Cinder Lake Landfill Leachate Monitoring Project Proposal

CENE 476

Prepared for:
Ken Fergason
Cinder Lake Landfill Project Manager
6770 E. Landfill Road
Flagstaff, AZ 86004

Submitted by:
TJB Associates Inc.
Tristan Wheeler, Brandon Bennehoff, Jimmie Devany
1899 S. San Francisco Street
Flagstaff, AZ 86011

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List of Abbreviations

EPA-Environmental Protection Agency
RCRA-Resource Conservation and Recovery ACT
MULTIMED-Multimedia Exposure Assessment Model
ADEQ-Arizona Department of Environmental Quality
HELP-Hydrologic Evaluation of Landfill Performance
GI-Grading Instructor
TA-Technical Advisor
SENG-Senior Engineer
ENG-Engineer
INT-Intern

1.0 Project Understanding

The project understanding will outline the purpose for the project, relevant site background information, necessary technical considerations, challenge that may be encountered over the course of the project

1.1 Project Purpose

The City of Flagstaff is looking for opportunities to improve the detection and modeling of the potential for leachate to migrate to groundwater underlying the City of Flagstaff (City) Cinder Lake Landfill (landfill). The engineering team will analyze the benefits and drawbacks of the new upcoming methods and technology of modeling of leachate migration through the vadose zone at the landfill. The team will also conduct a cost benefit analysis of the current methods and potential new methods to develop recommendations for the city to amend its monitoring protocol for leachate migration.

1.2 Project Background

Cinder Lake began operation in 1965, 5 years before the EPA was created and 11 years before RCRA was passed in congress [1]. Over the course of 50+ years of operation, the landfill has been producing leachate that may have been migrating into the vadose zone located 1,600 feet below it. Though it might not pose an immediate threat to the groundwater, laws and regulations mandate that landfills in the United States monitor the groundwater for potential pollutant exceedance from the leachate. Current contaminant monitoring at Cinder Lake is done using methods which provide limited results.

The current landfill footprint covers 115 acres and receives municipal solid waste from a 70-mile radius [1]. It receives waste from Flagstaff, Munds Park, Tuba City, and Williams. The landfill currently uses a hydroprobe at two wells within the footprint of the landfill for vadose zone monitoring of leachate. A third well outside of the landfill footprint is utilized as a control. The hydroprobe has a sphere of influence that analyzes the moisture content of the soil 18 inches around the hydroprobe [1].

Figure 1-1 [3] shows the location of the Cinder Lakes Landfill in relation to the state of Arizona. The landfill is located in central northern Arizona just north of I-40 approximately 15 miles northeast of Flagstaff as shown in Figure 1-2 [4].

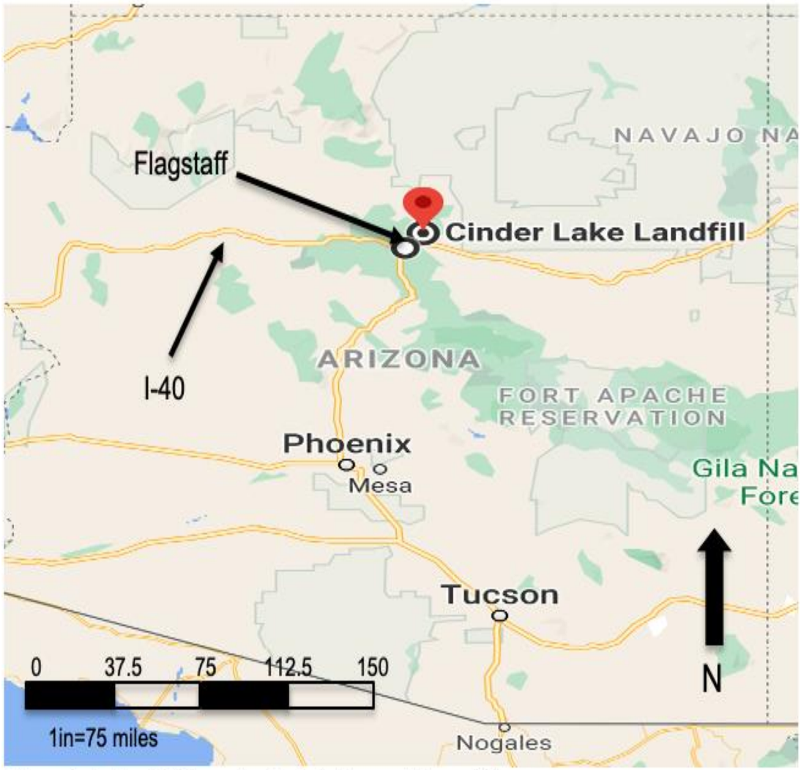


Figure 1-1: Landfill Location in Relation to Arizona

Figure 1-2: Landfill Location in Relation to Flagstaff

Figure 1-3 shows the Cinder Lakes Landfill site layout. The image was obtained from the landfill 2018 Solid Waste Plan [2]. Cells A-C show the current cells used for disposal of municipal solid waste. Cells D and E are for future landfill expansion.

