NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

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Course: CENE 476

Date: December 15, 2017

Assignment: Final Proposal

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1.0 Project Understanding

1.1 Project Purpose

The Pacific Southwest Conference (PSWC) is a regional competition held annually through the American Society of Civil Engineers (ASCE). Colleges within this region compete against one another through technical projects including the concrete canoe. This project entails a team of students designing and constructing a canoe composed of a unique concrete mix. Northern Arizona University (NAU) adopted the concrete canoe as a senior design project for civil engineering undergraduates. The National Concrete Canoe Competition (NCCC) committee released the rules for the 2018 competition on September 11, 2017. These rules include specifications pertaining to the concrete mix, structural, and reinforcement design, final product aesthetics, and the final design report. Scores for the final product are awarded to teams based off these parameters. Other scored components include passing a “swamp-test”, placement in the races, and ensuring durability. The swamp-test demonstrates the canoe’s buoyancy by submerged it in a body of water. Once the canoe is fully submerged, a time period of two minutes will begin. If the canoe floats to the water surface within these two minutes, the canoe passes the swamp-test; otherwise, it fails. There are 5 races that take place after the swamp-test: men’s endurance, women’s endurance, men’s sprints, women’s sprints, and co-ed sprints. The canoe must be able to withstand the forces applied by the paddlers, which are supported by the hull and reinforcement. Inspections of the canoe will be made before and after the races check for cracks, chips, and fractures to determine the durability of the canoe. Points will be deducted if damages appear on the canoe after racing. By following the 2018 NCCC rules and regulations, the team’s objective is to design and construct a concrete canoe that is safe, durable, and buoyant.

1.2 Project Background

The first Pacific Southwest competition for ASCE was documented in the 1970’s [1]. NAU participates in the PSWC with regions 8 and 9 of ASCE [2]. The annual competition is held at a university campuses located in the Western U.S., with a different host each year. This year the conference will be co-hosted by Arizona State University (ASU) and Northern Arizona University (NAU). The competition will be located at ASU’s campus. The oral presentation of the project will be at College Avenue Commons. The races will be located at South Side Tempe Beach Park.

1.3 Technical Considerations

1.3.1 Mix Design

The concrete canoe will be constructed with a concrete mixes developed and tested by the team throughout the semester. The canoe will be composed of up to three mixes: a structural mix, patch mix and a finishing mix. The major components of each mix includes cement, aggregates, admixtures, and water, with each component of the mix design serves a specific purpose. Cement serves as a binder or adhesive for the mix. The lightweight aggregate provides compressive strength to the mix. Admixtures provide desired mix properties such as workability and shrinkage reducer. The mix design will be developed by testing various mixes with different proportions of each component. Each mix will be analyzed according to its performance in four categories: slump test, compressive test, split tensile test, and unit weight. Each category is described in detail in the scope section of this report. The proportions of each material will be chosen based off of its performance after testing.

The mix designed for the concrete canoe must abide by the rules and American Society of Testing Materials (ASTM) standards outlined by the NCCC such as ASTM C330 for lightweight aggregate, C150 for Portland cement, and C618 for fly ash. The NCCC mix design rules regulate the materials that can be used in the mix as well as the percentage by volume required for specific materials. According to the NCCC rules, the mix design must contain at least 25% aggregate from the overall volume. Further, 25% of the aggregate volume shall be commercially available lightweight aggregate. Commercially available is defined as easily obtainable since it is available industry wide. The other 75% of the mix is comprised of cementitious materials, admixtures, and water.

1.3.2 Structural Design

The design of the canoe will incorporate the successes of previous canoes and learning from their failures. The dimensions of the canoe cannot exceed 22' (L) x 36" (W) to comply with the regulation provided by the 2018 NCCC rules [5]. To ensure that the design can safely be used during the competition, the structural analysis of the canoe will be completed using RISA 2-D and hand calculations. The analysis will include multiple loading conditions based on the different races the canoe will compete in. The strengths used in the structural analysis will be based on the test results for the concrete mix and reinforcement. Additional structural components for the hull design such as ribs, gunwales, and thwarts will be used if deemed beneficial after completing the structural analysis for the canoe.

