CENE 476 – SINCLAIR WASH RIPARIAN HABITAT ENHANCEMENT FEASIBILITY STUDY

Agassiz Consulting Engineers Design Proposal

December 16, 2015

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Fall 2015

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1.0 PROJECT UNDERSTANDING

1.1 PROJECT PURPOSE

1.1.1 GENERAL STREAM CHANNEL RESTORATION

Stream channel restoration is a method of human modification to return a channel to its natural state in order to improve the health and the functionality of a stream. A functional river remains in a state of "dynamic equilibrium," where it transports a varying range of flows and sediment [6]. A typical healthy natural channel should support riparian biodiversity, flood management, groundwater recharge, sediment and water transport, and the management of pollutants [6]. The equilibrium of a natural channel shifts as the shape, vegetation, flow, and sediment transport change over time. The purpose of this project is to analyze previous inventory data compiled regarding Sinclair Wash, note any outstanding issues along the wash, and create design alternatives to rectify stream channel problems for the City of Flagstaff.

1.1.2 ALTERNATIVES ANALYSIS

The Sinclair Wash channel is eroded in many reaches and has a tendency to flood into commuter roadways during large storm events. Due to vegetation growth, erosion, sedimentation, and man-made infrastructure, the wash has become less effective in conveying storm flow. In order to propose design alternatives to the City of Flagstaff, our team of engineers will identify problematic channel sections along the wash. For these specified areas, the physical and biological components of the stream will be assessed using engineering analysis and in-depth research. Our team will conduct and report on a feasibility study to show potential solutions to the channel problems identified. Possible restoration measures include adding vegetation, reshaping the channel, constructing stream structures, removing garbage that disrupts the flow, and planting vegetation for erosion prevention [7] may be proposed. Because natural or human induced disturbances to streams can cause impairment to stream functions over time, the life cycle of our designs will be taken into consideration before they are proposed.

1.2 PROJECT BACKGROUND

1.2.1 LOCATION AND SPAN

Figure 1.2.1 below shows the seven mile span of Sinclair Wash in relation to the Flagstaff City Limits.

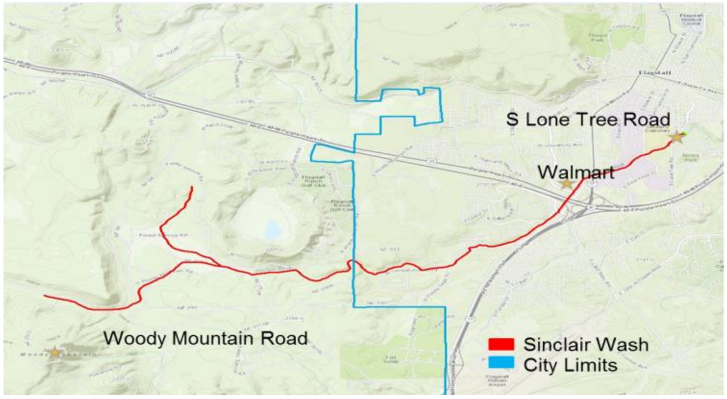

Figure 1.2.1: Map of the extents of Sinclair Wash

Located in Flagstaff, Arizona, Sinclair Wash originates near Woody Mountain and runs east through Fort Tuthill Park along the Flagstaff Urban Trail System. The wash travels northeast through Northern Arizona University, and continues until it meets with the Rio De Flag as shown in Figure 2.2.1 below.

1.2.2 EXISTING CONDITIONS

Sinclair Wash is not flowing as effectively because many years have passed since it was first constructed and because it has been modified several times for city utility line purposes. Along the reach of channel by Northern Arizona University, bricks were installed to slow the water flow speed, but due to the channel shape modifications made, there is over sedimentation and vegetation reduction. The increase of sediment has started to fill the gaps between the bricks, negating their positive effect on the channel. Because the bricks are no longer serving their initial purpose, the resulting water flow speed is much higher than it needs to be, and erosion on the opposite side of the channel is occurring.