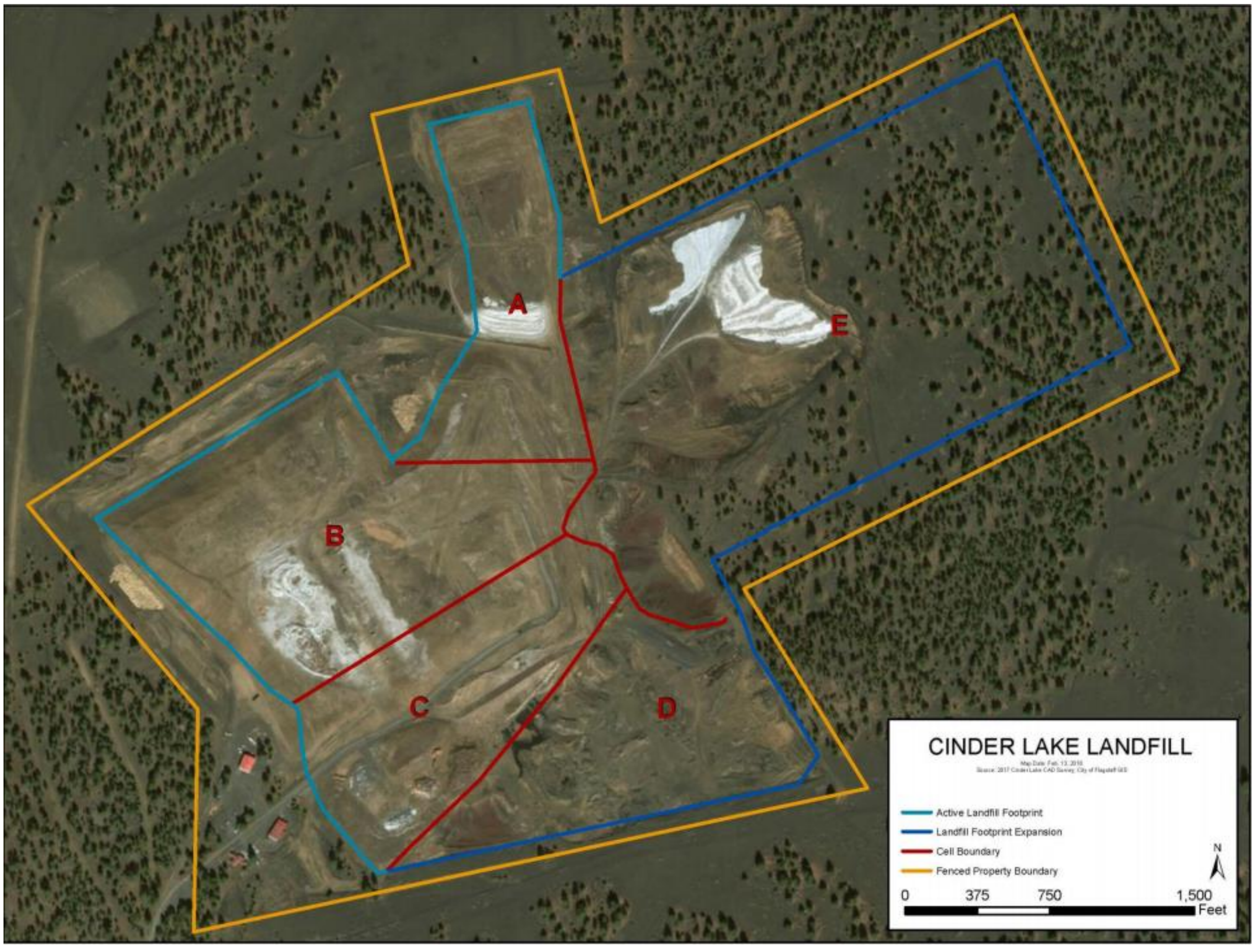


Figure 1-2: Cinder Lake Landfill Site Map

1.3 Technical Considerations

The team will obtain existing site data from the landfill. The necessary data includes topography, precipitation records, soil/rock properties, hydroprobe measurements, moisture content data, and waste characteristics. Before running the HELP model, the team must determine the input data required, how well the model responds to input changes, and the accuracy of the model. Alternative 3-D contaminant migration models will be considered and compared to the HELP model. The team will consider the accuracy/inaccuracy of interpolating 2-D leachate data into a 3-D map that shows the entire landfill area. The social, economic, environmental, and health impacts of landfill excavation will be considered. The updated HELP model and 3-D plume map will be used to evaluate how well the current hydroprobe technology is at comprehensively modelling the leachate levels over the entire landfill area.

1.4 Potential Challenges

The geotechnical properties of the geologic deposits below the landfill vary across the site and at different depths, which poses a challenge to accurately modeling leachate migration. Additionally, creating an inclusive model that shows the moisture content and leachate migration over the entire 115-acre area of the landfill could pose a challenge due to uncertainties at all points in the landfill. The team will analyze the data from the two hydroprobe measurement points and previous geophysical reports to determine potential migration patterns along with leachate concentrations over distance and time. The largest obstacle of the project will likely be the complex heterogeneous geologic conditions underlying the landfill and the limitations of determining the correct parameters for running the models. This will pose an issue to the creation of an accurate migration model. Some assumptions and interpolations of the geotechnical characteristics of underlying soil and rock may have to be made.