1.3.3 Reinforcement Design

Reinforcement in the concrete canoe adds tensile strength and shear resistance to the concrete. Reinforcement materials including carbon fiber mesh, grids, and glass fibers distribute shear stress and comply with the NCCC rules. The NCCC rules require the reinforcement to have a minimum percent open area (POA) 40% to provide a sufficient amount of open space for the mechanical bonding between the concrete and reinforcement. The reinforcement materials used in the concrete canoe will be selected through a decision matrix to analyze the cost, accessibility, and test results of each material. The reinforcement materials will be tested for the POA, thickness, and tensile strength. Pre and post tensioning will also be research as alternative methods to add extra tensile strength to the canoe.

1.3.4 Construction Component

To construct the canoe a mold must be designed and built based on the hull design. Concrete is then applied to the mold to create the canoe. The concrete application methods include shotcrete and hand placement. A detailed construction plan will be created to ensure construction goes smoothly and the concrete does not set before it is placed.

1.3.5 Aesthetics

Aesthetics of the canoe are judged during the competition. A theme is generated at the beginning of the project. Specific deliverables must comply with the chosen theme for aesthetic appeal. These deliverables include the canoe itself, the display board, and the design paper.

1.4 Technical Challenges

The two main technical challenges are technology limitations and access to material. Limitations in technology include laboratory equipment and software available for use. The farm has mixing tubs, a scale, humidifiers, and cylinder molds. There are labs available at the Engineering Building that have a compression testing machine and a chop saw. Other limitations include software's like Civil3-D, RISA 2-D, and AutoCAD. These programs are not are not available unless accessed at the Engineering Building. There are time restrictions for when the building is open creating a challenge for when they can be used. Obtaining material for the project can also be a challenge due to a limited supply or budget.

1.5 Stakeholders

There are multiple levels of stakeholders for this project. At the broadest level; there is the NAU ASCE chapter and the NAU Civil and Environmental Engineering (CENE) department. The concrete canoe team will be representing NAU and its organization at a regional and, possibly, national level. The success of the canoe will prove that NAU has a civil engineering department that is well supported and can compete with highly regarded schools. The next level of stakeholders are the sponsors and private supporters. These companies and private citizens provide financial and material donations to assist with the construction of the canoe. These donations are seen as an investment in the future of the team members. By competing well during the competition and completing capstone, this investment will be seen as a success. Another stakeholder for this project is the client. The client is whom the team members seek approval from and the final product must meet their expectations. The final stakeholders for this project are the team members themselves. The team is investing their time and money to create a successful product to present at the competition and capstone. By proving that they can successfully design and create a product, the team can prove that they are ready to join the professional field.

2.0 Scope and Major Deliverables

2.1 Task 1: Fundraising

The concrete canoe team will need to fundraise all material and monetary donations required to design, construct, and transport the concrete canoe. As a club the concrete canoe team will seek funding from the Associated Students of Northern Arizona University (ASNAU) for the team members to attend and compete in the conference. The team will create a GoFundMe account and raise money from private donors such as family members, friends, and coworkers/employers. Fundraising is a continuous process for the concrete canoe, with all money be used strictly for materials, tools, and competition fees.

2.2 Task 2: Mix Design

The mix design for this project is one of the main components needed to complete the canoe. The mix will be instrumental in determining if the canoe will have the strength and buoyancy to compete in races.

2.2.1 Research Materials

Material research includes reviewing materials used by previous teams and the proportions of those materials. External research comprises of looking at how different materials will affect the properties of the mix such as the required strength and unit weight. The properties and proportions of each material will affect the reactions within the mix design. The proportions of each material will be determined based on their individual reactions. Research regarding material interactions shall be done for three ratios: fly ash to cement, cementitious materials to aggregate, and solid material to liquid. The main components that will be analyzed for future mix designs are the unit weight for buoyancy, and tensile and compressive strength for durability.

2.2.1.1 Unit Weight- The unit weight of the concrete is a large factor for determining the canoes bouncy. To achieve an appropriate buoyancy, the unit weight of the concrete should be less than the unit weight of water. While this is not required to, the team believes following this design scope would help create a more successful canoe. The unit weight can be determined by knowing the specific gravity of each material. This information can be found in the technical data sheet(s) that contains the engineering properties of the materials. The specific gravities can then be converted into unit weight and added together based on their proportions to find the unit weight of the concrete.