Sinclair Wash east of San Francisco Street has shown signs of flooding during major storm events and has a tendency to overflow the Flagstaff Urban Trail System, creating a hazard to trail users. This is shown in Figure 1.2.2a below. Also, some of the reaches of Sinclair Wash have been reported to show signs of over sedimentation by the existing trail system. Garbage has piled up in front of and behind culverts and is affecting the water flow in the wash. The pooling of water creates an environment for harmful bacteria to grow and mosquitos to breed. An example of this is shown below in Figure 1.2.2b.

Figure 1.2.2b Culvert under South Knoles Drive

1.3 TECHNICAL CONSIDERATIONS

1.3.1 OVERVIEW OF TECHNICAL ANALYSES

The technical considerations necessary to provide the City of Flagstaff with a feasibility study for stream enhancement of Sinclair Wash are detailed below. The stream will be sectioned into workable reaches, and a field assessment will be completed in order to identify areas of the channel that will be redesigned for physical and biological improvements. Once the areas requiring redesign are selected, detailed surveying of the section will be conducted to gather thorough data for further analysis. Redesigning the new sections of the wash will require comprehensive research on Low Impact Development (LID) designs and other hydraulic infrastructure designs. The surrounding riparian habitat will be evaluated to ensure that any changes to the stream will conserve the existing plant diversity and wildlife habitat. Previously found hydrologic data will be useful in determining the maximum flows through the channel, and the proposed designs must be able to pass the 100-yr flood flow with no outstanding issues. Once the designs are proposed, different methods of hydraulic channel analysis will be performed on the specified sections in order to gather information about the velocities flowing through the design, the normal depth, the flow regime, and any outstanding issues with the design. The designs must meet standard specifications of Flagstaff's LID manual, and improve the overall function of the channel. The technical analyses of Sinclair Wash will provide critical information that will be necessary in the redesign of areas of Sinclair Wash. The feasibility of these design alternatives will be evaluated and presented to the City of Flagstaff for feedback on a potential future conceptual project for the restoration of Sinclair Wash.

1.3.2 FIELD ASSESSMENT

A site assessment of Sinclair Wash will be completed in order to gather necessary information before any design consideration can be proposed. Reaches along the channel will be identified and divided by physical boundaries. The conditions of the reaches will then be identified and segmented into the three categories. The first category includes reaches that are in good condition and need no reconstruction. The second category will be reaches that are in such critical condition that no design implementation will be beneficial at this stage of design. The third category will be reaches that are in poor condition but have the potential to be improved with a new design; these are the reaches that will be considered for design implementation. Photographs of the reaches will be taken for reference tools. Any current hydraulic infrastructure residing in the design reaches will be evaluated using previous hydraulic data and measurements. Before design implementation, the reaches will be assessed for its existing riparian habitat. Any design proposals should not negatively affect the existing wildlife, and should promote a healthy and thriving ecosystem along the wash.

1.3.3 SURVEYING AREAS FOR DESIGN

The entire channel of Sinclair Wash was previously surveyed using LiDAR data, which will be useful for further hydraulic analysis. Although the wash was previously surveyed, reaches identified for redesign will be surveyed again thoroughly so that analyses of the proposed designs are accurate. Surveyed points will provide the team with workable topographical data that can be imported into AutoCAD and Civil 3D to formulate design alternatives. The entire area of the proposed reaches will be surveyed in order to run hydraulic analyses through the existing reach and new designs.

1.3.4 LOW IMPACT DEVELOPMENT

Low impact developments (LIDs) are a means to mitigate the effects of increased storm water runoff from developed sites and to protect water quality. Increased development causes a decrease of storm water infiltration and groundwater recharge, an increase in peak runoff, and an increase in the amount of contaminants leading into the stream. LIDs aim to reduce the amount of runoff from impervious areas as well as increase water conservation. They use techniques that harness, filter, store, and infiltrate runoff in developed areas in order to bring the hydrologic levels at the site back to the predevelopment hydrology. Goals of LID include "protecting water quality, reducing runoff, reducing impervious surfaces, encouraging open spaces, protecting significant vegetation, reducing land disturbances, and decreasing infrastructure costs." (LID Manual). The benefits of LID technologies are broad and include protecting water quality, reducing point-source pollution and habitat degradation, and providing groundwater recharge. As our primary sources of drinking water in Flagstaff become polluted and scare, the implementation of low impact developments may greatly improve the quality and abundance of Flagstaff's potable water. For these reasons our team of engineers will consider LIDs when designing alternatives for Sinclair Wash.

