2023 ASCE CONCRETE CANOE

Project Proposal

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List of Abbreviations

ASCE	American Society of Civil Engineers
ASCM	Alternative Supplementary Cementitious Material
C4	Concrete Canoe Competition Committee
CECMEE	Civil Engineering, Construction Management, Environmental Engineering
ISWS	Intermountain Southwest Student Symposium
MTDS	Material Technical Data Sheet
NAU	Northern Arizona University
POA	Percent Open Area
PPE	Personal Protective Equipment
RFP	Request for Proposal
QA/QC	Quality Assurance and Quality Control

1.0 Project Understanding

1.1 Project Purpose

The purpose of the American Society of Civil Engineers (ASCE) Concrete Canoe Competition is to provide civil engineering students with an opportunity to explore concrete mix design and project management through hands-on, practical experience and exposure to new leadership roles. This allows students to gain real-world experience by collaborating as a team to achieve a common goal for a client. The importance of exhibiting professionalism is emphasized to participants as they develop an understanding of the versatility of concrete as a construction material. The project highlights ASCE's commitment to students, educators, and the general public by inspiring the next generation of civil engineers to develop solutions to rising problems. The Concrete Canoe Competition also helps the participants to recognize the dynamic and innovative aspects of the profession that are essential to the engineering and construction industry. Additionally, this project provides students with the opportunity to work with professional engineers and company contacts as well as experience with the many aspects of project management [1].

The Concrete Canoe Competition Committee (C4) is looking to produce concrete canoes for interested consumers and has asked that pre-qualified ASCE Student Chapters design and construct full-scale concrete canoe prototypes. Participating Student Chapters are required to submit a project proposal and create a display and presentation for a selection panel from the *World of Concrete Expo*. The display should detail the canoe's design, its durability, and the materials used, in addition to the process of manufacturing a prototype that is able to withstand the rigors of transportation and a series of race demonstrations. Student Chapter teams present their display and canoe at regional ASCE student conferences every spring, and qualifying teams from each region are invited to the Society-Wide Final Competition [1].

1.2 Project Background

While the first official ASCE Concrete Canoe Competition wasn't held until 1988, ASCE Student Chapters have been constructing and racing concrete canoes since the early 1960's. Northern Arizona University (NAU) has been building canoes since 1977 [2].

Much of the work for this project will be completed at either the NAU Engineering Building or the Civil and Environmental Engineering, Construction Management (CECMEE) Field Station, known as the 'Farm', both of which are located on the Northern Arizona University Mountain Campus in Flagstaff, Arizona. *Figure 1* on the next page shows the location of Flagstaff in relation to other major cities in Arizona, and *Figure 2* highlights where in Flagstaff the NAU campus is. Boxed in red in *Figure 3* is the Engineering building, while the Farm and its access road are emphasized in green.

Figure 1. Location of Flagstaff in Arizona [3]

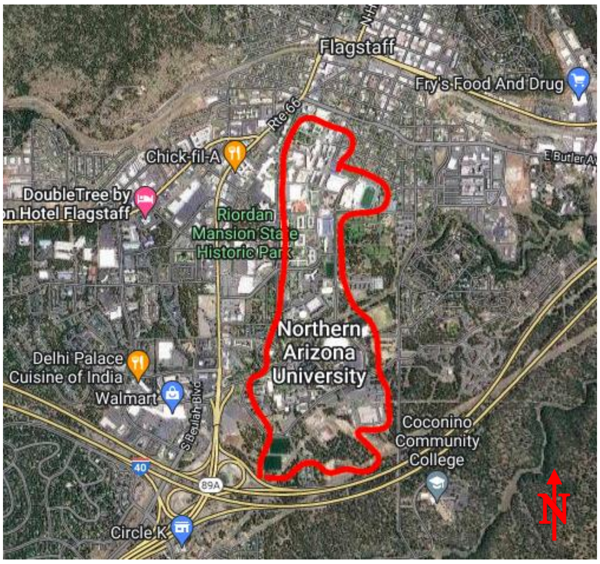


Figure 2. Location of NAU in Flagstaff, Via Google Maps

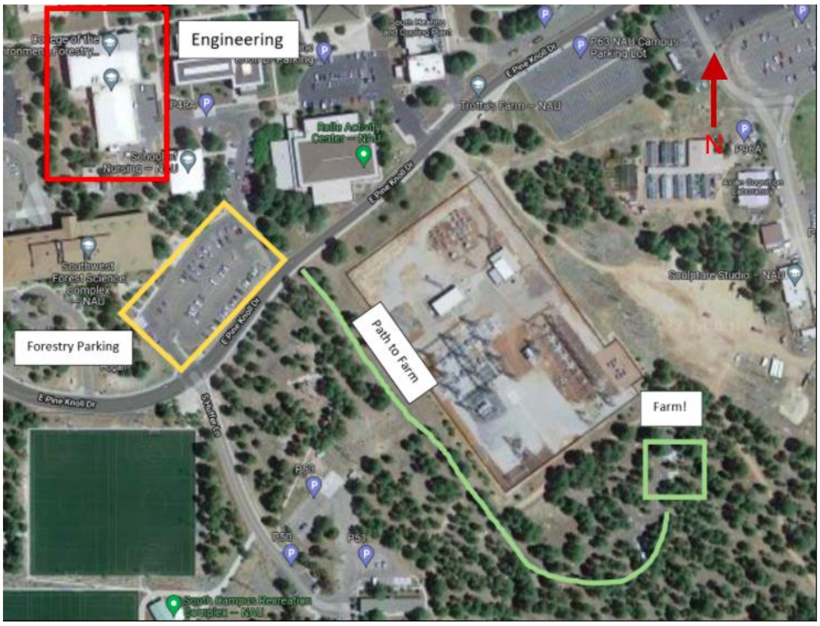


Figure 3. Location of Engineering Building and Farm Field Station

The project is composed of the following four main phases:

- Research – This phase is necessary to develop and fully understand the project constraints and requirements.
- Design – Information from the initial research phase will be used to create suites of potential canoe and concrete mix designs.
- Construction – After final designs are chosen, the mold and physical canoe will be prototyped and constructed.
- Competition – Following the construction phase, the canoe will be presented at the Intermountain Southwest Student Symposium (ISWS) in April of 2023. This event is being hosted by the University of Nevada, Reno, whose location is shown in *Figure 4* and *Figure 5*.

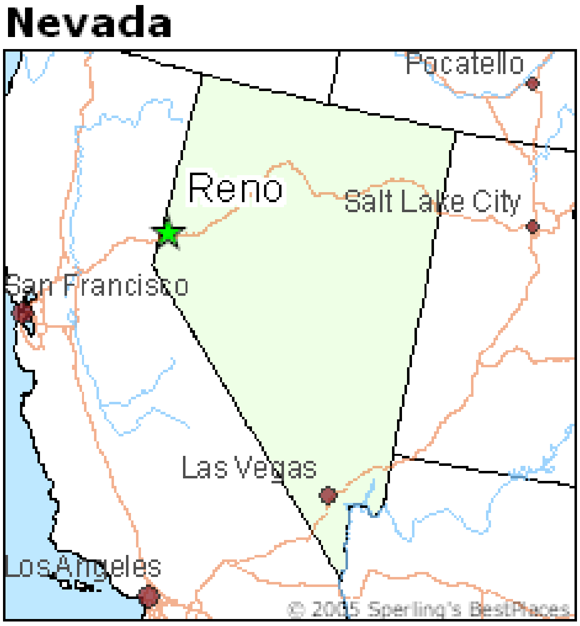


Figure 4. Location of Reno in Nevada [4]