2.2.1.2 Sample Preparation- For a successful process, materials must be ordered and recorded to ensure that there will be enough material for each mix. Once the mix is determined, materials can be batched out in advance of the mix to allow for a quick mixing time.

2.2.2 Developing Mix

After researching materials and finding those available for use, multiple mix designs will be developed. These designs will start with a preliminary mix which will then be modified until the desired parameters are met. One of the main details that needs to be considered in the mix is the aesthetics of the canoe. This includes incorporating coloring admixtures into the mix to develop a color. The amount of coloring in the mix needs to be considered as it adds extra water to the concrete. This will affect the design since adding water will reduce the strength of concrete.

2.2.3 Executing Mix

The mix will be executed at the farm by measuring and mixing the needed materials in a proper procedure. This will help to produce the optimum amount of concrete per batch. After the mix is performed, a slump test will be completed to determine workability. The concrete will then be poured into cylinders and consolidated to prepare for testing. These cylinders will then be stored at the farm until they are ready for testing. The cylinders are filled and cured using ASTM C31 [6].

2.2.4 Concrete Testing and Analysis

2.2.4.1 Slump Test- After a batch of concrete is thoroughly mixed, a slump test must be performed. This test determines how workable the concrete will by comparing the height of the concrete before and after the slump cone is removed. This process is done following ASTM C143 [7].

2.2.4.2 Cylinder Testing- The cylinders used for testing include a 7, 14, or 28 day cured sample of the concrete mix. Once a sample is ready for testing, it is removed from the cylinder and weighed to determine the unit weight. The sample is then prepared for either a compression or split tensile test.

2.2.4.2.1 Compression Test- This tests begins by placing a cylinder into the compression machine until the concrete fails and cracks. The process followed for this test is from ASTM C39 [8]. Using these testing methods will give values relating to how strong and durable the concrete is. These values will then influence future decisions for mix design.

2.2.4.2.2 Split Tensile Strength Test- This test requires a compression machine, too; however, it is larger than the one used for the previous test. To begin the process, a cylinder will be placed horizontally in the machine. A load will be applied to the curved surface of the cylinder until it reaches failure. When the cylinder experiences a tensile failure, the values displayed will be recorded and used for further analysis. This procedure will follow ASTM C496, so that proper results are received [9].

2.2.5 Analyzing Mix

Analysis of the concrete mix will start with reviewing recorded numbers for the unit weight, compression and tensile strengths, and the slump. These numbers will be compared to the results of previous canoes to determine if the mix needs to be refined. The next step includes looking at why the mix had acceptable or unacceptable values in terms of unit weight, strength, and slump. Further analysis of this will include determining what materials need to be adjusted.

2.2.6 Refining Mix

Modification of the mix will take place after analyzing the results from the two strength tests and slump test. Refining will include adjusting quantities of a material based on the desired parameters. This process will continue until all desired properties of the mix are reached.

2.3 Task 3: Hull Design and Analysis

The objective of this task is to create a hull for the canoe that is structurally competent and possesses dynamic components for racing based contests. This includes determining the shape and size of the canoe, creating a detailed model, and conducting structural analysis of the model. Incorporating the concrete and reinforcement into this design must be accounted for during this process. The design and testing is a circular process where the results are used to modify the design to be tested again. The final design will be constructed using a mold created from this design.

2.3.1 Create Design Envelope

Creating an envelope for the canoe consists of a design range for the length, width, height, and thickness of the canoe. These ranges are listed in the NCCC rules and influenced further from research conducted on previously constructed canoes. The purpose this envelope is to provide flexibility to alter the final design based on the results of the structural analysis.

2.3.2 Determine Shape

Determining the primary shape of the canoe varies based on the goal parameters for racing. Each shape possesses individual benefits compared to others. Factors that can alter the shape of the canoe include stability, speed, capacity, and weight. These factors should be weighed based on the goals for the canoe to determine the most efficient shape.

2.3.3 Draft the Hull in Civil3-D

A detailed three-dimensional model for the hull will be created using the chosen design envelope and shape in Civil3-D and DELFship. This will include detail and section-cut views including callouts to these views. The reinforcement built into the canoe and added between the concrete layers will be included into this model. The completed model will be used for the structural analysis of the canoe and to create the mold.

