4.

3.0 SCHEDULE

The duration of the project from start to finish is 145 working days. This includes breaks for Thanksgiving (November 25, 2021 through November 28, 2021), Christmas and New Year's (December 21, 2020 through January 4, 2021). In the schedule, working days are classified as weekdays, Monday through Friday, 8 hours per day. The tasks within the schedule follow the same numbering system as the tasks in Section 2.0 Scope shown above. The milestones identified within the schedule are shown as black diamonds and include enhanced focus areas, final mix design, final hull design, conference technical proposal, enhanced focus areas report, Conference Presentation, transportation of canoe, and racing. The sub-tasks shown under Task 8: Deliverables, are all shown with their assigned durations milestones so that the team will stay on-task with the starting dates of each assignment. Refer to Appendix A for the full Gantt chart. *Figure 1*, displayed in *Appendices A*, shows the schedule created for this project.

3.1 Critical Path

The critical path is shown in red on the attached Gantt chart. The items included in the critical path must be completed on time to meet the set project end date of May 6th, 2021. The starting date of each critical task will be closely monitored through weekly team meetings to ensure the team stays on track with the critical path. The first critical task in the schedule is Task 2.1: Mix Design Research which includes Task 2.1.1: Cementitious Materials, Task 2.1.2: Aggregates, and Task 2.1.3: Admixtures. The following critical task is Task 4: Reinforcement which includes Task 4.1: Research and Task 4.2: Analysis. The next critical task is Task 5: Construction. The sub-tasks included in the critical path are Task 5.4: Concrete Pours, Task 5.5: Curing and Removal from Mold, and Task 5.7: Stand. The final set of critical tasks are under Task 7: Deliverables for 486, which include Task 8.1: 30% Submittal, Task 7.2: 60% Submittal, Task 7.3: 90% Report, Task 7.4: Final Report, Task 7.5: Website, and Task 7.6: Final Presentation. The items listed above make up the critical path because in order for the project to finish by its deadline, these specific tasks must be completed on time. If any of these items are delayed, it would delay all succeeding critical path tasks and would affect the project end date.

4.0 STAFFING PLAN

4.1 Staff Positions

The staff positions for this project are as follows: Principal Design Engineer (PDE), Design Manager (DM), Project Construction Manager (PCM), Construction Superintendent (CS), Project Design Engineer (PE), Quality Manager (QM), Graduate Field Engineer (EIT), Technician/Drafter (TD), Laborer/Technician (LT), Clerk/Office Admin (OA), and Outside Consultant (OC).

The Principal Design Engineer oversees and approves all of the work completed throughout the project. The Design Manager is in charge of all things design, from mix to structural. The Project Construction Manager oversees all aspects of construction, with prioritized focus on reinforcement and concrete pours. The Construction Superintendent assists the Project Construction Manager in the overseeing of construction activities. The Project Design Engineer works under the Design Manager to work on all design aspects. The Quality Manager ensures that all of the work completed meets the required standards while analyzing the economic, social, and environmental impacts of the project. The Graduate Field Engineer works on all parts of the project and must have their work reviewed and approved by the Principal Design Engineer. The Technician/Drafter works solely on drafting plans such as the hull design. The Laborer/Technician performs lab testing and mix design tasks. The Clerk/Office Admin works on the payroll and financial related aspects of the project. The Outside Consultant is a generalization of the people to be contacted and worked with outside of the firm. The staffing positions are summarized in *Table 2*.

Table 2: Staffing Positions

Staff Positions	
Title	**Abbreviation**
Principal Design Engineer	PDE
Design Manager	DM
Project Construction Manager	PCM
Construction Superintendent	CS
Project Design Engineer (P.E.)	PE
Quality Manager	QM
Graduate Field Engineer (E.I.T.)	EIT
Technician/Drafter	TD
Laborer/Technician	LT
Clerk/Office Admin	OA
Outside Consultant	OC

4.2 Personnel Qualifications

Each of the five senior level students that will contribute to the project have taken necessary classes that directly relate to the work done for the canoe. These classes include Mechanics of Materials lecture and lab, Geotechnical Engineering Lab, Reinforced Concrete Design, Structural Analysis, and Water Resources lecture and lab. Passing these classes ensures the students working on the project have sufficient knowledge to successfully complete the project.