1.3.5 HYDROLOGIC ANALYSIS

A hydrologic assessment of the watershed around Sinclair Wash was previously completed. This data will be useful in developing design solutions for the necessary reaches along Sinclair Wash. The 100-yr flood flow, the 50-year flood flow, and the 10-year flood flow data will be gathered as well as the runoff coefficients and runoff infiltration will be used in the analyses of designs. If new infrastructure is proposed as a design alternative, a hydrologic assessment of the local runoff will be done to gauge the affects the infrastructure has on the flow downstream. Local runoff may be increased by new designs depending any impervious design areas. The channel downstream of the design must be able to pass the new flow.

1.3.6 HYDRAULIC ANALYSIS

A hydraulic analysis must be done on the sections of the channel that are proposed for redesign. Using our design data the flow, velocity, headloss, and normal depth through the channel will be calculated. If the culverts along Sinclair Wash are chosen for redesign a culvert analysis will need to be performed to optimize the function it was originally design for. Software such as FlowMaster and CulvertMaster will be used. This information is necessary to check that the proposed changes in channel design or culvert design will improve the purpose of Sinclair Wash.

1.3.7 GEOMORPHOLOGY

In order to assess the feasibility of stream restoration, channel geomorphology will be evaluated to properly address channel degradation, deposition, channel widening, bank stability, and other issues caused by natural and human disturbances to the channel. The geomorphology of a stream naturally changes as the stream attempts to move towards a state of equilibrium. There are five interdependent parts to a channel's morphology, and a modification to one may have an affect on the other four. The five aspects are water and sediment inputs, channel slope, channel width and depth, bank resistance, and roughness coefficients [3]. Proposed designs must ensure that the altercations of the channel do not negatively affect the channel geomorphology, and maintain the channel's stability, depth, width, and shape. Shear stress can cause detrimental changes to channel geomorphology.

1.3.8 RIPARIAN HABITAT

A riparian habitat includes all biota residing near a body of water. Vegetation is a crucial aspect of channel stability and health, and research needs to be done on vegetative native species along Sinclair Wash. Native vegetation along the wash should be designed to provide bank stabilization, storm water filtration, channel roughness, and aesthetic qualities. There are guidelines for habitats in the Flagstaff habitats in the "Open space Recommendations and Guidelines" that require "sensitive" and exotic plant species to be preserved [4]. Any altercations also may not remove any trees that are over 200 years old [4]. Riparian ecosystems are very fragile, and today less than 10% of riparian areas within Arizona have retained their natural system. Invasive plants and animals threaten the health of riparian ecosystems. Invasive species are aggressive, overcrowd native species, and can be difficult to control or maintained once established in an area [5]. Previous studies on Sinclair Wash determined that there were six different invasive plants along the stream. The natural wildlife around Sinclair Wash, which includes elk, deer, small mammals, and birds will be preserved and encouraged to thrive along the wash [4]. According to the Arizona Experience website, the seventy percent of Arizona's threatened or endangered vertebrates depend on riparian habitats for survival. Riparian habitats are critical to the wildlife diversity in Arizona. Design alternatives will preserve the native plant and wildlife species, and promote optimum health of these systems along the reach so that species are able to thrive. Design alternatives will also emphasize the use of native vegetation for bank stabilization, filtration, and channel aesthetics. Research on invasive species will need to be done in order to determine the risk that they pose to the health of the channel, and will require mitigation and possible removal.

1.4 POTENTIAL CHALLENGES

Surveying the channel presents several potential challenges. The weather conditions highly affect surveying capabilities and Flagstaff is predicted to get a very large snowfall this year. In order to avoid waiting for the snow to melt to start surveying, the channel will be surveyed this fall/winter, prior to the point in which snow might stay on the ground.

Runoff calculations present another challenge. In order to analyze the channel, several assumptions need to be made for the calculations and the formulas used. The regression equations that will be used to analyze the data give approximate values. Although these equations are based off historical data and strive to be as accurate as possible when estimating the storm water events in the area, they give approximate answers. The relevancy of our results is also a challenge. There is a possibility that after recommendations for the channel are complete, the weather drastically changes for the next several years or longer. In the case of weather change, the designs we present would need to be reanalyzed with regard to the new data, and solutions might need to be adjusted.

