Verde Valley Water Treatment System

Proposal to Provide Professional Engineering Services

CRKL Engineering

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LIST OF ABBREVIATIONS

Arsenate (As V)
Arsenic (As)
Arsenite (As (III))
Autotrophic Bacteria Nitrate Reduction (ARoNite)
Blast Furnace Slag (BFS)
Deionized (DI)
ElectroChemical Arsenic Remediation (ECAR)
Environmental Protection Agency (EPA)
Field Emission Scanning Electron Microscopy (FE-SEM)
High-resolution Transmission Electron Microscopy (HR-TEM)
International Atomic Energy Agency’s (IAEA)
Ion Exchange (IE)
Maximum Contaminant Levels (MCL)
Nitrate (NO_3^-)
Northern Arizona University (NAU)
Surface-modified Iron Nanoparticles (S-INP)
Technical Advisor (TA)
Total Dissolved Solids (TDS)
X-ray Photoelectron Spectroscopy (XPS)

TEAM ORGANIZATION

Project Personnel

Different project roles are required for ensuring completion of each aspect of a design project. Each of these roles will be performed by each member of CRKL Engineering throughout the course of the project. The project personnel titles and abbreviations are displayed in Figure 1 below.

Senior Engineer	SENG
Engineer	ENG
Lab Technician	LAB
Engineering Intern	INT
Administrative Assistant	AA

Figure 1: Personnel Positions

The Senior Engineer is the project leader and will therefore be involved with the critical items. The Senior Engineer can assign tasks, such as research, to the rest of the group and provide leadership that requires a greater level of experience. The Senior Engineer will provide guidance during water contamination, take the lead during model construction and running the model, and will perform the final analysis of the results to check for accuracy.

The Engineer will be the most heavily involved member of the project team. The Engineer will be responsible for completing a large portion of the research for the project and will also be expected to assist the Senior Engineering with model construction and running the model. Lastly, the Engineer will provide the initial analysis of the results.

The Lab Technician is responsible for all activities that are to be completed inside of the lab located within the Northern Arizona University (NAU) Engineering Building. The Lab Technician is mainly responsible for water contamination, as he or she will be handling potentially harmful materials. The Lab Technician will also assist with model construction, as he or she will have access to the required materials and apparatuses within the lab. Lastly, the Lab Technician will oversee the model while it is in use within the lab.

An Engineering Intern will be available for completion of this project. The Engineering Intern will assist the Senior Engineer and Engineer with any tasks that are requested of them. Due to a lack of experience, the Engineering Intern will not be performing an analysis of the results.

The Administrative Assistant is responsible for documentation of all work completed by CRKL Engineering throughout the course of this project. This includes meetings (team, client, and technical advisor), project details, and results. The Administrative Assistant's main job is to synthesize all of the results obtained from modeling and compose them into a final report documenting the success or failure of the project.

STAKEHOLDERS

The stakeholders in this design project are Dr. Gremillion, the 10,000 residents of the community the water is being treated for, and Dr. Baxter. Dr. Gremillion is a technical representative of the International Atomic Energy Agency's (IAEA) Rural Waters Program and he will be a representative of the hypothetical Verde Valley community. Dr. Gremillion will be involved in all relevant project information, such as the desired type of facility, community water standards, average water usage, water demand, and all other deliverable necessities.

The residents of the community are important stakeholders to consider for this project. Any proposed/implemented changes to the area will need to be approved by city boards and members. A community needs a safe and reliable water source to thrive. If the water treatment system created does not adequately reduce arsenic and nitrate levels to state and Environmental Protection Agency (EPA) standards, negative health effects could arise in the community. The team will focus the project on increasing the quality of life for the people within this community.

Dr. Baxter, P.E., will be the Technical Advisor (TA) for CRKL Engineering. Typical treatment methods of contaminated groundwater will be discussed with him. Dr. Baxter will also advise the team on any modeling systems that must be created in the design process. Lastly, Dr. Baxter will offer information about how to build a bench scale treatment system and can guide the team in designing a successful project.