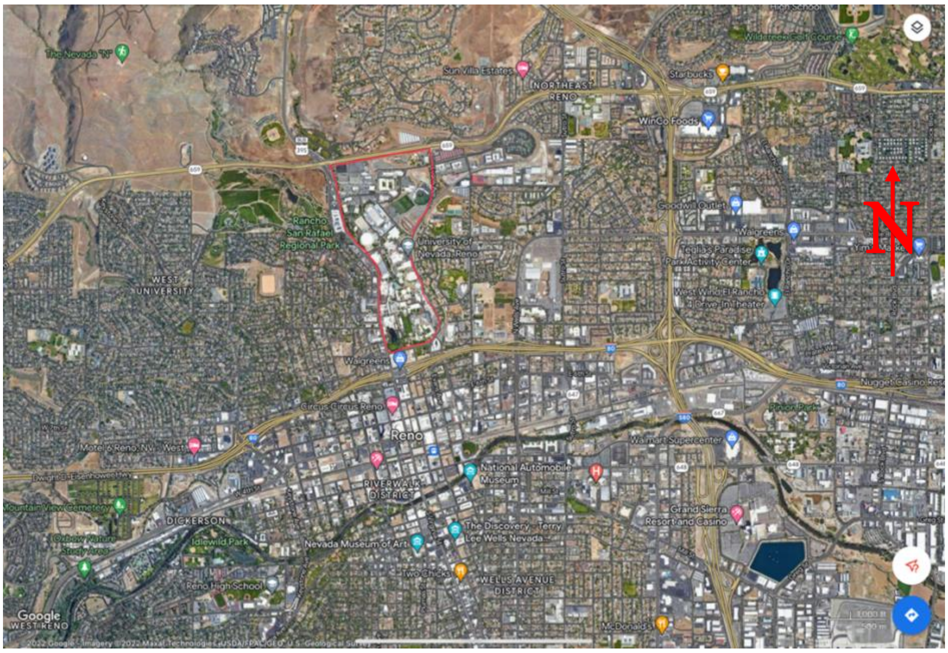


Figure 5. Location of University of Nevada, Reno in Reno, via Google Maps

1.3 Technical Considerations

1.3.1 Reinforcement

Reinforcing material for this project is defined as any material that is not a part of a concrete mixture or floatation material and all primary reinforcement is required to be covered in concrete. A reinforcement scheme should be created and it shall follow the percent open area (POA) minimum requirement of 40 percent to allow for proper mechanical bonding of the concrete [1].

Primary reinforcement must not exceed 50 percent of the canoe wall or any structural element at any point. The hull, ribs, gunwales, thwarts, bulkheads, and any connections between two elements are considered structural components under the competition rules [1].

1.3.2 Hull Design

This year's competition rules state that the hull can be a maximum 22 feet in length while all other dimensions are not regulated and are at the discretion of the team [1]. Several hull designs will be proposed, and from those a final design will be chosen and modeled in 3D modelling software and analyzed in a hydrodynamic simulation software

1.3.3 Concrete Mix Design

Following the mix design guidelines set forth in the Request for Proposal (RFP) issued by C4, a maximum of three concrete mixes will be used in the construction of the canoe. Concrete mixtures are required to be a minimum of 30 percent aggregate and a maximum of 30 percent cementitious material, where the aggregate used adheres to a specified particle size distribution. Cementitious materials, alternative supplementary cementitious materials (ASCM), and pozzolans are allowed under the competition rules, so long as they adhere to ASTM standards specified in the RFP. Information regarding the regulations and requirements for concrete mixes is discussed in depth in *Appendix A*.

A series of tests adhering to ASTM standards will be performed on several of the designed concrete mixes. C4 has requested that, at a minimum, the following tests be conducted: compressive strength, tensile strength, composite flexural strength, concrete slump/spread, and air content [1]. The team will follow procedures for both 7- and 28- day recommended ages of testing.

1.3.4 Structural Analysis

The canoe must be analyzed to ensure that it can sustain the tension and compression stresses it may endure while it is in the water. These expected tension and compression forces will be compared to values found during the mix design phase. In addition, shear force and bending moment diagrams must be created for the canoe when loaded with two point loads, each representing a male paddler [1]. These diagrams will consider buoyancy as the primary force resisting the loading of the two paddlers and the canoe. A hydraulic analysis will also need to be completed to determine the magnitude of the water pressure acting on the hull both while it is empty and when a maximum allowable load is applied.

1.3.5 Construction

Construction of the canoe will be completed following a Quality Assurance, Quality Control (QA/QC) model. Construction can begin only after final concrete mix and hull designs are selected and a hull mold is created, causing these three stages of the project to be integral parts of the canoe's completion. The team will recruit mentees to help place the concrete when it comes time. After the concrete is placed and shaped, it will be left to cure for 28 days in a humid environment such that the concrete can reach the desired compressive strength.

1.4 Potential Challenges

The team predicts that a considerable number of challenges may arise over the duration of this project. These challenges include, but may not be limited to acquiring sponsors and material donors, handling unforeseen circumstances, and construction techniques.

An immediate challenge for this project is securing stakeholders who are willing to invest in the canoe. Without proper funding, it will be difficult to purchase the supplies necessary to construct the final product. Acquisition of materials and funds must happen before many stages of the critical path can be started or completed. The team will put together a proposed material and expenses budget to determine approximate costs for required materials and services as well as the amount of additional funding needed. The NAU ASCE Student Chapter is set to donate $4000 to cover some of the project costs, though the team has also identified a number of other potential sponsors and donors. These potential sponsors include previous employers with which team members have developed and maintained positive professional relationships, and with whom this project was previously discussed in the context of them and their company's interest in providing monetary and/or design assistance to the team. The team continues to uphold these relationships and anticipates sponsorship from several identified companies and individuals. In the event that none of these entities are able to provide monetary support to the team, the project budget will need to be modified such that it is kept within the donation from the NAU ASCE Student Chapter, with special consideration placed on leveraging both the team's local connections in the industry to perform various project tasks either as favors or for a discounted price, and the work time of mentees to complete project tasks when appropriate. The team has created an informative website that will be sent out to these prospective sponsors and donors such that they can learn more about the competition, who each of the team members are, and the different sponsorship packages offered. Each package has an incentive designed to encourage companies to support the project.

An unavoidable challenge for the project is the uncertainty that comes with supply chains and delivery times. These aspects of the project are outside of the team's control, and it is the team's job to be prepared to overcome any unforeseen obstacles. To combat this, the team will ensure that the same or comparable materials can be obtained from a secondary source if necessary. Concrete materials and any additional supplementary materials or tools will need to be acquired such that sufficient time is allowed for key stages of the project to be completed, including mix design, mold acquisition, and construction. The team will make a detailed schedule which will be checked and updated frequently, keeping in mind the project milestones, deadlines, and deliverables. This schedule will ensure that work is completed on time over the course of the project.

Proper construction techniques are required to guarantee that the canoe is safe and structurally sound. Hull mold design and assembly are an important part of the project, and outsourcing for its creation ensures that minimal errors occur. The team's technical advisor, Russell Collins, has been building concrete canoes for the past five years and has been passing on techniques used in previous years to younger students. The team will use his guidance, along with the help of mentees interested in learning the process, to ensure that the canoe is constructed properly.

1.5 Stakeholders

Stakeholders for the project include NAU and the client as well as any material donors and sponsors that support the project. NAU has entrusted the team with the responsibility of representing the institution at this year's ASCE Concrete Canoe Competition events. Performing well can inspire future students to continue the tradition of participating in the Concrete Canoe Competition.

Mark Lamer, the team's client, expects high quality results in the form of a canoe that holds up to the rigorous required testing and high placement at the regional conference achieved through hard work.

Sponsors and material donors can also be seen as stakeholders in the project as it is expected that their beneficence is met with proper representation of their company and its products. It is the team’s job to ensure that the quality and consistency of materials provided is showcased in addition to placing well in the competition to demonstrate to companies that their investments were worthwhile.

2.0 Scope of Services

2.1 Task 1: Concrete Mixture Design

2.1.1 Task 1.1: Concrete Materials Research

2.1.1.1 Task 1.1.1: Competition Rules

The team will thoroughly review the competition rules and use the RFP released by C4 as a guideline throughout the mix design process. A list of allowable materials outlined in the RFP is provided in *Appendix A*.

2.1.1.2 Task 1.1.2: Materials Research

The team will research concrete materials that may be involved in the project. Such materials include, but may not be limited to: aggregates, cementitious materials, pozzolans, admixtures, and fiber reinforcing. Material research will focus on how different properties and compositions impact the overall strength of concrete.

2.1.2 Task 1.2: Concrete Mixture Development

2.1.2.1 Task 1.2.1: Procurement of Concrete Materials

The team will schedule consulting meetings with concrete material supplies and order various cementitious materials, aggregate, admixtures, and secondary reinforcement materials and document their recommendations, taking them into consideration when selecting materials.