1.5 Stakeholders

The main project stakeholder is the City, who funds the operation and maintenance of the landfill and would also fund the project [1]. ADEQ holds stake in the project because they handle the landfill operating permit and enforce necessary regulations. Additionally, landfill users and nearby landfill neighbors are stakeholders due to the concern of the potential water supply air quality contamination.

2.0 Scope of Services

The scope of services outlines all major tasks and subtasks that are the team will complete.

2.1 Task 1: Site Investigation

The team will conduct a site visit. During the site visit, the team will tour the relevant site elements. This includes the hydroprobe monitoring locations and any sampling sites. The site visit also allows the team to develop a relationship with the client. The team will ask the client any questions to develop a further technical understanding of the sampling methods used and technical information of the hydroprobes.

2.2 Task 2: Analyze Site Documents

The team will analyze site documents to collect relevant geotechnical and hydroprobe data. The data allows for the creation of an accurate model and ability for the team to analyze the impacts of the hydroprobes in later tasks.

2.2.1 Task 2.1: Geotechnical Data Collection and Analysis

The team will analyze the relevant geotechnical documents provided by the landfill. The data collected from the documents will include geotechnical data of the vadose zone under the landfill across the entire 115-acre area of the landfill. The data collected will include all soil and rock layers present in the vadose zone, the dimensions of each soil/rock layer, the depth of each soil/rock layer from the surface of the landfill, the slope of each layer of soil/rock, and the porosity of each soil/rock layer. The location of any pockets of perched groundwater present within the vadose zone under the landfill will also be noted. The data will be analyzed to determine its usefulness to the alternative modeling software over the HELP model.

2.2.2 Task 2.2: Hydroprobe Data Collection and Analysis

The team will analyze the hydroprobe data. The exact model of hydroprobe used will be found. The dimensions and depth of the boreholes at each hydroprobe location will be researched. This will allow the team to conduct a cost analysis of the hydroprobe and analyze the effects of hydroprobe technology and its effectiveness of vadose zone monitoring.

2.2.3 Task 2.3: Landfill Layer Data and Analysis

Geotechnical data will be gathered from past geotechnical investigations , so an accurate model of the landfill can be created in future tasks. The team will research the depth of municipal solid waste in the landfill and analyze if the depth of municipal solid waste varies across the area of the landfill. The team will collect data regarding which soil types are present, where each layer of soil is located, and the thickness of each soil type.

2.3 Task 3: Modeling

The team will use the data obtained from Tasks 1 and Tasks 2 as input data into the HELP Model. The new model will be evaluated against the existing HELP Model from the landfill. Research will then be conducted to find alternative modeling software, which will be compared to the HELP Model to determine which model is best suited for the project.

2.3.1 Task 3.1: Create Updated HELP Model

The team will create a new HELP model using the current site data. This new model will be compared to the previous HELP model produced by the city. The comparison will provide insight on how variables affect the model.

2.3.1.1 Task 3.1.1: Create and Run Updated HELP Model

The team will research and learn to use the HELP model software. The new relevant data will then be inputted into the HELP model to run a simulation of the landfills performance.

2.3.1.2 Task 3.1.2: Compare HELP Model Results

The HELP model that landfill staff has created from previous data will be compared against the HELP model the team will create based on newer geotechnical data. Any differences in input landfill characteristics will be identified and updated if necessary. Discrepancies between the two models regarding leachate leaving the landfill will also be noted.

2.3.2 Task 3.2: Alternative Model Research

The team will research different available models that determine moisture content in either 2-D or 3-D analysis. Data about each alternative model will be collected, including cost, effectiveness, widespread use and what data inputs are needed for moisture content analysis.

2.3.3 Task 3.3: Model Comparison

The team will compare and contrast the HELP model to alternative modeling software that is available. The comparison will account for the accuracy of individual models in their ability to create a representative plume map of the leachate leaving the landfill.

2.3.3.1 Task 3.3.1 Sensitivity Analysis

In order to ensure that the HELP model and potential alternative are providing accurate results a sensitivity analysis will be performed to evaluate which input parameters are most critical to getting accurate results/. A sensitivity analysis will act as an in-depth study to assess future predictions of the leachate and the models reliability.

2.3.3.2 Task 3.3.2: Cost Estimate Comparison

The team will compare the costs of obtaining and running a selected model alternative to the cost of keeping the current HELP model. Possible cost evaluations are initial setup cost, maintenance costs, costs of obtaining input data, and labor costs of employing people to track data and maintain equipment.

2.3.4 Task 3.4: Justification Report for Selected Model

Based on the sensitivity analysis results of the model and its reliability, accuracy and cost, a justification for the selection of the model will be provided.

2.4 Task 4: Research and Compare Geophysical Methods

A list of alternative technologies to monitor moisture content under the landfill will be explored, compared to one another and to the hydroprobe to determine if the hydroprobe should stay in use, or if another method of moisture content measurement should be recommended.

2.4.1 Task 4.1: Develop List of Alternative Modeling Technologies

The team will research other viable technologies that measure moisture content under a landfill.

2.4.2 Task 4.2: Cost Analysis of Alternative Modeling Technologies

The short term costs, long term costs, and capital investment of the alternative modeling technologies will be researched and compared.

2.4.3 Task 4.3: Efficiency Analysis of Alternative Modeling Technologies

The accuracy and implementability of each modeling technology will be analyzed to determine how effective each technology is at monitoring moisture.