WORK PLAN

The work plan will include a brief project description, the order of tasks to be completed, and time to complete these tasks. CRKL Engineering has estimated how long each task will take and have included extra time within each task in case of any delays or errors during the construction or analysis phases. The schedule of these tasks is detailed later in this proposal.

Introduction

This project entails treating groundwater contaminated with arsenic (As) and nitrate (NO_3^-) starting at 1-2 mg/L and 25-40 mg/L, respectively. Even though additional contaminants may exist, the ones most pervasive in this system are arsenic and nitrate and will be focused on for removal. Arsenic and nitrate are both naturally occurring and can contaminate a water system without an outside mechanism. Arsenic is a waste product of agricultural and industrial activities. Nitrate can be found in fertilizers as well as animal and plant waste. Runoff from all of these sources can enter groundwater sources, which would introduce the contaminants to the water source. Multiple alternatives will be examined to determine the most effective way to lower the concentration to, or below, the EPA's drinking water limits. These alternatives range from, but are not limited to, adsorption, precipitation, ion exchange, and membrane filtration. It is imperative to remove both contaminants because of adverse health effects. Arsenic is linked to cancer and pregnancy complications, and nitrate is linked to vascular collapse and Blue Baby Syndrome. For this project to be considered a success, the contamination concentration levels will need to be lowered to reach the community and EPA regulations.

Understanding

The team will be designing a water treatment system for a hypothetical community in the Verde Valley. The groundwater in this community of 10,000 people is contaminated with arsenic and nitrate ranging in concentrations of 1-2 mg/L and 25-40 mg/L, respectively. These contaminants can enter the water source naturally and also through runoff from agriculture, fertilizers, animal and human wastes, and industrial activities.

Health effects involved with arsenic can be cancerous or noncancerous. Prolonged exposure to arsenic can directly affect the skin, bladder, and lungs, including skin and lung cancer [1]. Noncancerous effects of arsenic include pregnancy complications, joint pain, loss of hearing, and increased risk for developing type two diabetes. Nitrate also causes several health effects, specifically due to ingestion. As nitrate is ingested, the human body transforms nitrate to nitrite causing issues for all ages, especially infants to three month olds. Blue Baby Syndrome is caused by nitrate ingestion in infants and toddlers, since they do not yet have a developed immune system and convert 100% of the ingested nitrate to nitrite. Humans with developed immune systems only convert 10% of the total nitrate ingested to nitrite, where the effect is typically vascular collapse. These health implications were found to occur when the nitrate concentration within the subject was 10 mg/L and above, where anything below that level had no observable effects. Due to the health effects associated with these contaminants, the EPA has set forth standards for nitrate and arsenic.

The EPA regulates arsenic and nitrate in drinking water for the protection of the people against the harmful effects of these contaminants. The EPA has set forth maximum contaminant levels (MCL) to regulate arsenic and nitrate levels within water sources. Arsenic has an MCL of 0.01 mg/L and nitrate has a MCL of 10 mg/L [1]. The team will be designing a water treatment system for the theoretical community in Verde Valley of 10,000 residents, which will treat the water to EPA drinking water standards.

SCOPE OF SERVICES

There are multiple tasks that must be completed to ensure a cohesive design that meets all of the objectives. Accomplishing these tasks in a timely and orderly fashion is critical to the completion the project. The scope of services that CRKL Engineering will preform is described below.

Task 1 - Preliminary Engineering

The first task that will be conducted is preliminary engineering. CRKL Engineering will research varying chemical aspects of the project including water sample recipes, contamination techniques and concentrations, treatment methods, safety precautions, and construction options. CRKL Engineering will also establish the staffing and cost for the project. These are both described later in the proposal. The last item included in preliminary engineering is acquiring funding. Obtaining funding will involve submitting a proposal to the Northern Arizona University Honors Program, the client, and Northern Arizona University Department of Civil and Environmental Engineering. The team will create a project outline and budget proposal to submit to acquire funds from the NAU Honors Program. Once the proposal is submitted, the Honors Program will review the document and will determine if the team receives funding. Other funding pathways include speaking with the client about using the department budget.