2.1.2.2 Task 1.2.2: Sieve Analysis

The team will perform a sieve analysis following ASTM C136 procedures. The aggregate gradation will be modified to follow percent passing guidelines as outlined in the RFP.

2.1.2.3 Task 1.2.3: Mixing of Concrete

Materials will be combined in appropriate containers and mixed by hand or with small hand tools. The team will ensure that all necessary safety measures are taken during the mixing process, especially the use of personal protective equipment (PPE).

2.1.2.4 Task 1.2.4: Collection of Test Cylinders

The team will collect test cylinders in accordance with ASTM C192, the Standard Test Practices for Making and Curing Concrete Test Specimens in the Laboratory. At a minimum, three cylinders should be collected for each unique mix such that required compressive testing can be completed. It is at the team's discretion whether or not more than three cylinders will be collected per mix for additional testing.

2.1.2.5 Task 1.2.5: Curing of Test Cylinders

Collected test cylinders should be stored in a large container which shall be filled with water such that the surface level is near the top of the cylinder tubes without entering the containers. This is done to minimize the deformation of the cylinders during the curing process. The test cylinders shall be left to cure for the appropriate amount of time for the test in which they are to be used.

2.1.3 Task 1.3: Testing

2.1.3.1 Task 1.3.1: Air Content Testing

ASTM C231, the Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method, will be used to determine the air content as a percentage of each freshly made mix. Knowing the air content of a mix will be a necessity in creating a mix that is as dense or less dense than water, though too high of an air content can result in a weak concrete. The team will contact a local geotechnical firm to obtain the necessary equipment to perform this test.

2.1.3.2 Task 1.3.2: Slump Test

To meet the requirements set forth in the RFP, it is necessary that slump tests following ASTM C143, the Standard Test Method for Slump of Portland Cement, be conducted. Results from these tests will provide information on how fluid and workable each concrete design is, both of which are important factors for the design phase.

2.1.3.3 Task 1.3.3: Density Testing

Results from testing that complies to ASTM C642, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete will allow the team to understand how much water each mix absorbs and how much water infiltrates each due to voids. These values are important as any water that enters the hardened concrete will increase the weight of the canoe.

2.1.3.4: Task 1.3.4: Compressive Strength Testing

The team will perform compressive strength testing per ASTM C39, the Standard Test Methods for Concrete Cylinder Testing. Cylinders procured from Task 1.2.2 will be utilized to determine the maximum compressive strength for the various mix designs at the 7- and 28-day marks following the procedure outlined in the ASTM method. The results from these tests will allow the team to proceed with structural analysis and design.

2.1.3.5 Task 1.3.5: Flexural Strength Testing

Using ASTM C78, the Standard Test Method for Flexural Strength of Concrete, the team will be able to determine the flexural strength of each mix using a three-point loading device. The flexural capacity is important in the design process as well as in deciding what materials should be utilized as reinforcement. These tests will be conducted at the 7- and 28-day marks. The team will contact a local geotechnical firm to perform this test.

2.1.3.6 Task 1.3.6: Tensile Strength Testing

Results from tests adhering to ASTM C496, the Standard Test method for Splitting Tensile Strength of Cylindrical Concrete Specimens will inform the team of what the tensile capacity is of each mix tested. These results will be used during structural analysis and design comparisons.

2.1.3.7 Task 1.3.7: Specific Gravity Testing

ASTM C127, Standard Test Methods for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate, will be essential during the mix design process. The results from this test will be vital in designing a successful mix as the values are used in determining the solid volume of aggregates.

2.1.4 Task 1.4: Analysis of Concrete Test Results

The team will collect and analyze data from all tests performed to determine the properties of each tested mix design. These properties and results will be compared to each other to fully understand the benefits and disadvantages of each mix design as it pertains to the project.

2.1.5 Task 1.5: Suite of Potential Designs

2.1.5.1 Task 1.5.1: Development of Decision Matrix

The team will consider multiple factors to create a decision matrix that will aid in the selection of the final mix designs. These factors include: concrete strength, visual appeal, aesthetics, ease of staining, relative density, and whether or not the project constraints and criteria are met. Each category will have a maximum number of points associated with it, and each design will be scored in each category.

2.1.5.2 Task 1.5.2: Selection of Final Designs

A team meeting will be held to discuss the results of the decision matrices based on the selected parameters. The three designs with the highest cumulative scores based on the intended use of the mix will be chosen as the final designs.

2.2 Task 2: Reinforcement Design

2.2.1 Task 2.1: Reinforcement Materials Research

The team will perform research regarding the types, availability, and other defining parameters of several reinforcing materials for potential use in the project. The RFP issued by C4 will be read thoroughly to ensure that each member of the team fully understand the constraints and criteria for reinforcement under this year's competition rules. The team will consult with the project's Technical Advisor to determine the best materials to be used based on the research completed and the availability of materials.

2.2.2 Task 2.2: Procurement of Reinforcement

The team will select reinforcing materials in a timely manner such that they can be acquired while still remaining on track in terms of project progress. In addition, test data will be obtained for each of the selected materials.

2.2.3 Task 2.3: Reinforcement Testing

Experiments and testing will be conducted using the selected reinforcing materials and final concrete mix designs to determine the overall effectiveness of each reinforcing material. Determination of effectiveness could include, by may not be limited to the quantity needed, location of the reinforcement, and extent of added tensile strength.

2.2.4 Task 2.4: Creation of a Reinforcement Scheme

Based on information collected during the testing phase, a detailed reinforcement scheme will be created that adheres to the reinforcement requirements outlined in the RFP. Percent open area calculations will be completed to ensure that the concrete can properly bond to any reinforcement used.

2.3 Task 3: Hull Design

2.3.1 Task 3.1: Hull Design Preparation

2.3.1.1 Task 3.1.1: Software Skills and Training

It will be ensured that each member of the team knows how to use any necessary computer software, including SolidWorks, MAXSURF, and ENERCALC. If a team member does not have prior or sufficient knowledge of any required software, training will be completed.

2.3.1.2 Task 3.1.2: Contacting Mold Manufacturer

To mitigate error in the hull mold fabrication process, the team will research and contact an individual or company that specializes in or has the ability to create a mold for the final hull design.

2.3.2: Task 3.2: Suite of Potential Hull Designs

2.3.2.1 Task 3.2.1: Drafting

Several potential designs will be created that meet the project constraints and criteria set forth in the RFP released by C4.

2.3.2.2 Task 3.2.2: Structural Analysis

Each potential design will be analyzed using the principles of structural analysis to determine the maximum allowable loading. Calculations will initially be completed by hand and verified using ENERCALC. Shear force and bending moment diagrams will be created for each design under different loading conditions, including one that represents two male rowers, as requested by C4.

2.3.2.3 Task 3.2.3: Hydrodynamic Analysis

The team will use the naval architecture tool MAXSURF along with the fundamentals of buoyancy and Archimedes' Principle to analyze each design to determine if the proposed hull can withstand the anticipated hydrodynamic and hydraulic forces.

2.3.2.4 Task 3.2.4: Development of Decision Matrix

The team will assess each potential design based on the following categories: aesthetics, speed, maneuverability, construction feasibility, and floatation stability. Each category will have a maximum number of points associated with it, and each design will be scored in each category.

2.3.2.5 Task 3.2.5: Selection and Modelling of Final Design

Based on the results from the decision matrix, the team will select a final design, which will then be modeled in SolidWorks.

2.3.3 Task 3.3: Mold Acquisition

2.3.3.1 Task 3.3.1: Contracting

The team will contact an individual or company that has the ability to create a mold for the final hull design and hire them for their services. The team will provide the contractor with shop drawings of the final hull design.

2.3.3.2 Task 3.3.2: Mold Pick Up or Delivery

Once the independent contractor or company has completed the mold, the team will need to either obtain the mold from them or schedule a delivery date and time.

2.4 Task 4: Construction

2.4.1 Task 4.1: Recruitment of Mentees

Mentees will be recruited to help assemble the concrete canoe. Canoe construction can take up to 12 hours depending on how many individuals are available to help. The team has planned several workshopping events in hopes of gaining the interest of underclassmen who may want to help with the assembly process.