Another, less intense, challenge is the feasibility of our designs with respect to budget. For this reason, it is important that a thorough discussion with the client takes place about the anticipated funds for this project and other concerns that could affect the magnitude of improvements recommended in this study. The study will make sure to only include channel improvements that will yield results, but make economic sense and are practical for the city to implement.

1.5 STAKEHOLDERS

Stakeholders for the feasibility study of the restoration of Sinclair Wash include the City of Flagstaff (COF), Northern Arizona University (NAU), Coconino County, the Arizona Department of Transportation (ADOT), the Arizona Game and Fish Department, and the community and businesses located near the stream channel.

The client, The City of Flagstaff, has economic stake in the project and expects quality work because they will fund the implementation of the design. The COF will move forward with construction if the design proposed functions properly and will not be able to continue with the stream restoration efforts if our designs are not credible. Northern Arizona University, although not responsible for funding this project, will have almost the same stake in this project as the COF, especially along the reaches of Sinclair Wash that run directly through NAU’s campus.

Coconino County will be affected by this study because they are the governing county over the piece of land that Sinclair Wash is located in. ADOT is a stakeholder because this stream is located mainly in an urban setting. With that said, many roads go over and directly cross Sinclair Wash. If design alternatives are proposed, there is potential they will affect the surrounding roads and highways. The Department of Fish and Game is directly affected by our project because of the habitat surrounding Sinclair Wash. The wash has many fish and animal species that must be preserved throughout restoration efforts.

The community and businesses near Sinclair Wash will be directly affected if the wash floods into residential homes and buildings. Flooding of the wash could result in costly damages and potential injury. The community is a stakeholder because the wash has the potential to negatively affect their quality of life. Community members who use areas around the stream recreationally will also be impacted by the results of the design.

2.0 SCOPE OF SERVICES

2.1 FIELD ASSESSMENT

2.1.1 STREAM REACH DETERMINATION

In the beginning stages of this project, the team will walk Sinclair Wash in order to determine the length of reaches. The type of stream for each reach will be determined, and the desired stream type will be identified.

Problematic areas along Sinclair Wash that are in need of redesign will be identified during this initial site walk. The conducted site visit will give the team a better understanding of the required analysis of the areas identified, and the potential design possibilities of the stream sections.

Our team of engineers will fill out the field inventory forms with regard to the areas identified as being problematic. The inventory forms will be presented to the City of Flagstaff and used to determine specific methods of analysis required for each different selected region. Also, pictures will be taken during the site walk in order to document Sinclair Wash's current conditions and convey to the City of Flagstaff the areas that will be chosen for redesign.

2.1.2 INFRASTRUCTURE ASSESSMENT

Culverts will be identified as either large or small per their sizing and their designed maximum allowable flow. At the City of Flagstaff request, the previously installed infrastructure will be analyzed to confirm proper flow and function.

Low water crossings will be identified along the stream reaches of Sinclair Wash so that the engineering team understands the implications of this type of channel structure and how they affect the rest of the channel. Bridges will also be identified along Sinclair Wash for informational purposes.

2.2 STREAM RESTORATION DESIGN ALTERNATIVES

2.2.1 ACQUIRE TOPOGRAPHIC DATA

The engineering team will analyze existing LiDAR data that has been provided to us by the City of Flagstaff to assess if it is relevant data. If this data is pertinent to our areas of analysis, it will be used. Also, a survey will be conducted for the identified problematic areas to gain station and elevation data for the existing conditions of such areas. The surveying will occur only at the areas that are hard to study, redesigned and remodeled using the LiDAR surveying data.

2.2.2 RIPARIAN HABITAT ASSESSMENT

Research will be conducted on natives species of Arizona's riparian habitats. The channel will be assessed for the existing biota along Sinclair Wash. Non-native species to the stream have previously been identified, and research will be conducted on how to mitigate invasive species along the wash. Native vegetation will be identified and used as channel stabilizers, storm water filters, and to provide aesthetic value. The existing riparian habitat will be preserved as much as possible with the addition of any new items.