2.4.4 Task 4.4: Compare Alternative Methods to Hydroprobe

The effectiveness and associated costs of the alternative modeling technologies will be compared to the current hydroprobe technology to determine if a newer technology should be used, or if the current use of the hydroprobe to measure moisture content is the most effective.

2.5 Task 5: Develop 3-D Plume Visualization

The moisture content data obtained from the modeling done in Task 3 will be used as input data to create a 3-D plume map. This will require interpolation of 2-D data and a sensitivity analysis to determine areas of concern.

2.5.1 Task 5.1: Interpolate 2-D Geophysical Data

Dependent on what modeling software is selected, the team will interpolate any geophysical data such as soil type, geosynthetic materials, initial moisture conditions, layer thickness, and slopes to create a 2-D plume map.

2.5.2 Task 5.2: Create 3-D Plume Migration Map

A 3-D plume map will be created based on the interpolated geophysical data or the 3-D model results obtained if an alternative 3-D modeling software is chosen.

2.5.3 Task 5.3: Sensitivity Analysis for Potential Moisture Exceedance

Using the 3-D map, an additional sensitivity analysis will be conducted. This sensitivity analysis evaluates scenarios where the moisture content of well V-5 (observation well) is above exceedance levels. This will help predict the nature of the migration pattern of the leachate leaving the landfill.

2.5.4 Task 5.4: Analyze Landfill Excavation Requirements for Various Plume Scenarios

Based on the data found in the sensitivity analysis performed for a moisture content exceedance any areas of concern can become identified. These are areas of which are indicative of extreme seepage of leachate. The volume of these problem areas can be determined and an estimate for excavation can be provided. This estimate will be weighed against the estimate of continual monitoring with the HELP model.

2.6 Task 6: Analysis of Project Impacts

The social, economic, environmental, and human health impacts of the project will be evaluated based on the results found.

2.6.1 Task 6.1: Social Impacts

The potential social impacts that the project may have on any of the stakeholders will be evaluated.

2.6.2 Tasks 6.2: Economic Impacts

The potential economic impacts that the project may have on any of the stakeholders will be evaluated.

2.6.3 Task 6.3: Environmental Impacts

The potential environmental impacts that the project may have on any of the stakeholders and that area around the landfill will be evaluated.

2.6.4 Task 6.4: Human Health Impacts

The potential human health impacts that the project may have on any of the stakeholders will be evaluated.

2.7 Task 7: Project Deliverables

The project deliverables show the required submittals for 486C and the client.

2.7.1 Task 7.1: 30% Submittal

2.7.1.1 Task 7.1.1: 30% Report

The 30% report will outline the project's progress, which will include the analysis and results from Task 1 and up to Task 2.2.

2.7.1.2 Task 7.1.2: 30% Presentation

The 30% presentation will provide a summary of the 30% report.

2.7.2 Task 7.2: 60% Submittal

2.7.2.1 Task 7.2.1: 60% Report

The 60% report will incorporate comments from the 30% report. The information added to the 60% report will include the model comparison analysis and interpolated geophysical data to create a map (up to Task 3.1).

2.7.2.2 Task 7.2.2: 60% Presentation

The 60% presentation will provide a summary of the 60% report.

2.7.3 Task 7.3: 90% Submittal

2.7.3.1 Task 7.3.1: 90% Report

The 90% report incorporate comments from the 60% submittal. It will evaluate the results from all tasks.

2.7.3.2 Task 7.3.2: Practice Final Presentation

The final practice presentation will provide a summary of the 90% report

2.7.3.3 Task 7.3.3: 90% Website

The 90% website will outline the project site, tasks, methods, analysis, and results in a clear and aesthetically pleasing website.

2.7.4 Task 7.4: Final Submittal

2.7.4 Task 7.4.1: Final Presentation

The final presentation will be given at UGRADS, which will present the final project results.

2.7.5 Task 7.4.2: Final Website

The final website incorporates feedback from instructors and technical advisors.

2.7.8 Task 7.4.3: Final Report

The final report will incorporate the feedback given to the team by the GI, TA, and client from the 90% report.

2.7.9 Task 7.4.4: White Paper

A white paper document will be provided to the landfill. This document will provide a non-technical outline of the research done, analysis methods, and projects findings in a succinct manner. The document will draw from major deliverables and project milestones to provide the most pertinent details of the project to the client.

2.7.10 Task 7.4.5: Final Poster

The final poster will provide concise visual and verbal portrayal of the analysis done and results obtained over the course of the project. The poster will be organized in a manner that is easy to read and understand for students, professors, clients, and prospective employees.

2.8 Task 8: Project Management

The project management will occur throughout the semester. It ensures the project stays within the scope of work, budget, and allocated resources.

2.8.1 Task 8.1: Meetings

2.8.1.1 Task 8.1.1: Grading Instructor Meetings

Grading instructor meetings will provide the team an opportunity to ask the grading instructor questions and receive feedback. The team will provide the grading instructor project updates and prove that the project is staying within the given scope and schedule.

2.8.1.2 Task 8.1.2: Technical Advisor Meetings

Meetings with the technical advisor will allow the team to provide project updates, ask questions, and receive feedback from the technical advisor.