2.4.2 Task 4.2: Assemble Formwork

Once the canoe formwork is acquired, it will be assembled following instructions from the hired mold contractor. The surface of the mold will then be coated with releasing agents and lubricants to ensure that the concrete does not stick to the formwork.

2.4.3 Task 4.3: Concrete Batch Mixing

The team will create a maximum of three concrete mixes to be used for the canoe's construction. To limit the waste of materials, batches of each mix will be made on an as-needed basis during ‘Pour Day’. Batches will follow strict guidelines, such as percentage of aggregate, cementitious material, and water, to ensure the concrete is consistent throughout the canoe.

2.4.4 Task 4.4: Concrete Placement

Concrete placement will occur on ‘Pour Day,’ where all five team members and all mentees will place the concrete over or within the canoe mold using trowels to shape the canoe. The placed concrete will be layered with reinforcement materials such as rubber, steel, or plastic according to the reinforcement scheme designed by the team. To reduce cracking and increase strength, the reinforcement will be applied in areas throughout the canoe that are expected to experience high magnitudes of shear stress, determined during the structural analysis phase of the design process.

2.4.5 Task 4.5: Concrete Surface Finishing

Before curing the concrete, trowels will be used on the interior body and bulkheads of the canoe to smooth surfaces. After the curing process, the canoe will be released from the mold and the exterior of the canoe may be sanded depending on smoothness levels. Lastly, finishers, such as stains, may be applied to either the inside or outside surface of the canoe to achieve a polished look.

2.4.6 Task 4.6 Curing

2.4.6.1 Task 4.6.1: Curing Chamber Construction

To ensure the concrete can be properly cured for the full 28 days without cracking, a curing chamber will be constructed. The chamber shall have a lightweight frame such that it can be easily placed over the canoe after the concrete is shaped. The walls shall be made of a waterproof or water-resistant material that will allow water to be trapped within the chamber, creating a damp environment that will be beneficial to increasing the strength of the concrete. There must be enough room in the curing chamber for humidifiers.

2.4.6.2 Task 4.6.2: Refilling Humidifiers

Several humidifiers will be tested to determine how long it takes for each one to vaporize the water in its reservoir. Once these times are known, the team will create a schedule that details which humidifiers need to be refilled when in addition to who will refill them during the curing process.

2.5 Task 5: Competition

2.5.1 Task 5.1: Trailer Preparation

The NAU CECMEE Trailer will need to be prepared in order to transport the canoe to the competition location. Preparation will include labeling the trailer with promised sponsor items such as company names and logos in addition to clearing enough space within the trailer to fit the canoe, the mold used, display stands, oars, life vests, and seat cushions. These items must remain separated from other competition items being transported to prevent the mix-up of supplies.

2.5.1 Task 5.2: Transportation

2.5.1.1 Task 5.2.1: Student Transportation

Reno, Nevada is approximately 700 miles away from Flagstaff. Plane transport will likely be too expensive for competition. As a result, the canoe team and any mentees participating in the competition will look into vehicular travel, most likely in the form of eligible individuals procuring van licenses through NAU. Students eligible to drive will map out locations along the travel route to substitute drivers to prevent highway hypnosis.

2.5.1.2 Task 5.2.2: Canoe Transportation

The canoe will be transported in the ISWS trailer. This trailer will be towed by the project's client, NAU ASCE Student Chapter Faculty Advisor, Mark Lamer, and ASCE practitioner, Taylor Layland.

2.5.3 Task 5.3: Canoe Racing

One event of the Concrete Canoe Competition is the canoe race, which is worth 20 of the 100 points for the competition and will take place during the weekend of the ISWS Conference. The race event consists of a total of five races: a women's slalom, a men's slalom, a women's sprint, a men's sprint, and a co-ed sprint [1].

2.6 Task 6: Evaluate Project Impacts

2.6.1 Task 6.1: Social Impacts

Over the course of the project, the team will keep track of the social impacts of the work completed. A comprehensive evaluation of these effects will be presented in the final report. It is predicted that there will be an impact on the ASCE community, both the NAU Student Chapter and those present at the ISWS Competition, in addition to the mentees that help with the construction and competition phases of the project.

2.6.2 Task 6.2: Environmental Impacts

The environmental impacts of the project will be investigated over the course of the project and an assessment will be presented in the project's final report. It is the team's goal for the project to have a net positive or neutral environmental impact by utilizing environmentally conscious materials. Pending approval from C4, the team will use a sand replacer known as post-consumer calcium carbonate derived from recycled carpet.

2.6.3 Task 6.3: Economic Impacts

At the end of the project, a comprehensive analysis of the economic impacts of the project will be completed. The success or failure of the final prototype will largely depend on monetary and material donations and sponsorships, which will be acquired through team events and the consistent pursuance of sponsorships from a variety of companies.

2.7 Task 7: Project Deliverables

2.7.1 Task 7.1: CENE 486 Deliverables

2.7.1.1 Task 7.1.1: 30% Submittals

A report that is approximately 30 percent complete will be submitted to the project's Grading Instructor by the specified deadline, accompanied by a presentation. The report will act as a first draft of the final report, allowing the Grading Instructor to provide feedback and ensuring that the team is on track to successfully compiling a professional report. For this deliverable, the team will have Tasks 1 through 3 completed, with information for task 6 being collected over the course of the project.

2.7.1.2 Task 7.1.2: 60% Submittals

A report that is approximately 60 percent complete will be submitted to the project's Grading Instructor by the specified deadline, accompanied by a presentation. The report will act as a second draft of the final report, allowing the Grading Instructor to provide feedback and ensuring that the team is on track to successfully compiling a professional report. In addition to the work completed for the 30% deliverables, work associated with Task 4 will be partially completed; the concrete for the canoe will have been placed and will be left to cure.

2.7.1.3 Task 7.1.3: 90% Submittals

A report that is approximately 90 percent complete will be submitted to the project's Grading Instructor by the specified deadline, accompanied by a presentation. The report will act as a third draft of the final report, allowing the Grading Instructor to provide feedback and ensuring that the team is on track to successfully compiling a professional report. By this point, the team will have completed all deliverables associated with the ASCE Concrete Canoe Competition and the canoe will be in the curing phase, if not already removed from the mold and prepared for the ISWS Conference in Reno. All work through Task 6 will be completed for this deliverable.

2.7.1.4 Task 7.1.4: Final Report

The final report will be the last submission to the project's Grading Instructor by the specified deadline. The complete report will consist of information regarding the performance and design of the project and catalog the work completed by the team over the course of the project.

2.7.1.5 Task 7.1.5: Final Website

The team will create a professional website that includes team contact information and any required project information. The website will outline the work completed over the duration of the project, which may be beneficial to students who complete the project in the future.

2.7.1.6 Task 7.1.6: Final Presentation

The team will give a final presentation to the instructors of the CENE 486 class, which will cover a condensed version of everything in this proposal and everything in the final report.

2.7.2 Task 7.2: 2023 ASCE Concrete Canoe Competition Deliverables

2.7.2.1 Task 7.2.1: Letter of Intent and Pre-Qualification Form

The team will send a Letter of intent and a Pre-Qualifications Form to C4 by November 4, 2022. The letter will provide a synopsis of the team's understanding of the project in addition to the qualifications of each team member, why they were selected, and why they are suitable to complete the project.

2.7.2.2 Task 7.2.2: Preliminary Project Delivery Schedule

To be submitted no later than November 4, 2022, the team must compile a project delivery schedule that covers the time period ranging from when the RFP was issued until ISWS Conference. This schedule should include items such as design, construction, important milestones, and submission deadlines.

2.7.2.3 Task 7.2.3: Project Proposal

A project proposal that satisfies the guidelines outlined in the RFP will be submitted to C4 no later than February 17, 2023. This proposal is worth 30 of the competition's 100 points and must contain the following: an executive summary, project team delivery information, technical approach, project management, QA/QC, sustainability information, innovations of methods used, construction specifications, and the project schedule. Included as appendix items must be a detailed fee estimate, POA calculations, mixture proportions, a primary mixture calculation, and a references section.