Task 2 - Literature Reviews

Researching different treatment methods that meet the design criteria was important to determine a suitable and feasible design. The design alternative criteria given to the team included finding a conventional design, innovative design, and sustainable design. Each team member was assigned one of these alternatives, with two members researching sustainable design alternatives. Treatment methods for nitrate and arsenic falling within the assigned topic were researched. This task is crucial for the team to find alternatives meeting the provided criteria, in addition to finding treatment techniques that are feasible for the team to complete and analyze. This task is a critical item for the completion and success of the project, which needed to be completed in the Fall semester of 2016.

Task 3 - Design Decision

All literature reviews must be compared and studied to choose a final design that will ensure a successful end project. The subtasks listed below explain how a final decision will be made.

3.1 Proposal Presentation

On December 9th, 2016, the team presented a proposal presentation to project clients, engineers throughout the community, and Capstone 476 professors. This presentation highlighted the work that was completed during the Fall 2016 duration and explained information that will be completed during Spring 2017. Any suggestions that the audience proposed were discussed and added within this document.

3.2 Preliminary Website

A preliminary website design was created for the completion of Fall 2016 CENE 476. The “Home” page and the “Documents” page were created and populated with information. The “Home” page identifies the project being completed, our client’s information, team information, technical advisor contact information, and links to the other website pages. The “Documents” page presents all written reports and presentations that were completed throughout the Fall 2016 semester.

3.3 Design Proposal

This subtask relates to the document being presented. Completion of this report will be the last deliverable for CRKL Engineering within Fall 2016.

3.4 Decision Matrix

A table will be created to evaluate the design alternatives that were presented in literature reviews. Several constraints will be chosen and assigned weights according to the level of importance. Within the initial proposal phase for Fall 2016, the team is considering time of completion, feasibility and sustainability as three important constraints. These items will be built on during Winter 2016-2017 break to create a complete decision matrix. A final design will be chosen based on this matrix before the beginning of the Spring 2017 semester.

Task 4 - Design Preparation

4.1 Lab Space

Lab space must be requested through Gerjen (Gary) Slim. A form must be filled out detailing who is participating in lab work and their contact information, which lab space is requested, equipment, general supplies, chemical needs, and must also include a description of the project as well as the faculty member sponsoring the project.

4.2 Certifications

The certification required before using the lab space includes NAU Chemical Hygiene Training Parts 1-3. All team members will complete these certifications by the beginning of the Spring 2017 semester so that design construction can begin on time

4.3 Materials

The materials needed for lab activities will be decided based on the outcome of the decision matrix. The same batch of contaminated water samples will be used throughout the modeling process.

4.4 Contaminating the Water Samples

The CRKL Engineering team will contaminate its own samples with arsenic and nitrate to match the concentrations defined in the project description. The water will need to be contaminated to a level of 1-2 mg/L of arsenic and 25-40 mg/L of nitrate.

Task 5 - Design Development

This set of tasks involves the construction, testing, and analysis of our design followed by the final deliverables to be completed in the Spring semester of 2017.

5.1 Construction

The team will construct a bench scale model based on the selected design. This task will involve building the structure of the design as well as elements that will be determined based on the selected alternative and treatment method.

5.2 Testing

CRKL Engineering will be testing the contaminated water samples in the system after the model has been built. The contaminated water will be tested prior to entering the system to determine the current contaminant concentrations. Several trials will be completed and samples of the end result will be sent to a third-party laboratory to test for arsenic concentrations, while the team will be testing the levels of nitrate remaining in the water sample. The team's technical advisor will have a role in this portion of the project to assist with methods and will be consulted during analysis.