2.2.3 GEOMORPHIC ASSESSMENT

Channel geomorphology for existing conditions and for the redesigned sections will be evaluated to properly address channel degradation, deposition, channel widening, bank stability, and other issues caused by natural and human disturbances to the channel. Five aspects of channel geomorphology must be taken into consideration including channel width and depth, channel slope, sediment input, bank resistance, and roughness coefficients. Shear stresses on the bedform and channel banks will be calculated to determine the erosion potential of the channel. The stream's sedimentation transportation process will be assessed to ensure that natural sedimentation remains a beneficial and nutritive process of the stream, and is not causing detrimental erosion, turbidity, or excess of soil deposition in any area of the reach.

2.2.4 HYDROLOGIC ASSESSMENT

The hydrologic assessment of the watershed around Sinclair Wash that was previously completed will be used for the hydraulic analyses of the reaches identified for alternative designs. New infrastructure proposed in design alternatives will require local hydrologic analysis to ensure that flows downstream of the design are not adversely effected. Because local runoff in the stream may change due to new hydraulic designs, it is important to verify that the channel downstream of the design is still able to pass the 100 year flood flow.

2.2.5 HYDRAULIC MODELING

2.2.5.1 BENTLEY CULVERT MASTER

If areas for redesign include culverts, they will be measured, assessed, and evaluated for their hydraulic characteristics, practicality, and necessity. Bentley CulvertMaster will be used in order to do this analysis and get familiar with the culverts characteristics and capacity. In order to use this program, specifics about the cross section such as size, shape, and the maximum discharge value will be calculated.

2.2.5.2 BENTLEY FLOW MASTER

With proposed designs taken into consideration, the flow of Sinclair Wash will be evaluated based on the channel hydraulic characteristics. Bentley FlowMaster will be used in order to analyze channel flow and get familiar with the flow characteristics and capacity. In order to use this program, specifics about the cross section such as size, shape, Manning's coefficients, and a maximum discharge value need to be calculated.

2.2.5.3 HEC-RAS (HYDRAULIC ENGINEERING CENTERS RIVER ANALYSIS SYSTEM)

HEC-RAS will be used to analyze the channel characteristics and channel geometry by running a model for the channel steady and non-steady flow for all proposed designs. In order to use this program, the engineering team will input cross sectional geometry, culvert and road data, Manning's coefficients, and any other infrastructure characteristics throughout the channel.

2.2.6 LOW IMPACT DEVELOPMENT (LID)

Consideration of low impact development designs will be used to enhance identified areas of the wash. The team will establish alternative hydraulic designs based on the suggestions and design requirements found in the low impact development manual of City of Flagstaff. LID will be used to provide the wash with storm water mitigation, ground water recharge, water quality improvement, and aesthetic qualities.

2.3 BROADER IMPACT ANALYSIS

An analysis of the broader impacts of the designs proposed will be done. This impact analysis will look at effects on the environment, community, economy, and health of patrons and habitats. This information will be presented to the City of Flagstaff in order to ensure that the completion of this project is beneficial to all parties involved.

2.3.1 ECONOMIC IMPACTS

It is anticipated that the project will have minimal economic impact because the stream restoration will not bring new tourists to the area. Also, the exploration of Sinclair Wash is free of charge to the public. The funding for this project will be provided by the City of Flagstaff, and it is expected to be easily attained.

2.3.2 ENVIRONMENTAL IMPACTS

The restoration of Sinclair Wash is expected to have a considerable impact on the ecosystem and environment in the surrounding area. By providing efforts to clean the wash, the trash build up on site will be reduced, and by reducing invasive species and potentially planting new vegetation, the riparian habitat surrounding the wash will thrive.

2.3.3 COMMUNITY IMPACT

The impact on the community surrounding Sinclair Wash is expected to be large. If design alternatives suggest a change in geomorphology, then the homes close to the changes will be effected by construction operations nearby. The impact on the surrounding community will not only be negative, but will be positive after the design alternatives are implemented. After Sinclair Wash is altered, the community will observe a more functional, aesthetically pleasing area of land.