4.3 Staffing Matrix

A staffing matrix was created to outline the total hours for each of the staffing positions. The staffing matrix is organized with task versus staffing positions. The team assigned hours for each staffing matrix, refer to Appendix B. A summary of the total hours for each staff position is shown below in *Table 3*.

Table 3: Staffing Matrix Summary

Staffing Summary	
Title	Hours
PDE	133
DM	121
PCM	36
CS	22
PE	183
QM	133
EIT	265
TD	65
LT	120
OA	27
OC	12
Total	1117

5.0 COST OF ENGINEERING SERVICES

To determine the cost of engineering services, a matrix was created that shows the cost of personnel, travel, lab use, and materials. The personnel descriptions and total hours correspond to *4.3 Staffing Matrix*. The raw labor rates were taken directly from Exhibit 8 of the C4 Request for Proposal [1], but do not presently reflect the multipliers.

The travel costs were estimated for material acquisition because the necessary materials are not often locally available and for conference as it is located in another state. Lab use costs refer to the use of NAU on-campus labs that will be used for both mix design and material testing. The lab use costs were directed by Mark Lamer, P.E., the client for the project. The material costs shown in the matrix are the materials used during mix testing. The summary table of the cost of engineering services is shown in the table below, *Table 4*. For the full matrix for cost of engineering services, refer to Appendix C.

Table 4: Cost of Engineering Service Summary [2], [3], [4], [5], [6]

Cost of Engineering Services Summary		
Description	Cost	
Personnel	$	39,600
Travel	$	1,795
Lab Use	$	1,000
Materials	$	1,514
Total	$	43,909

6.0 REFERENCES

[1] ASCE Concrete Canoe Competition Committee, "2022 American Society of Civil Engineers Concrete Canoe Competition Request for Proposals," Committee on Concrete Canoe Competitions, Reston, 2021.

[2] Northern Arizona University, "Welcome to NAU Travel," Northern Arizona University, 2021. [Online]. Available: https://in.nau.edu/comptroller/travel-welcome/. [Accessed 7 November 2021].

[3] "How much does it cost to travel to Palm Springs?," Budget Your Trip, 2020. [Online]. Available: https://www.budgetyourtrip.com/united-states-of-america/palm-springs. [Accessed 7 November 2021].

[4] S. Lock, "Average daily room rate in Las Vegas in the United States from 2002 to 2020," Statista, 2020. [Online]. Available: https://www.statista.com/statistics/221047/daily-room-rate-in-las-vegas/. [Accessed 7 November 2021].

[5] Northern Arizona University, Concrete Canoe (2021), *Capstone Final Proposal,* Flagstaff, 2021.