5.3 Analyzing Test Results

After receiving the results from the third-party laboratory, the team will review the results of the remaining levels of arsenic, as well as the already determined remaining nitrate levels. The results will be compared with EPA standards of arsenic and nitrate levels in drinking water.

5.4 Prepare Final Presentation

The project will be presented at the end of the Spring 2017 semester to peers, faculty and staff, and professionals. Through this presentation, the team will describe the project, the methods involved, and the overall results and analysis of the project.

5.5 Design Report and Website

The final deliverables of the project, including the design report and the project website will be completed and submitted and the end of the Spring 2017 semester. The design report will include all information pertaining to the project including the methods, the testing outcomes, and the analysis results, as well as cost, personnel hours and other important content. The website will be a navigable professional page of the project presentable to an interested observer. The completed website will act as a portfolio of the project and a project archive for future capstone students.

Task 6 - Project Management

This step in the project consists of meetings. These meetings are disbursed throughout the year and will be correlated to the upcoming deliverables and project task goals.

6.1 Team Meetings

Team meetings are used to evaluate the team's progress, set new smaller goals to achieve critical items, discuss the project direction, and ensure all members have the same understanding of the what needs to be completed. Meetings will be held on a weekly basis to ensure the team is on task.

6.2 Client Meetings

Client meetings are when CRKL Engineering meets with the client to discuss expectations, limitations, and scope of the project. This ensures that communication between the team and the client is straightforward and understood by both parties. Meetings will be dispersed throughout the semester as necessary.

6.3 Technical Advisor Meetings

These meetings are used during the semester to meet with the Technical Advisor. The TA ensures the team has sufficient technical knowledge to complete the required design and acts as an additional resource for technical ideas. The TA will not tell the team directly what do, but will guide them through the design process and provide feedback of completed work.

LITERATURE REVIEW RESEARCH

Conventional Method

The conventional treatment method researched for the removal of arsenic is oxidation. This was taken from a source basing its findings off of research done in India where arsenic levels are high. Oxidation treatment would come after pretreatment, converting arsenic to arsenate, which is a much easier form of arsenic to treat. For the true oxidation step of the treatment process, there are numerous ways to oxidize the water: aeration tube, in-situ oxidation, and solar oxidation. For the purposes of the article researched solar oxidation was the most used; this treatment takes more time, but it takes less energy [2].

The conventional nitrate treatment was the common process of ion exchange (IE), which acts similarly to the ion exchange process that removes hardness from water. The major difference between removing hardness and removing nitrate is the ion used for nitrate is chloride because this bonds better to the nitrogen than the traditional sodium ions. Two other commonly used methods are reverse osmosis, and distillation [3].

Innovative Method

The innovative method for removing arsenic researched is the process of ElectroChemical Arsenic Remediation (ECAR). ECAR uses a low electrical current to create rust from iron plates in contaminated water. The rust binds to arsenic, which can then be removed from the water through settling and/or filtration. It is targeted for communities or countries that do not have the resources for standard coagulation/filtration plants. The technology was developed at Lawrence Berkeley National Labs and is currently being pilot-tested by a company called SimpleWater. The ECAR process is reportedly much less expensive than conventional technologies [4].