2.7.2.4 Task 7.2.4: MTDS Addendum

A Material Technical Data Sheet (MTDS) following the format presented in the RFP must be submitted to C4 no later than February 17, 2023. The document should consist of information on all materials used to create the canoe itself, noting specifications for each individual material used in the concrete mixes.

2.7.2.5 Task 7.2.5: Display

It is required that the team create a prototype display that showcases the canoe. Worth 20 of the 100 points for the competition, the display must consist of the concrete canoe presented on stands, an exhibit that details the construction processes and materials used, as well as a cross section of the canoe and mold. In addition, samples of the materials used to create the canoe are required and include, but are not limited to: aggregates, composites, reinforcement, cementitious materials, and cylinders of each mixture used. One print copy of both the Project Proposal and MTDS Addendum must be made available in addition to any seats, mats, life jackets, and paddles to be used in the race demonstrations [1].

2.7.2.6 Task 7.2.6: Presentation

The technical presentation is worth 25 of the competition's 100 points and takes place during the weekend of ISWS. The team must have a minimum of two speakers give a five-minute presentation outlining the design, construction, and technical capabilities of the concrete canoe. The presentation acts as a sales pitch to C4 judges as to why the team's design should be chosen over the others at the competition. The five-minute presentation is followed by a seven-minute question and answer session pertaining to the content of the presentation [1].

2.8 Project Management

2.8.1 Meetings

2.8.1.1 Grading Instructor Meetings

The team will meet with the project Grading Instructor a total of six times: twice in the Fall of 2022 to discuss project progress and four additional times for the canoe's construction and any other questions associated with the project.

2.8.1.2 Technical Advisor Meetings

Meetings with the team's Technical Advisor will be held at least twice a semester for overall guidance on the project as well as specific background knowledge for certain areas of the project.

2.8.1.3 General Meetings

Team meetings will be held weekly at a minimum with every member present to ensure that all individuals are up to date on project progress and upcoming due dates.

2.8.2 Schedule Management

Project submittal dates will be organized in a project scheduling program which will provide the team with a snapshot of overall project progress and upcoming due dates.

2.8.3 Resource Management

Project materials and funds will be kept track of in shared spreadsheets available to each team member. Material stock on hand will be checked and updated frequently and replenished when required.

2.9 Exclusions

The full annual ASCE Student Chapter Report and Dues Payment Report are the two exclusions for this project, both of which are required by C4 in order for a team to participate in the ISWS competition. These reports are completed and submitted by the Student Chapter Branch secretary and treasurer.

3.0 Project Schedule

The project schedule is estimated to last approximately 220 days from September 6th, 2022 to April 14th, 2023. Major tasks for the project include concrete mix design, reinforcement design, hull design, construction, and competition. Vital deliverables include 30%, 60%, 90% submittals, final report, final website, final presentation, and conference deliverables. The project schedule is represented as a Gantt chart and is shown in *Appendix B.*

3.1 Critical Path

The project critical path roughly follows mix design through construction and competition, with reinforcement and hull design being encompassed within construction tasks. These steps are critical because they dictate the project timeline and project milestones. Timing and duration of the critical path will be maintained through weekly team progress meetings.

4.0 Project Staffing

4.1 Staffing Positions

This project consists of five staff positions: the senior engineer (SENG), engineer (ENG), lab technician (TECH), safety officer (SO), and intern (INT). These positions and their respective abbreviations are displayed in *Table 1*.

Table 1. Staffing Positions

Position	Abbreviation
Senior Engineer	SENG
Engineer	ENG
Lab Technician	TECH
Safety Officer	SO
Intern	INT

4.2 Personnel Qualifications

4.2.1 Senior Engineer

The Senior Engineer will serve as the project lead over the course of the project, overseeing all aspects. They are required to understand fully the Concrete Canoe Competition rules and regulations for the final product and all deliverables associated with the competition. They are to ensure that proper communication is practiced not only with sponsors and resource donors, but within the team as well. The Senior Engineer will guarantee that meetings are held on a regular basis and that all technical work is being performed accurately and efficiently. For these reasons, the Senior Engineer must have pertinent knowledge of and be qualified to work with structural analysis, concrete mix design, hydrostatic and hydrodynamic principles, human relations, time management, and corporate outreach. While they are not required to specialize in any one of these areas, it is necessary that the Senior Engineer understand completely the basics of each to ensure the correctness of deliverables.

4.2.2 Engineer

The Engineer is to oversee all material testing and the construction of the canoe over the course of the project. The Engineer is required to have extensive knowledge on applicable codes and testing standards and ensure that they are adhered to. They are responsible for the proper design and production of the canoe hull, which will meet or exceed the requirements for allowable loading, structural integrity, and hydrodynamic integrity. They will oversee the Lab Technician and verify that the results gathered from testing completed by the team are accurate and comply with requirements under the competition rules and regulations. The Engineer is required to have background knowledge on all aspects of the project, with a focus in test methods and structural analysis.

4.2.3 Lab Technician

The Lab Technician will conduct all tests to be completed by the team and will ensure that all tests and materials comply with the proper ASTM standards required by C4. They will be present for the construction of the canoe to ensure that materials used are eligible under the competition rules and to conduct periodic tests to analyze the canoe’s integrity. The Lab Technician will oversee the testing of each material to be used to confirm whether or not they are allowable. Because of this, they are required to have extensive knowledge pertaining to the required test methods, concrete mix design, and properties of relevant materials.

4.2.4 Safety Officer

The Safety Officer will ensure that proper safe practices are utilized over the course of the project during any and all concrete mixing, material testing, and construction. They will guarantee that each member of the team is knowledgeable about the risks involved with the equipment and materials being used and will uphold safe practice techniques. They will be required to make the lab advisor aware of any injuries sustained in labs or field stations over the course of the project in addition to any lab safety agreement violations. The Safety Officer will also ensure that all personal protective equipment and safety supplies, such as ventilation masks and first aid supplies, are stocked in work areas and comply with applicable standards. They must be knowledgeable about current safety regulations and have a basic understanding of test methods to be used.

4.2.5 Intern

The main task of the Interns is to learn from the Engineer and Lab Technician. They will help with most, if not all, aspects of the project, performing mixed duties, such as mix design calculations, concrete placement, and lab testing. Because of this, they should have basic knowledge pertaining to engineering design, concrete design and its applications, and relevant ASTM standards. The tasks they complete will be observed and checked by either the Lab Technician, Engineer, and Senior Engineer. The Interns will also be tasked with the physical acquisition of materials, being expected to obtain materials from material donors. They will also stand as the primary racers during the Concrete Canoe Competition Races in Reno.

4.3 Staffing Matrix

A staffing matrix was created to exhibit the total work hours to be completed by each position for each task outlined in the *Project Scope* section. The detailed matrix can be found in *Appendix C* while a summary of the total hours per position is provided in *Table 2*.

Table 2. Staffing Matrix Summary

Position	Hours
SENG	125
ENG	225
TECH	150
SO	150
INT	300
TOTAL	950

5.0 Cost of Engineering Services

Personnel hourly rates for each position were calculated based on the *Labor Rates* section of Exhibit 8 in the Request for Proposal [1]. With an expected 125 hours towards the project at an hourly rate of $120, the Senior Engineer will cost a total of $14,950. The Engineer totals 225 hours over the course of the project at a rate of $88 per hour, for a total of $19,872. The Lab Technician will spend approximately 150 hours working on the project at a rate of $62 per hour, for a total cost of $9,315. The safety officer will invest 150 hours into the project at a rate of $87 per hour for a total cost of $13,041. Lastly, the interns are expected to spend 300 hours on the project at a rate of $38 per hour for a total cost of $11,385. Combining the price of each worker, the total price of labor is $68,563.

Subcontracting will be performed for both mold creation and a portion of the concrete testing. Tests to be performed by subcontractors include flexural strength, tensile strength, density, and specific gravity lab work under the appropriate ASTM method required by C4. Each one of these tests can be performed within a workday costing $200 per hour based on Exhibit 8 of the RFP [1]. As a result, testing will cost a total of $1,600. Mold creation, although designed by the project team, may be subcontracted to a styrofoam mold cutter in Palm Springs California with an approximate cost of $2,000. In total, subcontracting will cost $3,600.