2.3.4 Structural Analysis

The CAD model will be used to create a representative beam in RISA 2-D to conduct the structural analysis of the canoe. This beam will incorporate the strength of the concrete and the reinforcement used in the canoe. Multiple tests will be conducted to account for the different load combinations the canoe will experience. The loads for these tests representing the average person using the canoe. The results for these tests will be used to modify the final design of the canoe within the ranges set by the design envelope and to provide analytical support for the design.

2.3.5 Design a Mold

Once the shape of the canoe is known, a mold will be designed and constructed. Two of the most common methods are 3D printing and Styrofoam blocks. If Styrofoam blocks are used, the shape of the mold will be achieved by either a wire cutter or manually sawed. Construction can begin once the mold is completed.

2.4 Task 4: Reinforcement

The reinforcement materials are used to increase tensile and compressive strengths to the finalized canoe. Materials permitted under the NCCC include mesh and grids, tendons and strands, bearing plates and fasteners, and fibers. Each material is to be tested for physical attributes, such as thickness of layer and percent of open area, mechanical bonding between concrete and the reinforcement material, and availability of the material.

2.4.1 Testing of Reinforcement Materials

Testing procedures will be conducted on required materials that abide under the NCCC rules. The material's thickness, mechanical bonding between concrete and reinforcement layers, and percent of open area will be tested. The materials will also be tested for flexural stress under the ASTM C1116 [10]. Completing these tests will provide results on each material's attributes.

2.4.1.1 Thickness- The thickness of the reinforcement layer cannot exceed 50% of the overall canoe thickness at any point. The thickness of the reinforcement layer is determined using the load of a1/4 inch glass plate or thinner on top of the reinforcement. Completing this task will provide the thickness of all the materials that meet the 50% required thickness.

2.4.1.2 Test for Mechanical Bonding- The mechanical bonding of the concrete and reinforcement layers will be tested to see if it will form and cure properly. The test is conducted by creating a sample of the predetermined mix with the reinforcement. Completing this test will provide results on how the reinforcement materials being tested will bind with the concrete mix.

2.4.1.3 Determine Percent of Open Area (POA) - Determining the POA of the reinforcement material must be 40% for any mesh or grid reinforcement used. This is determined by running a calculation provided in section 4.3.2 of the NCCC rule manual [5]. The objective of this task is to determine if the mesh used needs to be modified to meet the requirements.

2.4.2 Deciding Reinforcement Materials

All reinforcement materials will comply with the NCCC rules and regulations. The reinforcement materials will need to meet the thickness requirement, and have a POA of 40%. Reinforcement that meets these requirements will go through a testing process with the results placed into a decision matrix. The final reinforcement will be selected based on the results of this matrix.

2.4.3 Deciding on Pre or Post-Tensioning Reinforcement

This task will determine whether the canoe with have pre or post tensioning for reinforcement. This will be determined by comparing the strength each provides, the complication of the procedure, and the risks associated with them. Completing this test will determine the tensioning reinforcement to be used in the canoe.

2.4.3.1 Strength Reinforcement Applies- The determination in strength between post and pre tensioning will be a factor when deciding on which will be used in the canoe. The cables and tendons will be tested for both types of tensioning procedures. The type of reinforcement that provides the minimum amount of strength necessary will be used.

2.4.3.2 Simplicity of Procedure- This task will determine which type of tensioning is more efficient. Both procedures will be attempted, whichever provides the least amount of predicaments and can be completed in an efficient amount of time.

2.4.3.3 Risks- This task will view the potential hazards or complications that may occur when conducting pre or post tensioning. Predicting any issues that may occur on the testing procedures or construction of the canoe will also be considered for risk. The reinforcement type that has the least amount of risk will aid in the decision of reinforcement.

2.5 Task 5: Construction

Construction is another integral part of the project that includes building a construction table, designing a mold, and determining a concrete placement method.

2.5.1 Construction Table

A construction table is useful when placing the concrete onto the mold. The table elevates the mold to ensure proper placing of the concrete. The table used last year can be used as a base for this year's table. The table will be modified to reflect the final structural design.