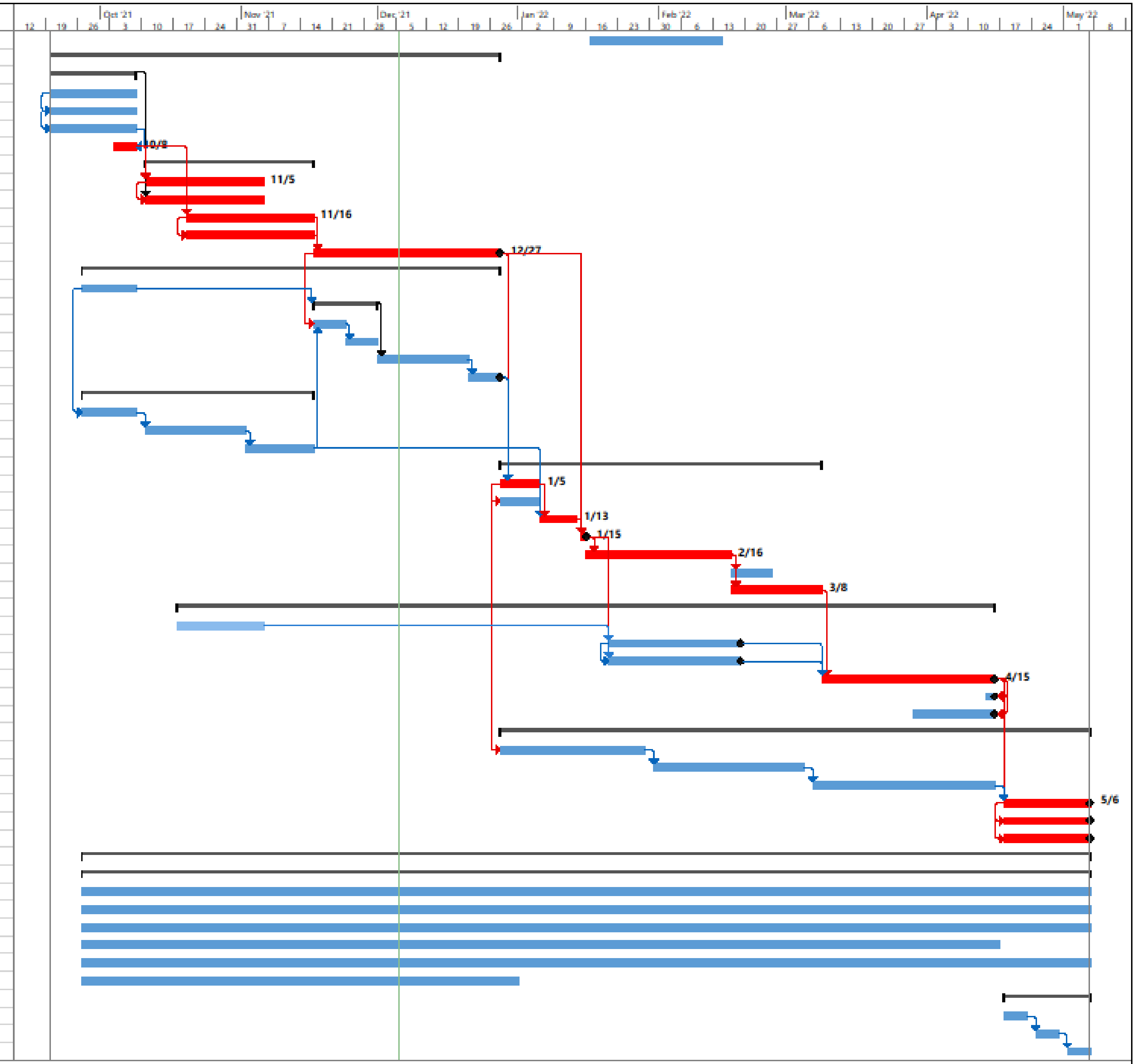
[6] J. Andre, *F3 Online, Inc. a.k.a. EPS Products - Fabrication of Foam & Metal Products,* Palm Springs, 2021.

7.0 APPENDICES

7.1 Appendix A: Project Schedule Gantt Chart

Refer to the next page for a full 11” x 17” project Gantt chart. The critical path is outlined in red.