2.8.1.3 Task 8.1.3: Client Meetings

The client meetings will be conducted biweekly to ensure the team is meeting the clients requests. The client will provide feedback on previous work and be there to guide the team for future deliverables.

2.8.1.4 Task 8.1.4: Team Meetings

Team meetings will be conducted weekly. Each team member will provide updates on the project of their individual work, and the team will review the schedule each meeting to determine what task must be completed for the upcoming week.

2.8.2 Task 8.2: Schedule Management

The team will review the schedule weekly to ensure all tasks are completed on time. Any necessary updates to the schedule will be made.

2.8.3 Task 8.3: Resource Management

The team will manage the staffing by ensuring that the allotted number of hours for each task is not exceeded. The associated travel and supplies cost will not be exceeded, which along with staffing management, will keep the project within budget.

2.9 Exclusions

The project will not include any implementation methods for the chosen sensor technology or any remediation analysis for reducing leachate. No survey of the site will be taken. Samples of moisture content from the hydroprobes will not be taken. Gas modeling will not be included in the migration modeling process.

3.0 Project Schedule

A Gantt chart of the project schedule can be found in the Appendix.

3.1 Schedule Duration and Deliverables

The total duration of the project will take about 3 and a half months to complete. It will start on January 11th and end on April 27th, 2020. Task 1 includes a site investigation, where the landfill will be visited and past sampling data will be obtained at the site, which will take 1 day. Task 2 will analyze geotechnical, hydroprobe, and layer documents, which will take 8 days. Task 3 will create an updated HELP Model using the site documents, and alternative models will be researched. Task 3 takes 24 days to complete. It contains a milestone on February 19th, which is a justification report for the selected model. Task 4 will research and analyze alternative geophysical monitoring methods. The alternatives will be compared to the hydroprobe. This task will start after Task 4 and will take 26 days to complete. Task 5 will develop the 3-D plume map of the moisture migration over the area of the landfill, which involves interpolation of the 2-D moisture data and performing a sensitivity analysis to determine area of concern. Task 5 will take 22 days to complete. Task 6 will analyze the social, economic, environmental, and human health impacts of the project, which will take 10 days. Task 7 shows the major project deliverables. As seen in the Appendix, there are milestones on February 12^{th} for the 30% submittal, March 2^{nd} for the 60% submittal, April 13^{th} for the 90% submittal, and April 27^{th} for the final submittal. The final project poster and white paper are also milestones on April 27^{th}. Task 8 includes grading instructor, technical advisor, and client meeting. It also includes schedule and resource management. Task 8 will occur over the entire project duration.

3.2 Critical Path

As on the Gantt chart in the Appendix, the task duration highlighted in red indicates the critical path for the project. Task 2 is a critical task because the data obtained in this task is needed before starting Task 3. Task 3.1 is a critical task because the updated HELP model must be completed before comparing it to the existing landfill HELP model. The results from Task 3 are also needed to create the plume migration map in Task 5. All parts of Task 5 are on the critical path because Task 6 cannot start until Task 5 starts. All 30%, 60%, 90%, and final submittals are milestones because they have strict deadlines that must be met. Task 4 is not on the critical path because it does not depend on site data and modeling tasks to complete. The critical path of the project must be followed to ensure timely completion. The team will employ schedule management to ensure the critical path is followed. The team will check the schedule daily to ensure all past tasks have been completed and all present tasks are being worked on. The deadlines of current tasks will be identified to predict if the team will be able to complete the task on time. If not, the team may have to allocate more hours to the task, or work on weekends to ensure the critical task deadlines are met. Additionally, weekly team meetings will be held to discuss project progress, review the schedule, and hold each team member accountable for staying up to date with their designated parts of the project.

4.0 Staffing Plan

The project will require the services of two professional positions, an administration personnel (ADM) and an intern (INT). The professional positions will be a Senior Engineer (SENG) and an environmental engineer (ENG) who will utilize their individual skills and knowledge to evaluate the landfills performance through modeling and interpolation. Below are the required qualifications for the employees.

4.1 Staffing Qualifications

Senior Engineer Qualifications

- Minimum of a master's degree in civil or environmental engineering with 15+ years' of experience related to geotechnical analysis and environmental remediation.
- Must have PE license.
- Familiar with US state and federal environmental regulations.
- Successful track record of direct client management and business development responsibilities.

Environmental Engineer Qualifications

- Minimum of a bachelor's degree in environmental engineering with 7+ years' of experience in designing, permitting, document preparation and construction quality assurance of waste disposal facilities.
- Must have PE or in process of obtain it.
- Knowledge of US federal and state regulations for air, water/wastewater and solid waste.

Administration Personnel Qualifications

- Minimum of a bachelor's degree in computer science, engineering, business management, or related study with 5+ years' of experience working for environmental engineering consulting firms.
- Proficient in the use of personal computers, word processing, spreadsheet and graphics/presentation software.
- Excellent written communication and organization skills.

Engineering Intern Qualifications

- Currently enrolled as senior at an accredited university pursuing a bachelors or master's degree in civil or environmental engineering.
- Minimum cumulative GPA of 3.0 in undergraduate coursework.