The surface-modified iron nanoparticles (S-INP) were synthesized, characterized and tested for the remediation of arsenite (As(III)). The S-INP material was fully dispersed in the aqueous phase with a particle size distribution of 2–10 nm estimated from high-resolution transmission electron microscopy (HR-TEM). X-ray photoelectron spectroscopy (XPS) revealed that an Fe(III) oxide surface film was present on S-INP in addition to the bulk zero-valent Fe0 oxidation state. Results using S-INP pretreated 10 cm sand-packed columns containing about 2 g of S-INP showed that 100 % of As(III) was removed from influent solutions (flow rate 1.8 mL min^{-1}) containing 0.2, 0.5 and 1.0 mg L^{-1} As(III) for 9, 7 and 4 days providing 23.3, 20.7 and 10.4 L of arsenic free water, respectively. In addition, it was found that 100% of As(III) in 0.5 mg/L solution (flow rate 1.8 mL/min^{-1}) was removed by S-INP pretreated 50 cm sand packed column containing 12 g of S-INP for more than 2.5 months providing 194.4 L of arsenic free water. Field emission scanning electron microscopy (FE-SEM) showed S-INP had transformed to elongated, rod-like shaped corrosion product particles after reaction with As(III) in the presence of sand. These results suggest that S-INP has great potential to be used as a mobile, injectable reactive material for in-situ sandy groundwater aquifer treatment of As(III) [5].

The innovative method for removing arsenic researched is ion exchange. IE is a commonly used nitrate treatment technology. Although nitrate-selective IE resins have been developed, most are more selective toward sulfate than nitrate, therefore the impact of sulfate on nitrate exchange capacity must be considered. IE technologies are simple to design, operate and monitor. They are cost-effective for smaller applications such as direct treatment of groundwater at well sites, and usually feature fully automated regeneration sensors and equipment. These systems are regenerated using sodium chloride. IE is best for waters with total dissolved solids (TDS) concentrations of less than 500 mg/l. Salts and organics in water eventually spoil IE resins, but many systems operate for 5 to 10 years without requiring resin replacement [6].

Testing is being done of a titanium dioxide-based hybrid IE media that performs simultaneous removal of arsenic and nitrate. The estimated maximum adsorption capacity for arsenic per mass of titanium ranged between 16.6 mg As g^{-1} Ti, 24.9 mg As g^{-1}Ti, and 27.3 mg As g^{-1} Ti for different types of tested titanium dioxide-based hybrid IE media [7].

Sustainable Method (1)

Researching water treatment methods to remove arsenic and nitrate using low energy and at a low cost resulted in a few possible treatment methods. A low cost, low energy method was found for each arsenic and nitrate treatment separately. The method discovered to treat arsenic contaminated water was also found to be suitable for developing countries. Developing tubular ceramic adsorbers by depositing synthesized nanoscale iron oxide particles on porous alumina tubes creates a cost effective, low energy, and simplistic method to remove arsenic from water [8]. The ceramic is porous allowing and promoting adsorption and ultrafiltration. The combination of the ceramic membrane and the metal oxides removes the arsenic because heavy metals, like arsenic, are attracted to the oxides reducing the concentration in the water [9]. In addition to the metal oxides, blast furnace slag (BFS) has been used to assist in the adsorption process [10]. BFS is a steel production by-product that has been tested and proven to be effective and suitable as a low cost and highly available assistant in the adsorption process [10]. The entirety of this solution is low cost, low energy, minimal operation, and user friendly [9]. This method for removing arsenic can be scaled for residential use or municipal plant use and there are no liquid wastes generated, making this a suitable and sustainable option to remove arsenic from groundwater [8].

The removal of nitrate from groundwater can be a costly endeavor. Permeable reactive barriers are a lower cost, low energy solution to remove nitrate from groundwater [11]. This process is a form of subsurface denitrification where the nitrate is naturally oxidized to nitrogen gas.

Injecting additional carbon sources, such as woodchips or straw, mixed with sand or gravel to create an underground wall, which the groundwater flows through [11]. The sand and gravel allows for permeability greater than that of the surrounding soil so the water is forced through the barrier and the added carbon sources can activate the oxidation process of the nitrate [11]. This process costs a quarter of the cost of a typical conventional method and removes 60 to 100% of the nitrate present [11]. This process involves little maintenance, has a life expectancy of decades, and has been proven successful for the removal of nitrate in groundwater.