2.3.4 HEALTH IMPACT

It is expected that the restoration of Sinclair Wash will have an impact on the health conditions in the area. With the use of low impact designs, there is potential that the water that flows through Sinclair Wash will be filtered and sink into the ground at a higher level of quality. The result of this will be better water to recharge into the atmosphere. The riparian habitat will also have higher quality water to feed off of and less pollution to disturb their living space.

2.4 PROJECT SUBMITTALS

2.4.1 50% DESIGN REPORT

This deliverable will contain 50% of the final design report, which will be helpful for the client and the design team to determine if the project is progressing on the right track. Feedback is expected from the client, technical advisor, and grading instructor. This is due March 14, 2016.

2.4.2 100% DESIGN REPORT

The 100% deliverable will include the final design report and the analysis. This deliverable is due May 12, 2016.

2.4.3 PROJECT WEBSITE

A website will be created by our team of engineers to archive the project for future use. It will contain a main page including a short discretion of the project, team information, and technical advisor information. Also, it will include a page with all of the documentation of the project. This deliverable is due on April 29, 2016.

2.4.4 FINAL PROJECT PRESENTATION

This deliverable will be a presentation of the final study for the client and capstone instructors. This deliverable is due on May 6, 2016.

2.5 PROJECT MANAGEMENT

2.5.1 STAFFING MANAGEMENT

The senior engineer will be in charge of controlling all of the staffing needed to complete the project. The projects staffing will consist of developing the correct engineering team for the job with engineers with expertise in surveying, surface water design, traffic engineering, storm water treatment, and environmental engineering.

2.5.2 PROJECT COMMUNICATION

Meetings will occur between the team and the client to provide the client with a feedback of the project process. The mid-level engineer will be in charge of dealing with and fixing any concerns the client will have. The engineer-in-training will be in contact with the technical advisor for detailed strategies on how to complete the engineering work for the project. They will relay questions and concerns from the engineering design team to the technical advisor and from the technical advisor to the design team. The entire team will be in charge of correcting technical advisor comments and resubmitting.

2.5.3 BUDGET MANAGEMENT

It will be the senior engineer's responsibility to track and control the budget for the project. If the project starts to go over budget, the senior engineer will need to analyze and work with the design team to come up with a strategy to get the project back on budget. The team will log every hour spent on the project in order to keep on track and within budget. At the end of the project, the entire team will do a comparison between the estimated and actual cost to check if the project budget went as expected or not.

2.5.4 RESOURCE MANAGEMENT

The design team will develop a strategy to best utilize the resources that are available. This will include developing the teams of professionals needed to complete the project as well as controlling the budget and schedule.

2.5.5 SCHEDULE MANAGEMENT

Scheduling the design team and sub-contractors for the job will be the senior engineer's responsibility. They will also be in charge of strategically controlling the float for the schedule so the project runs as efficiently as possible and the project stays on schedule.

2.6 EXCLUSIONS

2.6.1 CONSTRUCTION

The construction of the designs presented by our team of engineers is not included within this contract's binding scope of work. The implementation of the designs presented will be left up to the City of Flagstaff.

2.6.2 GEOTECHNICAL ANALYSIS

If a geotechnical analysis is required at any point during this project, it is understood that the City of Flagstaff will outsource this work to another entity. Our team of engineers is in no way responsible for the geotechnical analysis required along Sinclair Wash.

2.6.3 PROPERTY ACQUISITION

The City of Flagstaff will handle any property acquisition needed for this project.

Anything not exclusively identified within this binding document entitled "Sinclair Wash Capstone: Scope of Work" is not included.

3.0 SCHEDULE OF PROJECT

Attached to this report is the Sinclair Wash Gantt Chart and a list of tasks describing the schedule for the lifetime of this project.

The Gantt Chart for this project was developed using a software called GanttProject. The Gant Chart is used as a timeline for the completion of tasks and deliverables and illustrates the critical path of the project. The critical path is needed so that float can strategically be determined for the different tasks to maximize efficiency and identify areas in the project schedule that have flexibility. The critical path is shown in red so that it can clearly be distinguished. The project schedule was broken down into four major tasks, the field assessment, design restoration alternatives, impact analysis, project management, and project deliverables. Each task contains several sub-tasks that further break down and give more detail to what needs to be completed to finish the task. The durations for any of the main tasks or sub-tasks can be seen above each bar represented in the Gantt Chart. All of the dates associated with the project can be seen at the top of the Gantt Chart or to the right of the schedule of tasks listed. The dates listed throughout the schedule and the identified milestones will inform the owner when the design work will be available for them to review and be able to move forward with the project. The start date for the project schedule is October 29th, which was when the survey work was started and the end date is May 12th, when the final presentation and 100% deliverable is due.