Transportation will be provided through NAU’s vehicle renting program, for which current rates and prices are made public and are subject to change. The team requires a 12-person van to transport all 10 members of the concrete canoe team. NAU charges $340 to rent a van for a week, plus $0.40 cents per mile [5]. The round trip to Reno, including additional driving to lakes and competition sites, is 1,500 miles. An additional 300 miles was added to the transportation mileage for material pick-up. Total van pricing and mileage costs are estimated to total $1,060.

Overnight housing prices are based upon nearby hotel costs around the University of Nevada, Reno. With average room prices of approximately $200 a night, and two employees staying inside a room, the total price for two hotel rooms over three nights is $1200.

Lab usage for the project will cost $100 per day. It is estimated that lab testing will take approximately 12 days, for a total cost of $1,200 for lab usage.

Concrete and reinforcement materials for the canoe include aggregate, cement, pozzolans, admixtures, and hull reinforcement. Aggregate pricing is conducted on a cubic foot basis. It is estimated that approximately 12 cubic feet of aggregate will be used in the concrete mixture at a rate of $22 per cubic foot, costing approximately $265. An estimated 10 cubic feet of cementitious material will be used for concrete mixture at a rate of $8 per cubic foot, and will cost approximately $80. A gallon of various admixtures will cost about $20. Lastly, roughly 15 square yards of reinforcement at a rate of $20 per square yard will cost $300. With these estimates in mind, the total cost of concrete materials will be approximately $665.

Summing all of these costs presents a project total of $76,323, as shown in *Table 3*.

Table 3. Cost of Engineering Services Matrix

Description	Quantity	Unit of Measure	Rate (USD)	Cost
Personnel				
SENG	125	Hr.	$120	$14,950.00
ENG	225	Hr.	$88	$19,872.00
TECH	150	Hr.	$62	$9,315.00
SO	150	Hr.	$87	$13,041.00
INT	300	Hr.	$38	$11,385.00
			Total Personnel	$68,563.00
Travel				
Travel for Material Acquisition				
Transportation	300	Miles	$0.40	$120.00
Travel for Competition				
Transportation	1,500	Miles	$0.40	$600.00
Van Rental	1	Van/Week	$340	$340
Hotel Rooms	3	Nights (2 rooms)	$400	$1,200
			Total Travel	$2,260.00
Lab Use				
Field Station	8	Days	$100	$800
Materials Testing Lab	4	Days	$100	$400
			Total Lab Use	$1,200.00
Sub-Contracting				
ASTM Testing	8	Hr.	$200	$1,600
Mold Cutting	1	Mold	$2,000	$2,000
			Total Subcontracting	$3,600
Materials				
Cementitious Materials	10	Cubic Feet	$8	$80
Aggregate	12	Cubic Feet	$22	$264
Admixtures	1	GAL	$20	$20
Reinforcement	20	Square Yard	$15	$300
			Total Materials	$664
Project Total				$76,287

6.0 References

[1] ASCE Committee on Concrete Canoe Competitions, "2023 American Society of Civil Engineers Concrete Canoe Competition Request for Proposals," American Society of Civil Engineers, Reston, 2022.

[2] ASCE, "ASCE Concrete Canoe Competition," American Society of Civil Engineers, [Online]. Available: https://www.asce.org/communities/student-members/conferences/asce-concrete-canoe-competition/. [Accessed 18 September 2022].

[3] Sperling's Best Places, "Flagstaff, Arizona," [Online]. Available: https://www.bestplaces.net/city/arizona/flagstaff. [Accessed 24 September 2022].

[4] Sperling's Best Places, "Reno, Nevada," [Online]. Available: https://www.bestplaces.net/city/nevada/reno. [Accessed 24 September 2022].

[5] "University Transit Services Vehicle Rental," Northern Arizona University, [Online]. Available: https://in.nau.edu/university-transit-services/fleet-services/vehicle-rental/. [Accessed 4 November 2022].

7.0 Appendices

Appendix A – Allowable Materials

The 2023 Concrete Canoe Competition Request for Proposal (RFP) states that the concrete mixture used for the canoe must be made of a minimum of 30 percent aggregate materials and a maximum of 30 percent cementitious materials. Aggregates must follow the particle distribution presented in *Table 1* and a maximum of three concrete mixtures can be used.

Table 4. Aggregate Gradation Requirements [1]

Sieve	Percent Passing
9.5-mm (3/8-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-um (No. 30)	25 to 60
300-um (No. 50)	5 to 30
150-um (No. 100)	0 to 10

Cementitious materials, alternative supplementary cementitious material (ASCM), and pozzolans are all permitted under the competition rules, so long as they adhere to ASTM standards specified in *Table 2*. Hydraulic cement is limited to 30 percent of the total cementitious material content in any of the three concrete mixtures used.

Table 5. Allowable Cementitious Materials [1]

Cementitious Material	ASTM
Hydraulic Cement (c)	C150, C595, or C1157, C845
Fly Ash	C618 (Class C or F)
Metakaolin	C618 (Class N)
Slag Cement	C989 (Grade 100 Minimum)
Silica Fume	C1240
Hydrated Lime	C207 (Type N or S) or C821
Ground-Glass Pozzolan	C1866
Ground Pumice, Pumicite, or Volcanic Ash Natural Pozzolan	C618 (Class N)

Materials such as admixtures and fibers are also acceptable in the mix design. Legal admixtures must be used in accordance with their corresponding ASTM standards presented in *Table 3*. Fibrous materials meeting the requirements outlined in ASTM C1116 may be used in the mix design process to aid in the minimization of cracking and as a form of secondary reinforcement.

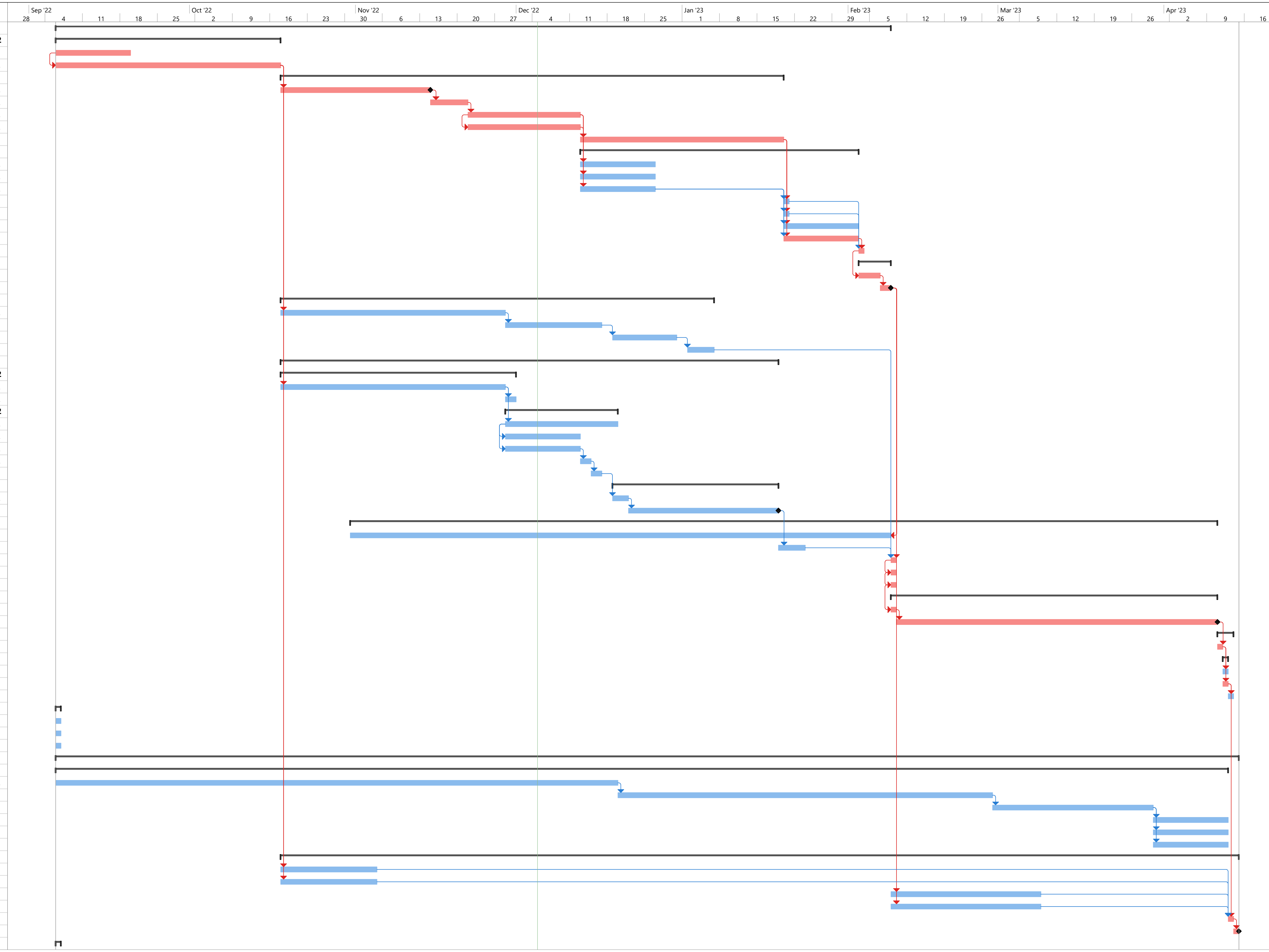
Table 6. Allowable Admixtures [1]