4.2 Staffing Expanded

The intern will be involved in Task 1: Site Investigation and Task 2: Analyze Site documents to help collect and analyze pre-existing site documents and geological data. The intern will also assist the SENG and ENG in Task 3: Modeling by utilizing their research experience in finding alternative models and by helping assist in the models sensitivity analysis. This will provide software experience to the intern to help them gain real world engineering experience. The SENG and ENG will be working together in Task 3: Modeling as well since they are the most competent in data verification and visualization. The ADM will also help in Task 3: modeling in the creation of the justification report for the selected model. Task 4: Research and Compare Geophysical Methods will be conducted by the ENG and INT with little help from the SENG since it requires research into modeling technologies and no engineering calculations. Task 5: Develop 3-D Plume visualization will be conducted only by the SENG and ENG as it is the most pertinent data to be found in this project's entirety. Task 5 requires engineering analysis done by the SENG and ENG in developing a 3-D plume map. The INT and the ENG will conduct Task 6 with the help of the ADM. The intern will be able to identify all impacts the project will have on local social, economic, environmental and human health and provide great experience for their future career. Task 7: Project Deliverables and Task 8: Project Management will be a group effort between all staffing but mainly conducted by the ENG and ADM as the quality of work must be presentable and understandable. The SENG will ensure that all of the project tasks are completed on time and will oversee work of the ENG and INT throughout the project.

Table 4-1 and 4-2 shows the Staffing Plan that summarizes the staffing hours per task that each staff member will work. These assigned hours are based on the time estimated that each task will take and the amount of involvement by each staffer based on their qualifications and competency. The total amount of hours required to complete this project in time is expected to be 602 hours.

Table 4-1: Staffing Plan

Task	SENG Hours	ENG Hours	INT Hours	ADM Hours
Task 1: Site Investigation	4	4	8	4
Task 2: Analyze Site Documents		12	24	
Task 2.1: Geotechnical Data Collection and Analysis		4	8	
Task 2.2: Hydroprobe Data Collection and Analysis		4	8	
Task 2.3: Landfill Layer Data and Analysis		4	8	
Task 3: Modeling	8	58	36	4
Task 3.1: Create Updated HELP Model	2	12	4	
Task 3.1.1 : Create and Run Updated HELP Model	2	8		
Task 3.1.2: Compare HELP Model Results		4	4	
Task 3.2: Alternative Model Research		6	8	
Task 3.3: Model Comparison	6	32	16	
Task 3.3.1: Sensitivity Analysis	4	16	8	
Task 3.3.2: Cost Estimate Comparison	2	16	8	
Task 3.4: Justification Report for Selected Model		8	8	4
Task 4: Research and Compare Geophysical Methods	6	44	24	
Task 4.1: Develop List of Alternative Monitoring Technologies	2	8	8	
Task 4.2: Cost Analysis of Alternaitve Monitoring Technologies	2	16	4	
Task 4.3: Efficiency Analysis of Alternative Monitoring Technologies	2	16	4	
Task 4.4: Compare Alternaitve Methods to Hydroprobe		4	8	
Task 5: Develop 3-D Plume Visualization	8	80	16	
Task 5.1: Interpolate 2-D Geophysical Data	2	20	4	
Task 5.2: Create 3-D Plume Migration Map	2	24	4	
Task 5.3: Sensitivity Analysis for Potential Moisture Exceedance	2	24	4	
Task 5.4: Identify Portions of Landfill Requiring Excavation	2	12	4	
Task 6: Analysis of Project Impacts		24	16	16
Task 7: Project Deliverables	24	44	24	48
Task 8: Project Management	12	12	22	20
Sum Hours	62	278	170	92

Table 4-2: Staffing Plan Continued

Task	SENG Hours	ENG Hours	INT Hours	ADM Hours
Task 6: Analysis of Project Impacts		**24**	**16**	**16**
Task 6.1: Social Impacts		**6**	**4**	**4**
Task 6.2: Economic Impacts		**6**	**4**	**4**
Task 6.3: Environmental Impacts		**6**	**4**	**4**
Task 6.4: Human Health Impacts		**6**	**4**	**4**
Task 7: Project Deliverables	**24**	**44**	**24**	**48**
Task 7.1: 30% Submittal	**4**	**8**	**4**	**8**
Task 7.1.1: 30% Report	2	4	2	4
Task 7.1.2: 30% Presentation	2	4	2	4
Task 7.2: 60% Submittal	**4**	**8**	**4**	**8**
Task 7.2.1: 60% Report	2	4	2	4
Task 7.2.2: 60% Presentation	2	4	2	4
Task 7.3: 90% Submittal	**6**	**12**	**6**	**12**
Task 7.3.1: 90% Report	2	4	2	4
Task 7.3.2: 90% Presentation	2	4	2	4
Task 7.3.3: 90% Website	2	4	2	4
Task 7.4: Final Submittal	**6**	**12**	**6**	**12**
Task 7.4.1: Final Presentation	2	4	2	4
Task 7.4.2: Final Website	2	4	2	4
Task 7.4.3: Final Report	2	4	2	4
Task 7.4.4: White Paper	**2**	**2**	**2**	**4**
Task 7.4.5: Final Poster	**2**	**2**	**2**	**4**
Task 8: Project Management	**12**	**12**	**22**	**20**
Task 8.1: Meetings	**8**	**8**	**16**	**14**
Task 8.1.1: Grading Instructor Meetings	2	2	4	2
Task 8.1.2: Technical Advisor Meetings	2	2	4	4
Task 8.1.3: Client Meetings	2	2	4	4
Task 8.1.4: Team Meetings	2	2	4	4
Task 8.2: Schedule Management	**2**	**2**	**4**	**4**
Task 8.3: Resource Management	**2**	**2**	**2**	**2**
Sum Hours	**62**	**278**	**170**	**92**