4.0 COST OF ENGINEERING SERVICES

4.1 STAFFING ROLLS AND QUALIFICATIONS

4.1.1 PROJECT MANAGER

- 4-year bachelorette degree in Civil Engineering
- Professional Engineering Licensure (Fundamentals of Engineering Exam taken and passed)
- 10 years of post-bachelorette experience in Water Resources Engineering
- 4 years of experience in project management and supervisory rolls
- Experience developing, reviewing, and stamping engineering plans for approval
- Familiarity with administering contracts for professional services
- Expertise in preparing and reviewing budgets and cost estimates

4.1.2 PROJECT ENGINEER

- 4-year bachelorette degree in Civil Engineering
- Professional Engineering Licensure (Fundamentals of Engineering Exam taken and passed)
- 6 years of post-bachelorette experience in Water Resources Engineering
- 1 year of experience in project management and supervisory rolls
- Experience developing, reviewing, and stamping engineering plans for approval
- Familiarity with administering contracts for professional services

4.1.3 ENGINEER-IN-TRAINING

- 4-year bachelorette degree in Civil Engineering
- Completion of the Fundamentals of Engineering Exam
- 3 years of post-bachelorette experience in Water Resources Engineering
- Experience developing engineering plans for review
- Working knowledge of Microsoft, AutoCAD, and some engineering software
- Good written and oral skills
- Experience working in teams

4.1.4 LAB TECHNICIAN

- 4-year bachelorette degree
- Proficiency in software such as HEC-RAS, FlowMaster, CulvertMaster, AutoCAD, StormCAD
- Good written and oral skills
- Experience working in teams

4.1.5 INTERN ENGINEER

- Pursuing a 4-year degree in Civil Engineering – 3 years completed
- Good written and oral skills

- Experience working in teams
- Organization skills and a desire to learn

4.2 BREAKDOWN OF HOURS

In order to complete a budget, the hours required to do each task for each employee were estimated. The senior project engineer will spend most of his/her hours on budgeting, client and technical advisor communications, and the development of the final report. The mid-level engineer and the engineer-in-training will spend most of their time doing analysis and developing design alternatives. The lab technician will primarily conduct hydraulic and hydrologic analysis for current conditions and design options. The intern on the job will assist in the project where needed, mainly shadowing the mid-level engineer and engineer-in-training. In Table 4.2.1 below, the hours required for each scheduled task are shown, with specific attention paid to who will be completing each task and how much time they will be spending. Table 4.2.2 shows the total number of hours that each staff member will work on this study.

Table 4.2.1: Summation of Hours per Task per Staff

Subtask	Project Manager	Project Engineer	EIT	Lab Technician	Intern
Identify Reaches					
Site Walk	1	4	10	10	10
Complete Inventory Forms	0	1	1	1	6
Assess Current Infrastructure					
Identify Low Water Crossings	1	2	4	2	8
Identify Bridge Types and Sizes	1	2	4	2	8
Identify Culvert Types and Sizes	1	2	4	2	8
Survey Identified Problematic Areas					
Access Previous Survey Data	0	0	2	1	5
Obtain Survey Equipment	0	1	1	1	1
Survey Identified Problematic Areas	0	3	15	12	16
Analyze Survey Data	0	3	5	10	8
Assess Riparian Habitat	0	0	4	6	4
Research Flagstaff Guidelines	0	1	4	3	3
Geomorphic Assessment					
Calculate Shear Stresses	0	1	4	8	5
Analyze Designated reaches for erosion	0	1	4	7	7
Hydraulic Analysis					
Acquire GIS data for project site	0	1	1	2	2
Develop Drawing in ArcMAp	0	3	9	12	10
Develop Drawing in AutoCAD	0	2	5	10	6
Use Appropiate Software	0	2	10	15	8
Model Design Alternative	1	4	19	22	15