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Task 1: Enhanced Focus Areas**	21 days	Mon 1/17/22	Mon 2/14/22	
2	**Task 2: Mix Design**	**71 days**	**Mon 9/20/21**	**Mon 12/27/2**	
3	**Task 2.1: Mix Design Research**	**15 days**	**Mon 9/20/21**	**Fri 10/8/21**	
4	Task 2.1.1: Cementitious Materials	15 days	Mon 9/20/21	Fri 10/8/21	
5	Task 2.1.2: Aggregates	15 days	Mon 9/20/21	Fri 10/8/21	4SS
6	Task 2.1.3: Admixtures	15 days	Mon 9/20/21	Fri 10/8/21	5SS
7	**Task 2.2: Develop an Initial Mix Design**	5 days	Mon 10/4/21	Fri 10/8/21	6FF
8	**Task 2.3: Mix Design Testing**	**27 days**	**Mon 10/11/2**	**Tue 11/16/2**	
9	Task 2.3.1: Slump Test	20 days	Mon 10/11/2	Fri 11/5/21	7
10	Task 2.3.2: Unit Weight of Mix	20 days	Mon 10/11/2	Fri 11/5/21	9SS,3
11	Task 2.3.3: Compressive Strength	20 days	Wed 10/20/2	Tue 11/16/21	7
12	Task 2.3.4: Tensile Strength	20 days	Wed 10/20/2	Tue 11/16/21	11SS
13	**Task 2.4: Final Mix Design**	29 days	Wed 11/17/2	Mon 12/27/2	12,11
14	**Task 3: Hull Design**	**66 days**	**Mon 9/27/21**	**Mon 12/27/2**	
15	**Task 3.1: Hull Design Research**	10 days	Mon 9/27/21	Fri 10/8/21	
16	**Task 3.2: Software Modeling**	**10 days**	**Wed 11/17/2**	**Tue 11/30/2**	15
17	Task 3.2.1: Solidworks	5 days	Wed 11/17/2	Tue 11/23/21	13SS,24
18	Task 3.2.2: MaxSurf	5 days	Wed 11/24/2	Tue 11/30/21	17
19	**Task 3.3: Structural Analysis**	14 days	Wed 12/1/21	Mon 12/20/2	16
20	**Task 3.4: Final Hull Design**	5 days	Tue 12/21/21	Mon 12/27/2	19
21	**Task 4: Reinforcement**	**37 days**	**Mon 9/27/21**	**Tue 11/16/2**	
22	**Task 4.1: Research**	10 days	Mon 9/27/21	Fri 10/8/21	15SS
23	**Task 4.2: Analysis and Testing**	16 days	Mon 10/11/2	Mon 11/1/21	22
24	**Task 4.3: Final Reinforcement Design**	11 days	Tue 11/2/21	Tue 11/16/21	23
25	**Task 5: Construction**	**53 days**	**Tue 12/28/2**	**Tue 3/8/22**	
26	**Task 5.1: Mold Procurement**	7 days	Tue 12/28/21	Wed 1/5/22	20,13
27	**Task 5.2: Cure Chamber Procurement**	7 days	Tue 12/28/21	Wed 1/5/22	26SS
28	**Task 5.3: Reinforcment Placement**	6 days	Thu 1/6/22	Thu 1/13/22	24,26
29	**Task 5.4: Concrete Pours**	1 day	Sat 1/15/22	Sat 1/15/22	28,13
30	**Task 5.5: Curing and Removal from Mold**	24 days	Sun 1/16/22	Wed 2/16/22	29
31	**Task 5.6: Aesthetics**	7 days	Thu 2/17/22	Fri 2/25/22	30
32	**Task 5.7: Stand**	14 days	Thu 2/17/22	Tue 3/8/22	30
33	**Task 6: Conference Deliverables**	**132 days?**	**Mon 10/18/2**	**Fri 4/15/22**	
34	**Task 6.1: Preliminary Conference Information**	**15 days?**	**Mon 10/18/2**	**Fri 11/5/21**	
35	**Task 6.1: Conference Technical Proposal**	21 days	Fri 1/21/22	Fri 2/18/22	29,34
36	**Task 6.2: Enhanced Focus Areas Report**	21 days	Fri 1/21/22	Fri 2/18/22	35SS,34
37	**Task 6.3: Conference Presentation**	28 days	Wed 3/9/22	Fri 4/15/22	36,35,32
38	**Task 6.4: Transportation of Canoe**	2 days	Thu 4/14/22	Fri 4/15/22	37FF
39	**Task 6.5: Racing**	14 days	Tue 3/29/22	Fri 4/15/22	37FF
40	**Task 7: Deliverables for 486**	**96 days**	**Tue 12/28/2**	**Fri 5/6/22**	
41	**Task 7.1: 30% Submittal**	26 days	Tue 12/28/21	Fri 1/28/22	26SS
42	**Task 7.2: 60% Submittal**	25 days	Mon 1/31/22	Fri 3/4/22	41
43	**Task 7.3: 90% Report**	30 days	Mon 3/7/22	Fri 4/15/22	42
44	**Task 7.4: Final Report**	15 days	Mon 4/18/22	Fri 5/6/22	43,37
45	**Task 7.5: Website**	15 days	Mon 4/18/22	Fri 5/6/22	44SS
46	**Task 7.6: Final Presentation**	15 days	Mon 4/18/22	Fri 5/6/22	44SS
47	**Task 8: Project Management**	**162 days**	**Mon 9/27/21**	**Fri 5/6/22**	
48	**Task 8.1: Project Meetings**	**162 days**	**Mon 9/27/21**	**Fri 5/6/22**	
49	Task 8.1.1: Team Meetings	162 days	Mon 9/27/21	Fri 5/6/22	
50	Task 8.1.2: Grading Instructor/Technical Advisor Meet	162 days	Mon 9/27/21	Fri 5/6/22	
51	Task 8.1.3: Client Meetings	162 days	Mon 9/27/21	Fri 5/6/22	
52	**Task 8.2: Budget**	148 days	Mon 9/27/21	Sat 4/16/22	
53	**Task 8.3: Schedule**	162 days	Mon 9/27/21	Fri 5/6/22	
54	**Task 8.4: Fundraising**	70 days	Mon 9/27/21	Fri 12/31/21	
55	**Task 9: Impacts**	**15 days**	**Mon 4/18/22**	**Fri 5/6/22**	
56	**Task 9.1: Social**	5 days	Mon 4/18/22	Fri 4/22/22	
57	**Task 9.2: Economic**	5 days	Mon 4/25/22	Fri 4/29/22	56
58	**Task 9.3: Environmental**	5 days	Mon 5/2/22	Fri 5/6/22	57