2.5.2 Determine Material Quantities for Construction

After the mix is determined, the quantity of required material for construction must be calculated by determining the volume of the canoe. This will allow for pre batching the materials, minimizing the cast time of the canoe.

2.5.3 Concrete Placement Method

Final mix designs will be pre-batched to minimize placement time ensuring the desire red workability. During construction, concrete will be placed on the mold soon after preparation. Previous years have used methods such as tiles and shotcrete.

2.5.4 Concrete Imprints

Imprinting designs into the concrete is allowed according to the NCCC: designs are based off the theme of the canoe.

2.5.5 Sealing

The canoe can be sealed once curing is completed. A sealant is applied to the canoe to prevent water from infiltrating and deteriorating the canoe.

2.5.6 Patching

Once the canoe is done curing, patch mixing can be applied to areas of the canoe that do not have an even amount of concrete to allow for a more aesthetically pleasing look.

2.6 Task 6: Competition

The concrete canoe is a national ASCE competition and senior design project at NAU. This section will discuss components of the concrete canoe capstone associated with the ASCE regional and national conferences.

2.6.1 Transportation

The concrete canoe must be transported to the Regional ASCE Competition in Tempe Arizona. A canoe coffin is used to protect the canoe from cracking during transportation. A canoe coffin is a wooden box designed to restrict the canoe's ability to slide and sway and is built accordingly to the canoe's dimensions.

2.6.2 Aesthetics

Part of competition scoring is based on the appearance of the canoe. This includes lettering, coloring of the concrete, graphics, imprints, stand, and display board. All components must comply with the NCCC regulations.

2.6.2.1 Lettering- Lettering is only allowable for the school name and the name of the canoe. The letters must be placed at the top of the gunwales and shall be visible when placed in the water.

2.6.2.2 Stand- The concrete canoe is displayed for judging on a stand. The canoe stand must support the weight of the canoe at a height of 2-3 feet off the ground.

2.6.3 Display

The concrete canoe is presented at the ASCE competition. This includes the tabletop display of the entire project, the cutaway section as a “sample” of the canoe, and an oral presentation regarding the process of the project.

2.6.3.1 Tabletop Display- The concrete canoe tabletop display presents the entire procedure of the design and construction process. It will display pictures taken throughout the design process along with paragraphs describing the steps.

2.6.3.2 Cutaway Section- A cutaway section of the canoe will be displayed at the conference to demonstrate the labeled casting, reinforcement, and finishing techniques used. The cutaway section shall be at least 3’ long, excluding the mold layer [5]. The cutaway section will be judged as part of the final product.

2.6.4 Oral Presentation

An oral presentation is required as part of the competition. The presentation must be 5 minutes long with a 5 second grace period [5]. This time is used to discuss students’ reasoning behind selected materials, structural design, reinforcement type, and the mold used. After the presentation, judges will spend 7 minutes asking the presenters technical questions. This portion of the competition is worth 25% of the final score.

2.6.5 Design Report

The ASCE concrete canoe competition requires a separate design report from the reports completed for the capstone class. The 2018 NCCC rules require the design report to be organized according to their standards. The design report is worth 25% of the total competition score. The format is strictly enforced in scoring the design report.

2.7 Task 7: Project Management

It is essential for the concrete canoe team to coordinate with their client, technical advisors, and the Committee of the National Concrete Canoe Competition (CNCCC). Coordination with the client will comprise of formal meetings to discuss expectations and concerns. Technical advisor meetings will be used to address technical concerns and recommendations. Requests for information regarding the rules and regulations will go through the CNCCC. This task also requires the team to manage their budget and track their spending.

2.8 Task 8: Technical Challenges

There are many constraints and criteria that the concrete canoe must take into consideration. These constraints and criteria include challenges with technologies available for use and the gathering of materials.

2.8.1 Technology

Limitations with technology include tools and software programs available to assist with design. The farm has mixing tubs, a scale, humidifiers, cylinders, and cementitious materials. Then there are two rooms available at the Engineering Building that have a compression testing machine and a chop saw used to split cylinders. Other limitations include software's like Civil3-D, RISA 2-D, and AutoCAD. This is a limitation because the programs must be accessed at the Engineering Building and there are time restrictions for when the building is open.