Hydrologic Analysis					
Assess Local Runoff of Proposed Design	0	5	12	12	10
Low Impact Development					
Propose LID Design Alternatives	2	12	20	25	18
Client Communications					
Clint Meetings					
Client Meeting # 1	2	3	3	0	2
Client Meeting # 2	2	3	3	0	2
Client Meeting # 3	2	3	3	0	2
Client Meeting # 4	2	3	3	0	2
Review Client's Comments	3	4	4	6	4
Technical Advisor Communications					
Technical Advisor Meetings	2	3	4	3	3
Technical Advisor Meeting #1	2	3	4	3	3
Technical Advisor Meeting #2	2	3	4	3	3
Technical Advisor Meeting #3	2	3	4	3	3
Technical Advisor Meeting #4	3	2	4	3	4
Review Technical Advisor 's Comments	8	3	4	5	1
Budget Management					
Log Billable Hours	6	6	6	6	6
Compare Estimated cost to actual costs	6	6	9	6	5
Project Submittals					
50% Final Report	12	13	13	5	11
100% Final Report	12	10	10	5	7
Developed Website	5	10	10	5	7
Final Presentation	12	18	18	5	12
Broader Impacts Analysis					
Assess Impacts	6	6	5	0	4
TOTAL	**96**	**152**	**249**	**221**	**239**

4.3 COST ESTIMATION

In Table 4.3.1 below the billing rate for each staffing position is shown. This was calculated by taking the base pay rate, benefits, overtime, and profit into account. The rate used for base pay amounts was taken from an online source for engineering pay scales [15]. The benefits percentage was added to the base pay to calculate the actual pay, and the overhead was estimated based off known overhead amounts. The profit was assumed 10% of the actual pay.

Table 4.3.1: Billing Rate Calculation

Classification	Base Pay Rate $/hr	Benefits % of Base Pay Rate	Actual Pay $/hr	OH % of Base Pay	Actual Pay + OH $/hr	Profit % of Actual Pay	Billing Rate $/hr
Project Manager	65	30%	84.5	70%	143.65	10%	158
Project Engineer	40	55%	62	15%	71.3	10%	78
Engineer in Training	35	40%	49	15%	56.35	10%	62
Lab Technican	40	55%	62	10%	68.2	10%	75
Intern Engineer	18	0%	18	10%	19.8	10%	22

Table 4.3.2 summarizes the multipliers used for each different staffing position that will contribute to this project.

Table 4.3.2: Staff Multipliers

Classification	Base Pay Rate $/hr	Billing Rate $/hr	Multiplier
Project Manager	60	158	2.63
Project Engineer	40	78	1.96
Engineer in Training	30	62	2.07
Lab Technican	30	75	2.50
Intern Engineer	25	22	0.87

Table 4.3.3 shows the breakdown of cost by staff personnel, and Table 4.3.4 below shows the overall cost that this project is estimated to be worth. The hours of each different staff person were multiplied by their individual pay rate to calculate overall salaries. The salaries were then summed, with the addition of travel and equipment costs to find the total. It is shown that the total project cost came out to be $66,015.

Table 4.3.3: Breakdown Cost per Task per Staff Member

Task	Project Manager Cost ($)	Project Engineer Cost ($)	Engineer in Training Cost ($)	Laboratory Technician Cost ($)	Intern Cost ($)
Field Assessment	640	880	1380	1275	800
Design Enhancement Alternatives	160	3120	6900	10950	2360
Project Management	13280	7680	6360	4350	1540
Impact Analysis	960	480	300	0	80
TOTAL COST	**15040**	**12160**	**14940**	**16575**	**4780**

Table 4.3.4: Overall Cost

Personnel	Classification	Hours	Rate ($/hr)	Cost
	Project Manager	94	160	$15,040
	Project Engineer	152	80	$12,160
	Engineer-in-Training	249	60	$14,940
	Lab Technician	221	75	$16,575
	Intern	239	20	$4,780
	Total personnel			$63,495
Travel	6 meetings×50 miles/meeting		$0.40/mi	$120
Surveying		16	$150	$2,400
TOTAL				**$66,015**

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