5.0 Cost of Engineering Services

The total cost to complete this project is shown in Table 5-1: Cost Breakdown Summary and is projected to be $52,283. This cost of services is based on the time required to complete the project, the personnel and their time contributing to the project as well as travel back and forth to the landfill for an initial site visit and a follow up visit. Also, a $5,000 hypothetical estimate for precuring any modeling software that may be of us to the team is added into the cost. The hourly billing charge for each individual working on this project includes the employees base pay, the company benefits provided to the employee and their families, overhead to keep facilities functioning, and a profit for the company. This project will not result in the design or construction of any engineering plans.

Table 5-1: Cost Breakdown Summary

1.0 Personnel	Classification	Hours	Rate, $/hr	Cost
	SENG	62	194	$ 12,058
	ENG	278	98	$ 27,244
	INT	170	26	$ 4,342
	ADM	92	39	$ 3,618
	Total Personnel			$ 47,262
2.0 Travel	2 meetings @ 26 mi/meeting		$0.40/mi	$ 21
3.0 Supplies	Modeling Software			$ 5,000
4.0 Total				$ 52,283

6.0 References

[1] K. Fergason and M. Morales, Interviewees, *Cinder Lake Landfill Contaminant Migration Capstone Initial Client Interview.* [Interview]. 2 September 2020.

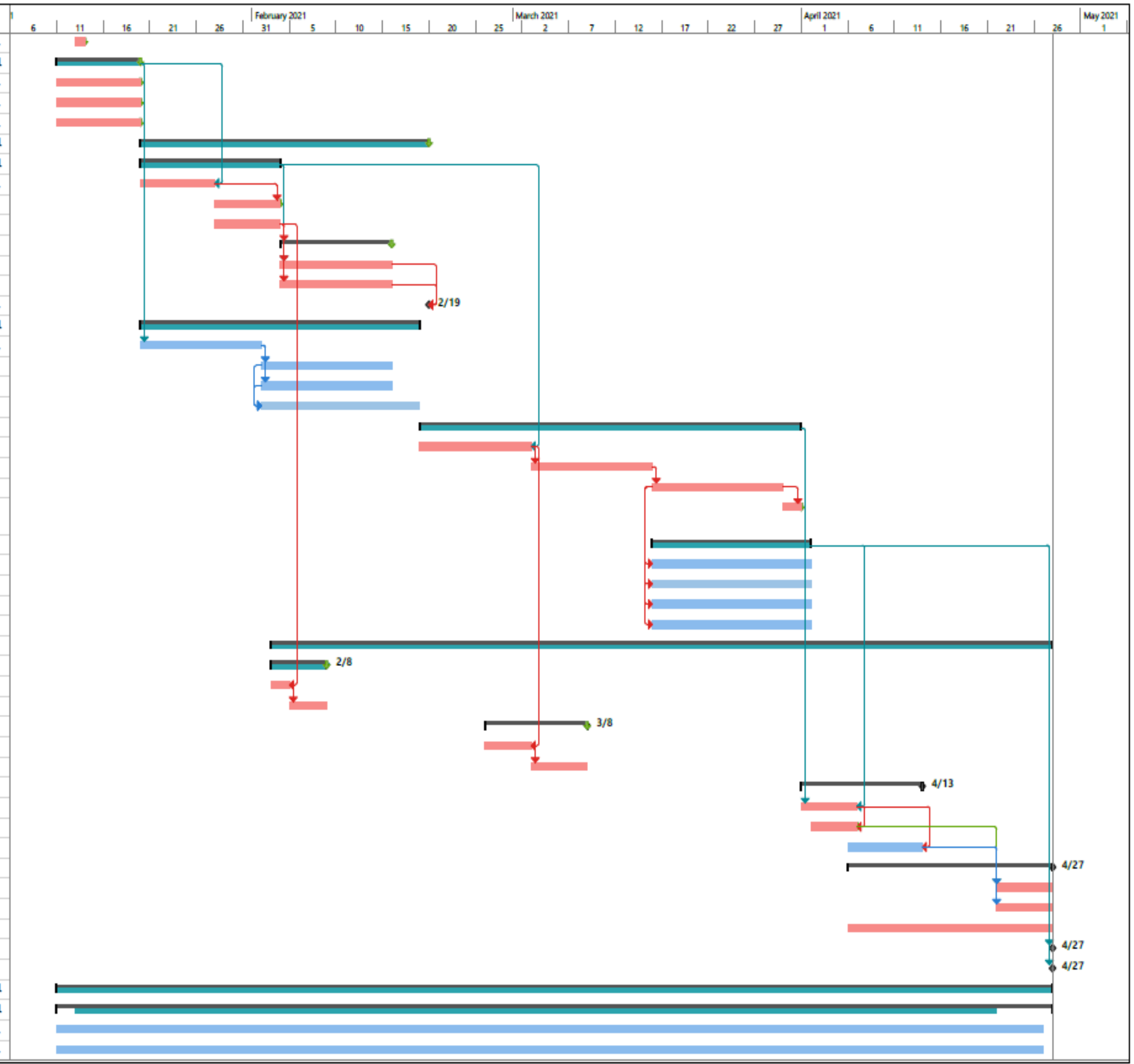
[2] T. Hanson, M. Morales and B. Bluelake, "City of Flagstaff Public Works-Solid Waste Plan," Flagstaff, 2018.