7.2 Appendix B: Staffing Matrix

Task	PDE	DM	PCM	CS	PE	QM	EIT	TD	LT	OA	OC
Task 1: Enhanced Focus Area	**4**	**4**	**4**	**0**	**4**	**4**	**4**	**4**	**4**	**0**	**0**
Task 2: Mix Design	**8**	**52**	**0**	**4**	**28**	**50**	**64**	**2**	**82**	**0**	**0**
Task 2.1: Mix Design Research	3	30	0	0	6	0	12	0	0	0	0
Task 2.1.1: Cementitious Materials	1	10	0	0	2	0	4	0	0	0	0
Task 2.1.2: Aggregates	1	10	0	0	2	0	4	0	0	0	0
Task 2.1.3: Admixtures	1	10	0	0	2	0	4	0	0	0	0
Task 2.2: Develop an Initial Mix	0	6	0	0	6	10	20	0	40	0	0
Task 2.3: Mix Design Testing	4	16	0	4	16	40	32	0	42	0	0
Task 2.3.1: Slump Test	1	4	0	1	4	10	8	0	10	0	0
Task 2.3.2: Unit Weight of Mix	1	4	0	1	4	10	8	0	10	0	0
Task 2.3.3: Compressive Strength	1	4	0	1	4	10	8	0	20	0	0
Task 2.3.4: Tensile Strength	1	4	0	1	4	10	8	0	2	0	0
Task 2.4: Final Mix Design	1	0	0	0	0	0	0	2	0	0	0
Task 3: Hull Design	**6**	**10**	**4**	**0**	**8**	**12**	**8**	**34**	**9**	**0**	**0**
Task 3.1: Hull Design Research	1	6	0	0	6	6	6	0	0	0	0
Task 3.2: Software Modeling	2	4	0	0	0	4	0	32	8	0	0
Task 3.2.1: SolidWorks	1	2	0	0	0	2	0	16	4	0	0
Task 3.2.2: MaxSurf	1	2	0	0	0	2	0	16	4	0	0
Task 3.3: Structural Analysis	2	0	0	0	2	2	2	0	0	0	0
Task 3.4: Final Hull Design	1	0	4	0	0	0	0	2	1	0	0
Task 4: Reinforcement	**11**	**24**	**8**	**0**	**0**	**10**	**8**	**10**	**10**	**0**	**0**
Task 4.1: Research	8	8	0	0	0	2	2	2	2	0	0
Task 4.2: Analysis and Testing	2	16	4	0	0	8	6	8	8	0	0
Task 4.3: Final Reinforcement Design	1	0	4	0	0	0	0	0	0	0	0
Task 5: Construction	**6**	**10**	**11**	**9**	**8**	**4**	**24**	**2**	**2**	**0**	**4**
Task 5.1: Mold Procurement	0	2	2	1	2	0	10	2	2	0	4
Task 5.2: Cure Chamber Procurement	0	0	2	0	0	0	4	0	0	0	0
Task 5.3: Reinforcement Placing	6	6	2	6	6	0	2	0	0	0	0
Task 5.4: Concrete Pours	0	0	2	2	0	2	4	0	0	0	0
Task 5.5: Curing and Removal from Mold	0	0	2	0	0	2	2	0	0	0	0
Task 5.6: Aesthetics	0	2	1	0	0	0	2	0	0	0	0
Task 6: Conference Deliverables	**32**	**12**	**0**	**0**	**46**	**10**	**58**	**0**	**0**	**0**	**0**
Task 6.1: Conference Technical Proposal	16	0	0	0	30	6	16	0	0	0	0
Task 6.2: Enhanced Focus Areas Report	4	0	0	0	16	4	12	0	0	0	0
Task 6.3: Conference Presentation	12	12	0	0	0	0	0	0	0	0	0
Task 6.4: Transportation of Canoe	0	0	0	0	0	0	5	0	0	0	0
Task 6.5: Racing	0	0	0	0	0	0	25	0	0	0	0
Task 7: Deliverables for CENE 486	**25**	**0**	**0**	**0**	**80**	**34**	**90**	**4**	**4**	**0**	**0**
Task 7.1: 30% Submittal	2	0	0	0	12	4	26	0	0	0	0
Task 7.2: 60% Submittal	2	0	0	0	16	4	26	0	0	0	0
Task 7.3: 90% Submittal	4	0	0	0	30	4	16	0	0	0	0
Task 7.4: Final Report	8	0	0	0	16	4	6	0	0	0	0
Task 7.5: Website	1	0	0	0	0	10	12	4	4	0	0
Task 7.6: Final Presentation	8	0	0	0	6	8	4	0	0	0	0
Task 8: Project Management	**41**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**27**	**9**
Task 8.1: Project Meetings	9	9	9	9	9	9	9	9	9	9	9
Task 8.1.1: Team Meetings	3	3	3	3	3	3	3	3	3	3	3
Task 8.1.2: Grading Instructor/Technical Advisor Mee	3	3	3	3	3	3	3	3	3	3	3
Task 8.1.3: Client Meetings	3	3	3	3	3	3	3	3	3	3	3
Task 8.2: Budget	10	0	0	0	0	0	0	0	0	6	0
Task 8.3: Schedule	12	0	0	0	0	0	0	0	0	6	0
Task 8.4: Fundraising	10	0	0	0	0	0	0	0	0	6	0
Task 9: Impacts	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**
Task 9.1: Social	1	0	0	0	0	0	0	0	0	1	0
Task 9.2: Economical	1	0	0	0	0	0	0	0	0	1	0
Task 9.3: Environmental	1	0	0	0	0	0	0	0	0	1	0
Total (EA- hours)	136	121	36	22	183	133	265	65	120	30	13
Project Total	**1124**										