Admixtures	ASTM
Water-Reducing & Set-Control	C494
Air-Entraining	C260
Coloring Admixture/Agents & Concrete Pigments	C979
Specialty Admixtures	C494 (Type S)

Prior to their use, any non-commercial products must be approved by C4 [1].

Appendix B - project Schedule Gantt Chart

ID	Task Name	Start	Finish
1	**TASK 1: Concrete Mixture Design**	**Tue 9/6/22**	**Wed 2/8/23**
2	**Task 1.1: Concrete Materials Research**	**Tue 9/6/22**	**Mon 10/17/22**
3	Task 1.1.1: Competition Rules	Tue 9/6/22	Mon 9/19/22
4	Task 1.1.2: Materials Research	Tue 9/6/22	Mon 10/17/22
5	**Task 1.2: Concrete Mixture Development**	**Tue 10/18/22**	**Thu 1/19/23**
6	Task 1.2.1: Procurement of Concrete Materials	Tue 10/18/22	Mon 11/14/22
7	Task 1.2.2: Sieve Analysis	Tue 11/15/22	Mon 11/21/22
8	Task 1.2.3: Mixing of Concrete	Tue 11/22/22	Mon 12/12/22
9	Task 1.2.4: Collection of Test Cylinders	Tue 11/22/22	Mon 12/12/22
10	Task 1.2.5: Curing of Test Cylinders	Tue 12/13/22	Thu 1/19/23
11	**Task 1.3: Concrete Mixture Testing**	**Tue 12/13/22**	**Thu 2/2/23**
12	Task 1.3.1: Air Content Testing	Tue 12/13/22	Mon 12/26/22
13	Task 1.3.2: Slump Testing	Tue 12/13/22	Mon 12/26/22
14	Task 1.3.3: Density Testing	Tue 12/13/22	Mon 12/26/22
15	Task 1.3.4: Compressive Strength Testing	Fri 1/20/23	Fri 1/20/23
16	Task 1.3.5: Flexural Strength Testing	Fri 1/20/23	Fri 1/20/23
17	Task 1.3.6: Flexural Strength Testing	Fri 1/20/23	Thu 2/2/23
18	Task 1.3.7: Specific Gravity Testing	Fri 1/20/23	Thu 2/2/23
19	**Task 1.4: Analyisis of Concrete Test Results**	Fri 2/3/23	Fri 2/3/23
20	**Task 1.5: Suite of Potential Solutions**	**Fri 2/3/23**	**Wed 2/8/23**
21	Task 1.5.1: Development of Decision Matrix	Fri 2/3/23	Mon 2/6/23
22	Task 1.5.2: Selection of Final Designs	Tue 2/7/23	Wed 2/8/23
23	**TASK 2: Reinforcement Design**	**Tue 10/18/22**	**Fri 1/6/23**
24	**Task 2.1: Reinforcement Materials Research**	Tue 10/18/22	Mon 11/28/22
25	**Task 2.2: Procurement of Reinforcement**	Tue 11/29/22	Fri 12/16/22
26	**Task 2.3: Reinforcement Testing**	Mon 12/19/22	Fri 12/30/22
27	**Task 2.4: Creation of a Reinforcement Scheme**	Mon 1/2/23	Fri 1/6/23
28	**TASK 3: Hull Design**	**Tue 10/18/22**	**Wed 1/18/23**
29	**Task 3.1: Hull Design Preparation**	**Tue 10/18/22**	**Wed 11/30/22**
30	Task 3.1.1: Software Skills and Training	Tue 10/18/22	Mon 11/28/22
31	Task 3.1.2: Contacting Mold Manufacturer	Tue 11/29/22	Wed 11/30/22
32	**Task 3.2: Suite of Potential Hull Designs**	**Tue 11/29/22**	**Mon 12/19/22**
33	Task 3.2.1: Drafting	Tue 11/29/22	Mon 12/19/22
34	Task 3.2.2: Structural Analysis	Tue 11/29/22	Mon 12/12/22
35	Task 3.2.3: Hydrodynamic Analysis	Tue 11/29/22	Mon 12/12/22
36	Task 3.2.4: Development of Descision Matrix	Tue 12/13/22	Wed 12/14/22
37	Task 3.2.5: Selection and Modelling of Final Design	Thu 12/15/22	Fri 12/16/22
38	**Task 3.3: Mold Acquisition**	**Mon 12/19/22**	**Wed 1/18/23**
39	Task 3.3.1: Contracting	Mon 12/19/22	Wed 12/21/22
40	Task 3.3.2: Mold Pick Up or Delivery	Thu 12/22/22	Wed 1/18/23
41	**TASK 4: Construction**	**Mon 10/31/22**	**Mon 4/10/23**
42	**Task 4.1: Recruitment of Mentees**	Mon 10/31/22	Wed 2/8/23
43	**Task 4.2: Assemble Formwork**	Thu 1/19/23	Mon 1/23/23
44	**Task 4.3: Concrete Batch Mixing**	Thu 2/9/23	Thu 2/9/23
45	**Task 4.4: Concrete Placement**	Thu 2/9/23	Thu 2/9/23
46	**Task 4.5: Concrete Suface Finishing**	Thu 2/9/23	Thu 2/9/23
47	**Task 4.6: Curing**	**Thu 2/9/23**	**Mon 4/10/23**
48	Task 4.6.1: Curing Chamber Construction	Thu 2/9/23	Thu 2/9/23
49	Task 4.6.2: Refilling Humidifiers	Fri 2/10/23	Mon 4/10/23
50	**TASK 5: Competition**	**Tue 4/11/23**	**Thu 4/13/23**
51	**Task 5.1: Trailer Preparation**	Tue 4/11/23	Tue 4/11/23
52	**Task 5.2: Transportation**	**Wed 4/12/23**	**Wed 4/12/23**
53	Task 5.2.1: Student Transportation	Wed 4/12/23	Wed 4/12/23
54	Task 5.2.2: Canoe Transportation	Wed 4/12/23	Wed 4/12/23
55	**Task 5.3 Canoe Racing**	Thu 4/13/23	Thu 4/13/23
56	**TASK 6: Evaluate Project Impacts**	**Tue 9/6/22**	**Tue 9/6/22**
57	Task 6.1: Social Impacts	Tue 9/6/22	Tue 9/6/22
58	Task 6.2 Environmental Impacts	Tue 9/6/22	Tue 9/6/22
59	Task 6.3 Economic Impacts	Tue 9/6/22	Tue 9/6/22
60	**TASK 7: Project Deliverables**	**Tue 9/6/22**	**Fri 4/14/23**
61	**Task 7.1: CENE 486 Deliverables**	**Tue 9/6/22**	**Wed 4/12/23**
62	Task 7.1.1: 30% Submittal	Tue 9/6/22	Mon 12/19/22
63	Task 7.1.2: 60% Submittal	Tue 12/20/22	Mon 2/27/23
64	Task 7.1.3: 90% Submittal	Tue 2/28/23	Wed 3/29/23
65	Task 7.1.4: Final Report	Thu 3/30/23	Wed 4/12/23
66	Task 7.1.5: Final Website	Thu 3/30/23	Wed 4/12/23
67	Task 7.1.6: Final Presentation	Thu 3/30/23	Wed 4/12/23
68	**Task 7.2: ASCE Concrete Canoe Competition Deliverables**	**Tue 10/18/22**	**Fri 4/14/23**
69	Task 7.2.1: Letter of Intent and Pre-Qualification Form	Tue 10/18/22	Fri 11/4/22
70	Task 7.2.2: Preliminary Project Delivery Schedule	Tue 10/18/22	Fri 11/4/22
71	Task 7.2.3: Project Proposal	Thu 2/9/23	Wed 3/8/23
72	Task 7.2.4: MTDS Addendum	Thu 2/9/23	Wed 3/8/23
73	Task 7.2.5: Display	Thu 4/13/23	Thu 4/13/23
74	Task 7.2.6: Presentation	Fri 4/14/23	Fri 4/14/23
75	**TASK 8: Project Management**	**Tue 9/6/22**	**Tue 9/6/22**