Sustainable Method (2)

Phytoremediation is the sustainable technology that was discovered through research of treatment techniques. This can be used interchangeably as an innovative or sustainable solution. This technology utilized aquatic plants to reduce high levels of arsenic from groundwater. One study that was found demonstrates that dried roots of the water hyacinth plant will create rapid arsenic removal in water [12]. The hyacinth plant is found in many waterways around the world, making this a viable technology for any community. The sample preparation required for this study included gathering hyacinth plants, washing them with deionized (DI) water and leaving the plants out to dry [12]. Plants were then ground into a fine powder using lab equipment. A mass-to-volume ratio of 30 mg roots per mL of solution was adopted for the remainder of testing after seeing almost 100% removal at this level [12]. This procedure also showed that optimum removal conditions were reached when water sources had a pH between 2.5 and 8.0. Analysis of the research proved that 93% of arsenite and 95% of arsenate (As V) were effectively removed from a 0.2mg/L arsenic contaminated source within 60 minutes [12]. In the end, it was discovered that 1000 liters of water could be treated using 30 kilograms of dried roots.

This technology could be used as a filtration steps in the bench scale model design. Not only will it effectively remove high levels of arsenic, but it can also be seen as sustainable due to the low operation cost and easily available media.

A sustainable technology that was found through research is the reduction of nitrate using autotrophic bacteria (ARoNite). This technology requires no organic carbon addition, uses hydrogen as a low-cost electron donor, is non-toxic, and has a low waste yield [13]. One downfall of this technology is that the hydrogen used as the electron donor is highly flammable, which will require extensive lab safety. ARoNite process is proven to reduce influent water with up to 150 mg/L of nitrate, produces less biomass and waste than other treatments, eliminates the need for resin regeneration and is environmentally friendly due to onsite hydrogen production availability [14]. A hollow fiber media that will serve as a biological growth platform and gas delivery system, hydrogen, and carbon dioxide will be needed to make this solution feasible [15]. If this treatment is chosen, a phone interview with APT Water may be necessary to receive technology details or additional information regarding this treatment.

A successful example of this treatment method was found in Rancho Cucamonga, CA where APT Water gained drinking water approval in 2013 after applying ARoNite [13]. The process used is a fixed-film biological treatment for the removal of oxidized contaminants [14]. Naturally occurring bacteria that use hydrogen has as an electron donor take carbon needed for cell synthesis from naturally occurring bicarbonate in a water source [14]. A membrane media is used to capture a naturally occurring bacteria culture. The autotrophic bacteria incorporate inorganic carbon from trace nutrients in the inflowing stream to create cell mass. The nitrate levels are then reduced using hydrogen gas as an electron donor. Nitrogen gas and clean water are the effluent that is produced. Hydrogen is delivered to the media and the biomass demands hydrogen, which diffuses across the membrane and is consumed during respiration [14].

Phytoremediation using hyacinth plants will allow a low cost, readily available source for arsenic removal in groundwater sources. The study found returned results of effective removal, meaning the effluent levels were below the EPA drinking water standards. For this treatment technique to be viable, there must be regulated pH levels in the water and a source to obtain hyacinth plants. To use ARoNite media nitrate removal techniques, APT Water, an engineering company, may need to be consulted to determine necessary treatment details. This technology requires low maintenance and low-cost, which require a hydrogen source, carbon dioxide source, and hollow fiber media. Both technologies discovered are feasible options to implement in a bench scale model design.

PROJECT SCHEDULE

The team created a yearlong schedule after compiling all project tasks and subtasks. The two tables below highlight the tasks and subtasks that were/will be completed each semester. The bold tasks represent the main deliverables and the italicized text represents subtasks.