7.3 Appendix C: Cost of Engineering Services Matrix

Engineering Services Cost Estimate				
Description	**QTY**	**Unit of Measure**	**Rate (USD/UM)**	**Cost**
PERSONNEL (direct employee costs + indirect employee costs)				
Principal Design Engineer	136	HR	$ 50	$ 6,800
Design Manager	121	HR	$ 45	$ 5,445
Project Construction Manager	36	HR	$ 40	$ 1,440
Construction Superintendent	22	HR	$ 40	$ 880
Project Design Engineer (P.E.)	183	HR	$ 35	$ 6,405
Quality Manager	133	HR	$ 35	$ 4,655
Graduate Field Engineer (E.I.T.)	265	HR	$ 25	$ 6,625
Technician/Drafter	65	HR	$ 20	$ 1,300
Laborer/Technician	120	HR	$ 25	$ 3,000
Clerk/Office Admin	30	HR	$ 15	$ 450
Outside Consultant	13	HR	$ 200	$ 2,600
			Personnel Total	$ 39,600
TRAVEL				
Travel for Material Acquisition				
Transportation	800	Miles	$ 0.46	$ 368
Hotel Arrangements	1	Nights	$ 191	$ 191
Travel for Conference				
Transportation	600	Miles	$ 0.46	$ 276
Hotel Arrangements	4	Nights (for 2 rooms)	$ 240	$ 960
			Travel Total	$ 1,795
Lab Use				
General Lab Access	10	Days	$ 100	$ 1,000
			Lab Use Total	$ 1,000
Materials				
Cementious Materials	10	Cubic Feet	$ 10	$ 100
Aggregates	12	Cubic Feet	$ 15	$ 180
Admixtures	2	Gallon	$ 12	$ 24
Reinforcement	15	Square Yard	$ 14	$ 210
Mold	1	N/A	$ 1,000	$ 1,000
			Materials Total	$ 1,514
			Project Total	$ 43,909