[3] Google Maps, "Cinder Lake Landfill," [Online]. Available: https://www.google.com/maps/place/Cinder+Lake+Landfill/@35.2870724,-111.6941764,11.75z/data=!4m5!3m4!1s0x872d8a5f04e1fa95:0x21c811654031dea3!8m2!3d35.304864!4d-111.520972. [Accessed 7 September 2020].

[4] Google Earth Pro, "Cinder Lake Landfill," [Online]. [Accessed 7 September 2020].

Appendix: Project Schedule Gantt Chart

ID	Task Name	Duration	Start
1	Task 1: Site Investigation	1 day	Wed 1/13/21
2	Task 2: Analyze Site Documents	8 days	Mon 1/11/21
3	Task 2.1: Geotechnical Data Collection and Analysis	8 days	Mon 1/11/21
4	Task 2.2: Hydroprobe Data Collection and Analyis	8 days	Mon 1/11/21
5	Task 2.3: Landfill Layer Data Collection and Analysis	8 days	Mon 1/11/21
6	Task 3: Modeling	24 days	Wed 1/20/21
7	Task 3.1: Create Updated HELP Model	12 days	Wed 1/20/21
8	Task 3.1.1: Create and Run HELP Model	7 days	Wed 1/20/21
9	Tasks 3.1.2: Compare HELP Model Results	5 days	Thu 1/28/21
10	Task 3.2: Alternative Model Research	5 days	Thu 1/28/21
11	Task 3.3: Model Comparison	8 days	Thu 2/4/21
12	Task 3.3.1: Efficiency Analysis	8 days	Thu 2/4/21
13	Task 3.3.2: Cost Comparison	8 days	Thu 2/4/21
14	Task 3.4: Justification Report for Selected Model	8 days	Wed 2/10/21
15	Task 4: Research and Compare Geophysical Monitoring Methods	23 days	Wed 1/20/21
16	Task 4.1: Develop List of Alternative Monitoring Technologies	10 days	Wed 1/20/21
17	Task 4.2: Cost Analysis of Alternative Monitoring Technologies	10 days	Tue 2/2/21
18	Task 4.3: Efficiency Analysis of Alternative Monitoring Technologies	10 days	Tue 2/2/21
19	Task 4.4: Compare Alternative Methods to Hydroprobe	13 days	Tue 2/2/21
20	Task 5: Develop 3-D Plume Visualization	30 days	Fri 2/19/21
21	Task 5.1: Interpolate 2-D Geophysical Data	9 days	Fri 2/19/21
22	Task 5.2: Create 3-D Plume Migration Map	9 days	Wed 3/3/21
23	Task 5.3: Sensitivity Analysis for Potential Moisture Exceedance	10 days	Tue 3/16/21
24	Task 5.4: Analyze Landfill Excavation Requirements for Various Plume Scenarios	2 days	Tue 3/30/21
25	Task 6: Analysis of Project Impacts	13 days	Tue 3/16/21
26	Task 6.1: Social Impacts	13 days	Tue 3/16/21
27	Task 6.2: Economic Impacts	13 days	Tue 3/16/21
28	Task 6.3: Environmental Impacts	13 days	Tue 3/16/21
29	Task 6.4: Human Health Impacts	13 days	Tue 3/16/21
30	Task 7: Project Deliverables	61 days	Wed 2/3/21
31	Task 7.1: 30% Submittal	4 days	Wed 2/3/21
32	Task 7.1.1: 30% Report	2 days	Wed 2/3/21
33	Task 7.1.2: 30% Presentation	2 days	Fri 2/5/21
34	Task 7.2: 60% Submittal	8 days	Fri 2/26/21
35	Task 7.2.1: 60% Report	4 days	Fri 2/26/21
36	Task 7.2.2: 60% Presentation	4 days	Wed 3/3/21
37	Task 7.3: 90% Submittal	9 days	Thu 4/1/21
38	Task 7.3.1 90% Report	4 days	Thu 4/1/21
39	Task 7.3.2: Practice Final Presentation	3 days	Fri 4/2/21
40	Task 7.3.3: 90% Website	6 days	Tue 4/6/21
41	Task 7.4: Final Submittal	16 days	Tue 4/6/21
42	Task 7.4.1: Final Presentation	4 days	Thu 4/22/21
43	Task 7.4.2: Final Website	4 days	Thu 4/22/21
44	Task 7.4.3: Final Report	16 days	Tue 4/6/21
45	Task 7.4.4: White Paper	3 days	Fri 4/23/21
46	Task 7.4.5: Final Poster	3 days	Fri 4/23/21
47	Task 8: Project Management	80 days	Mon 1/11/21
48	Task 8.1: Meetings	80 days	Mon 1/11/21
88	Task 8.2: Schedule Management	79 days	Mon 1/11/21
89	Task 8.3: Resource Management	79 days	Mon 1/11/21



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