Task Name	Duration
1.0 Preliminary Engineering	**12 days**
1.1 Chemical Research	*6 days*
1.2 Staffing & Cost	*6 days*
2.0 Literature Reviews	**17 days**
3.0 Design Decision	**25 days**
3.1 Proposal Presentation	*6 days*
3.2 Website	*5 days*
3.3 Design Proposal	*4 days*
3.4 Decision Matrix	*10 days*

Figure 2: Fall 2016 Tasks

Task Name	Duration
4.0 Design Preparations	**27 days**
4.1 Acquire Lab Space	*5 days*
4.2 Lab Certifications	*5 days*
4.3 Acquire Lab Materials	*11 days*
4.4 Water Contamination	*6 days*
5.0 Design Development	**67 days**
5.1 Design Construction	*16 days*
5.2 Water Testing	*9 days*
5.2.1 Send Samples for Testing	*4 days*
5.3 Analyze Test Results	*9 days*
5.4 Final Presentation	*9 days*
5.5 Final Design Report & Website	*75 days*

Figure 3: Spring 2017 Tasks

Durations were specified for each task, which represents the amount of time that CRKL believes each task will require. Additional days have been added to task 5.1 to account for potential design construction challenges. Time was built into tasks 5.2.1 and 5.3 to account for outsourcing the samples to a different lab facility. In the case that the results take longer to receive, the team added more time in these two subtasks to ensure a final design report can be completed on time.

The figure below presents the project schedule in Gantt Chart format. This is a way to present the tasks in a sequential order, which shows when each deliverable will be completed for a successful project. The red tasks highlight our critical items, which the team has decided must be completed at a specified date for the project to be finished on time.

CRKL Engineering’s critical path began this semester with literature reviews. This item was necessary for the design proposal to be completed on time. Next semester, acquiring lab space and materials are the first two critical tasks at hand. The team must gather materials, or order them if necessary, by the end of February to confirm that the design construction can start in a timely manner. The most important critical item for Spring 2017 will be sending the water samples out for testing. If this is not completed by the end of March, it is uncertain if the team will receive their results in time to create their final report, or make any design modifications if necessary. Both design proposals span the length of each semester to show that these will be compiled throughout the semester.