2.8.2 Access to Material

Access of concrete, reinforcement, and mold materials is a constraint due to a limited budget and locations of materials produced. The reason this is a limitation is due to the fact that large quantities of materials are required for testing and a final product. The limitation of materials means that they need to be used efficiently during testing to ensure there will be enough for construction.

2.8.3 2018 NCCC Rules and Regulations

There are many regulations that are set by the CNCCC the concrete canoe teams must follow. These regulations are set for specific dimensions of the canoe, admixtures, reinforcement, concrete mix, racing rules, and display requirements.

2.8.4 Project Impacts

The concrete canoe will be raced in Tempe Town Lake located in Phoenix, Arizona. The concrete canoe shall not affect the natural chemical balance of the lake. The lightweight mix design used to construct the canoe should not deteriorate in the water. The finishing mix used for aesthetics should be environmentally safe. This is to ensure the canoe will not affect the lake if any pieces of concrete chip off. Having a functional canoe is important to the paddlers, so they can safely transport themselves around the lake and compete in a race. The concrete canoe must be able to keep paddler afloat, while it is in use and strong enough to withstand any unexpected hits.

3.0 Scheduling

The Gantt Chart for this project is located in Appendix A of this report. The Gantt Chart was made based off of projected timelines of the scoped tasks. Using that Gantt Chart, a critical path was developed. The critical path includes all necessary steps that must be completed before advancing to the next step. The Gantt Chart containing the critical path is in Appendix B. All required deliverables and tasks are scheduled within this section of the report.

4.0 Staffing

4.1 Project Manager

The Project Manager is responsible for overseeing every aspect of the project. They are the ones to organize and schedule meetings, overview submittals, make decisions, and ensure all team members are contributing. Project Managers must be able to direct the rest of the team for a successful product.

4.2 Project Engineer

The project engineer oversees the design portion of the project, making sure they are on schedule and acting as the liaison between the project manager and the technicians. The engineer will be in charge of designing the lightweight mix, hull, and the reinforcement. The engineer will provide the necessary specifications to the lab technicians, draftsman, and interns. They will compile the laboratory results and hull design drawings to refine and develop the final design.

4.3 Quality Assurance

The Quality Assurance position is essential for the concrete canoe to ensure all rules and regulations are followed. If rules and requirements are not met, the team will be disqualified. Quality Assurance must keep track of all aspects of the project to ensure all laboratory standards, and the rules and regulations are being followed. This includes attending meetings, assisting team members, and reviewing submittals. The position requires time management, organization, dedication, and attentiveness.

4.4 Draftsman

The Draftsman works with Civil-3D, RISA, and DELFship They are the primary person for design elements regarding structural analysis. They must understand how to use these programs to ensure a proper design is developed.

4.5 Lab Technician

The Lab Technician will help developed the mix and reinforcement design for the concrete canoe. They will be performing tests on the concrete and reinforcement samples. This individual will be working with the Intern to creating mixes at the Farm and testing samples at the Engineering Building. Most of their time will be dedicated to finding a successful concrete mix.

4.6 Intern

The Intern of the project is typically the person who assists with most of the "hands-on" work. They generally have less engineering experience and use opportunities of being an intern to gain more knowledge. The Intern will wore hours than most members of the team simply because this project majorly focuses on constructing a final product.

Table 1 in this document contains every task, sub-task, and how many hours each member of the team will contribute for completion of the concrete canoe.

Table 1: Subtask Breakdown with Hours

2.1 Fundraising							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Gather Contact Information	0	0	1	0	0	8	9
Visit Annie from BASF	5	0	1	0	0	5	11
GoFundMe	0	0	1	0	0	4	5
Fundraising Letter	0	0	1	0	0	2	3
Send Letters Out	0	0	1	0	0	1	2
Total	5	0	5	0	0	20	30

2.2 Mix Design							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Research Materials	5	5	5	0	5	10	30
Understanding Mix/Rules	5	5	5	0	5	10	30
Developing a Mix	5	10	10	0	10	20	55
Incorporating Color	0	5	5	0	10	10	30
Testing	0	0	5	0	20	10	35
Refining Mix	5	5	5	0	10	10	35
28 Day Cure	0	0	5	0	20	10	35
Total	20	30	40	0	80	80	250