Project: Concrete Canoe Schedu
Date: Mon 12/5/22

Task	Milestone	Project Summary	Inactive Milestone	Manual Task	Manual Summary Rollup	Start-only	External Tasks	Deadline	Critical Split
Split	Summary	Inactive Task	Inactive Summary	Duration-only	Manual Summary	Finish-only	External Milestone	Critical	Progress

Manual Progress

Appendix C – Staffing Matrix

Task Name	SENG	ENG	TECH	SO	INT
Task 1: Concrete Mix Design	20	59	78	32	72
Task 1.1: Concrete Materials Research	2	9	21	7	15
Task 1.1.1: Competition Rules	*1*	*1*	*1*	*2*	*5*
Task 1.1.2: Materials Research	*1*	*8*	*20*	*5*	*10*
Task 1.2: Concrete Mixture Development	0	15	24	14	32
Task 1.2.1: Procurement of Concrete	*0*	*10*	*4*	*0*	*8*
Task 1.2.2: Sieve Analysis	*0*	*0*	*8*	*2*	*8*
Task 1.2.3: Mixing of Concrete	*0*	*5*	*10*	*10*	*10*
Task 1.2.4: Collection of Test Cylinders	*0*	*0*	*2*	*2*	*2*
Task 1.2.5: Curing of Test Cylinders	*0*	*0*	*0*	*0*	*4*
Task 1.3: Concrete Mixture Testing	0	0	18	4	10
Task 1.3.1: Air Content Testing	*0*	*0*	*1*	*1*	*1*
Task 1.3.2: Slump Test	*0*	*0*	*1*	*1*	*1*
Task 1.3.3: Density Testing	*0*	*0*	*2*	*0*	*2*
Task 1.3.4: Compressive Strength Testing	*0*	*0*	*2*	*2*	*2*
Task 1.3.5: Flexural Strength Testing	*0*	*0*	*4*	*0*	*0*
Task 1.3.6: Tensile Strength Testing	*0*	*0*	*4*	*0*	*0*
Task 1.3.7: Specific Gravity Testing	*0*	*0*	*4*	*0*	*4*
Task 1.4: Concrete Test Results	18	35	15	7	15
Task 1.5: Suite of Potential Solutions	*5*	*20*	*5*	*0*	*5*
Task 1.5.1: Development of Decision Matrix	*5*	*10*	*10*	*5*	*10*
Task 1.5.2: Selection of Final Designs	*8*	*5*	*0*	*2*	*0*
TASK 2: Reinforcement Design	5	24	16	2	25
Task 2.1: Reinforcement Materials Research	0	10	5	0	10
Task 2.2: Procurement of Reinforcement	0	4	4	0	10
Task 2.3: Reinforcement Testing	0	0	5	2	5
Task 2.4: Creation of a Reinforcement Scheme	5	10	2	0	0
TASK 3: Hull Design	24	63	10	7	48
Task 3.1: Hull Design Preparation	10	10	0	0	10
Task 3.1.1: Software Skills and Training	*5*	*5*	*0*	*0*	*10*
Task 3.1.2: Contact Mold Manufacturer	*5*	*5*	*0*	*0*	*0*
Task 3.2: Suite of Potential Hull Designs	14	45	10	7	30
Task 3.2.1: Drafting	*0*	*10*	*0*	*0*	*10*
Task 3.2.2: Structural Analysis	*2*	*10*	*0*	*0*	*5*
Task 3.2.3: Hydrodynamic Analysis	*2*	*10*	*0*	*0*	*5*
Task 3.2.4: Development of Decision Matrix	*5*	*10*	*10*	*5*	*10*
Task 3.2.5: Selection and Modelling of Final Design	*5*	*5*	*0*	*2*	*0*
Task 3.3: Mold Acquisition	0	8	0	0	8
Task 3.3.1: Contracting	*0*	*8*	*0*	*0*	*0*
Task 3.3.2: Mold Pick Up or Delivery	*0*	*0*	*0*	*0*	*8*
TASK 4: Construction	18	22	29	36	49
Task 4.1: Recruitment of Mentees	10	4	5	5	10
Task 4.2: Assemble Formwork	2	4	5	5	5
Task 4.3: Concrete Batch Mixing	2	5	4	4	4
Task 4.4: Concrete Placement	2	5	5	10	10
Task 4.5: Concrete Surface Finishing	2	4	5	10	10
Task 4.6: Curing	0	0	5	2	10
Task 4.6.1: Curing Chamber Construction	*0*	*0*	*5*	*2*	*5*
Task 4.6.2: Refilling Humidifiers	*0*	*0*	*0*	*0*	*5*

TASK 5: Competition	0	2	0	28	33
Task 5.1: Trailer Preparation	0	2	0	0	5
Task 5.2: Transportation	0	0	0	28	28
Task 5.2.1: Student Transportation	*0*	*0*	*0*	*10*	*10*
Task 5.2.2: Canoe Transportation	*0*	*0*	*0*	*10*	*10*
Task 5.3 Canoe Racing	*0*	*0*	*0*	*8*	*8*
TASK 6: Evaluate Project Impacts	6	12	0	15	6
Task 6.1: Social Impacts	2	4	0	5	2
Task 6.2 Environmental Impacts	2	4	0	5	2
Task 6.3 Economic Impacts	2	4	0	5	2
TASK 7: Project Deliverables	16	19	10	5	59
Task 7.1: CENE 476 Deliverables	10	16	2	2	38
Task 7.1.1: 30% Submittal	*1*	*2*	*0*	*0*	*5*
Task 7.1.2: 60% Submittal	*1*	*3*	*0*	*0*	*8*
Task 7.1.3: 90% Submittal	*1*	*4*	*0*	*0*	*8*
Task 7.1.4: Final Report	*4*	*3*	*0*	*0*	*5*
Task 7.1.5: Final Website	*1*	*2*	*0*	*0*	*10*
Task 7.1.6: Final Presentation	*2*	*2*	*2*	*2*	*2*
Task 7.2: ASCE Concrete Canoe Competition Deliverables	6	3	8	3	21
Task 7.2.1: Letter of Intent and Pre-Qualification Form	*1*	*1*	*1*	*1*	*1*
Task 7.2.2: Preliminary Project Delivery Schedule	*1*	*1*	*2*	*1*	*5*
Task 7.2.3: Project Proposal	*3*	*0*	*0*	*0*	*10*
Task 7.2.4: MTDS Addendum	*0*	*0*	*5*	*1*	*5*
Task 7.2.5: Display	*0*	*0*	*0*	*0*	*0*
Task 7.2.6: Presentation	*1*	*1*	*0*	*0*	*0*
TASK 8: Project Management	**36**	**24**	**7**	**25**	**8**
Task 8.1: Meetings	23	24	7	25	8
Task 8.1.1: Grading Instructor Meetings	*4*	*2*	*2*	*2*	*2*
Task 8.1.2: Technical Advisor Meetings	*4*	*2*	*2*	*2*	*2*
Task 8.1.3: General Meetings	*15*	*10*	*0*	*10*	*4*
Task 8.2: Schedule Management	11	10	0	1	0
Task 8.3: Resource Management	2	0	3	10	0
Subtotal:	**125**	**225**	**150**	**150**	**300**
Total (person-hours)	**950**				