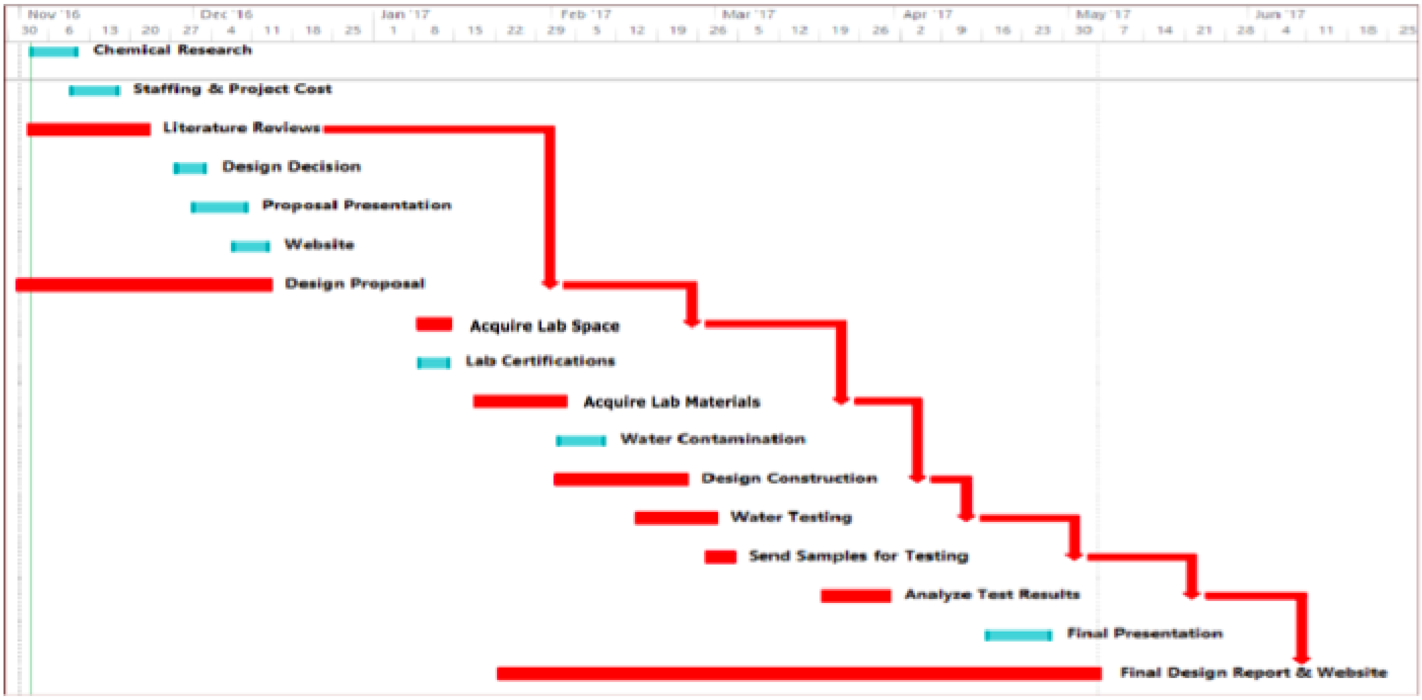

Figure 4: Gantt Chart Schedule

PROJECT COST

Breaking the project out into different tasks was necessary to cover the entirety of the scope. These tasks include research, water contamination preparation, model construction, and results analysis. The research is the only one of these tasks to be completed during the Fall 2016 semester and includes background on the project location, gathering information and details about arsenic and nitrate. Some details included are EPA drinking water standards, health effects, and sources of each contaminant. It was necessary to add the research component to the total project hours because the project requires research about the type of treatment to be used.

Water contamination preparation is necessary due to the outlined ranges of arsenic and nitrate, as well as the theoretical nature of the project. The model of construction is based off of the research incorporated into a decision matrix, and the results derive from this model. Table 1 outlines these details in terms of hours.

Table 1: Project Hours

Task	SENG Hours	ENG Hours	LAB Hours	INT Hours	AA Hours
Research	0	40	0	20	0
Water Contamination Preparation	24	0	80	80	0
Model Construction	40	56	40	24	0
Modeling	16	24	24	16	0
Result Analysis	32	32	0	0	160
Total	**112**	**152**	**144**	**140**	**160**
Total Project Hours	**708**				

Table 2: Total Project Cost

	Classification	Hours	Rate $/hr	Cost
Personnel	SENG	112	$132	$14,780
	ENG	152	$69	$10,490
	LAB	144	$52	$7,490
	INT	140	$19	$2,660
	AA	160	$41	$6,560
	Total personnel			$41,980
Lab Work	Materials		$2,500	$2,500
	Lab Rental	40 days	$100/day	$4,000
	Total Lab Work			$6,500
Subcontract	Analytical			$2,500
TOTAL				$50,980

Table 2 above shows the total hours divided up among the personnel, as well as pay rates, lab work costs, and subcontracting costs. Near the bottom of the table is the total cost for the project. This is the proposed cost of completion for the Verde Valley Water Treatment System based off of CRKL Engineering hour estimates.

CLOSING STATEMENTS

CRKL Engineering will continue to put effort into this project for the next 6 months. Beginning over Winter 16'-17' break, they will complete their decision matrix based on their design alternatives. A final design that meets stakeholder and client needs will be chosen based on the decision matrix. Completing these tasks over Winter Break will allow for the team to have an easy transition into the Spring 2017 semester when the design construction begins.

The task at hand fits CRKL Engineering specialties and career interests. As aspiring environmental engineers, creating a safe water source for a community allows the team to display what they have learned. Each team member strives to find projects that will increase the quality of life of citizens. Being able to treat arsenic and nitrate contaminated water in a low energy, sustainable manner can allow the design to be utilized in a community of any demographic. CRKL Engineering is truly the team for the job and is enthusiastic about the completion of the Verde Valley Water Treatment System.

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