2.3 Hull Design							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Research Shape	5	5	6	15	0	5	36
Create Design Envelope	2	5	6	10	0	5	28
Draft Hull	5	5	6	20	0	5	41
Structural Analysis	5	10	6	15	0	10	46
Design Mold	3	5	6	20	0	5	39
Total	20	30	30	80	0	30	190

2.4 Reinforcement Design							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Research Materials	10	10	10	0	15	30	75
Testing Materials	5	10	10	0	20	10	55
Decision Matrix	5	10	10	0	15	30	70
Total	20	30	30	0	50	70	200

2.5 Construction							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Mold	5	5	5	10	2	10	37
Table	2	2	2	10	2	10	28
Calculate Quantities	5	5	7	0	5	10	32
Format a Plan for Pour Day	3	3	6	0	1	10	23
Pour Day	5	5	10	0	0	80	100
Total	20	20	30	20	10	120	220

2.6 ASCE PSWC Competition							
Sub Task	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Task Total
Preliminary Schedule	1	1	2	0	0	5	9
Acknowledgement	1	1	2	0	0	5	9
Request for Information	1	1	2	0	0	5	9
Outline of Final Design Report	1	1	4	0	0	10	16
Rough Draft for Report	1	1	4	0	0	10	16
Final ASCE Design Report	2	2	2	0	0	5	11
Oral Presentation	2	2	2	0	0	5	11
2018 ASCE PSWC	1	1	2	0	0	5	9
Total	10	10	20	0	0	50	90

Projected Project Staffing Hours							
Tasks	Project Manager	Project Engineer	Quality Assurance	Draftsman	Lab Technician	Intern	Total Hours
2.1 Fundraising	5	0	5	0	0	20	30
2.2 Mix Design	20	30	40	0	80	80	250
2.3 Hull Design	20	30	30	80	0	30	190
2.4 Reinforcement Design	20	30	30	0	50	70	200
2.5 Construction Plan	20	20	30	20	10	120	220
2.6 ASCE PSWC Competition	10	10	20	0	0	70	110
Total Hours	95	120	155	100	140	390	1000

5.0 Cost of Engineering Services

The hourly rate for each engineer was determined using the average reported hourly rates for each kind of engineering. The base hourly rate for each engineering position is listed below:

- Project Manager: $150/hr
- Project Engineer: $135/hr
- Quality Assurance: $95/hr
- Draftsman: $75/hr
- Lab Technician: $75/hr
- Intern: $10/hr

The hourly rate was then factored using a net fee multiplier of 2.72. This multiplier was used to account for overhead costs. The projected costs for personnel, travel, materials, lab, and sub-contract costs. These final costs are described following Table 2.

Table 2: Projected Project Costs

Projected Project Staffing Costs				
	Classification	Hours	Total Rate	Cost
Personnel	Project Manager	95	$150/hr	$14,250
	Project Engineer	120	$135/hr	$16,200
	Quality Assurance	155	$95/hr	$14,725
	Draftsman	100	$75/hr	$7,500
	Lab Technician	140	$75/hr	$10,500
	Intern	390	$45/hr	$19,500
Travel	Transportation	10	$10/hr	$100
	Lodging	-	$200/person	$1,000
	Conference Registration	-	$120/person	$600
Material	-	-	-	$4,000
Lab	Concrete Testing	80	$100/hr	$8,000
	Reinforcement Testing	60	$100/hr	$6,000
Subcontract	3-D Print Mold	-	-	$600
Total				$102,975

All costs associated with the concrete canoe were estimated using the following guidelines:

- Personnel costs were projected through the staffing schedule. Personnel rates were determined using the listed hourly wages and the net fee multiplier.
- Travel costs were based off of previous conference cost estimates. These costs include transportation to the conference, lodging, and conference registration.
- The material costs were determined based off of previous year's budgeting.
- Lab costs were estimated based on the value of the machines used. Every sample tested using lab equipment results in wear and tear. The cost of using the equipment must accommodate this damage.
- The sub-contract cost is based off of the price of materials for 3D printing.

The sub-contractor has agreed to 3D print the mold for cost of materials with no additional fees.

The overall cost for the concrete canoe is projected to be $102,975.

6.0 References

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Appendix A: Gantt Chart

Appendix B: Critical Path