Final Design Report:

Missouri Creek & North Clear Creek Stream Restoration and Wildfire Prevention

Stream Team: Group 33

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I. Executive Summary

The Clear Creek River and its tributaries are the primary drinking water supply for many towns and communities, serving almost 350,000 residents of Colorado. Some of the critical areas for recreation, cultural and historical values, and transportation also occur in the forested areas of this watershed. When there are healthy stream corridors in post-wildfire scenarios, there is protection given to the overall stream system and the infrastructure surrounding it. In the spring semester and into the first weeks of the fall semester, Stream Team conducted preliminary field assessments with water quality and field data collection. This last semester will focus on designing a stream channel restoration project on Missouri Creek—a tributary to North Clear Creek.

Since the beginning of the project, five site visits have occurred where water quality data—such as turbidity, temperature, pH, conductivity, dissolved oxygen, and heavy metals—were collected, soil samples were taken along three different reaches around the river, and Civil3D designs were started. There has been water quality data collected in the spring, summer, and fall, allowing accurate comparisons to occur over the course of this class. In the spring visit, at the end of April of 2022, it was found that the upstream site had excess iron according to Colorado Department of Public Health and Environmental's (CDPHE) chronic health standard for aquatic life. In the summer visit during July of 2022, the turbidity was over the CDPHE's acceptable threshold by a ten-fold magnitude. The turbidity was also found to be over limits in September for all three tested sites which included the upstream, downstream, and pooling area. At the fourth site visit, the team tested the soil for the first time and took water quality samples at the pool that was discovered at the July visit. Measurements from the pool found that the dissolved oxygen, total phosphorous, and total and dissolved iron were well over the allotted limit for aquatic life. At the final site visit, a new soil control was taken above the culverts and GPS coordinates were obtained at the culverts to assist in further design.

The furthest most upstream and downstream points along the Pickle Gulch Campground Road/ Missouri Gulch Road have had soil testing completed, as well as a point in the middle of those two sites, around a pooling pond. This pooling pond had a pH of 5.8, a dissolved oxygen reading of 1.2 mg/L, and a yellow-orange hue. These combined factors indicate a mostly uninhabitable pond, and Stream Team can conclude there are high levels of heavy metals present as well.

Over the past two months, the team has completed the final Civil3D modeling that shows the desired serpentine lateral movement of Missouri Creek. Furthermore, the designs for the culvert outlets have been finalized. Cost analysis of final designs determined which solutions are most practical for each section of the creek. After this data is interpreted by Clients and future workers, further stream restoration processes can begin to take shape regarding natural treatments and sediment filtering systems in the river.

II. Design Narrative

Introduction

This stretch of Missouri Creek is located along Missouri Gulch Road. There were previous instances of dredging and mining around this creek, which are present in big out-of-place hills near the river—sometimes within a few feet of the stream bank. Stream Team has also noticed the bottom two-thirds of the creek have high-density forestry surrounding the river. These trees and bushes make parts of the creek un-walkable, and dead wood litters the area outside and inside the riverbed. These combined factors make for a vulnerable river because of the high probability of pollution with heavy metals, and very little protection against forest fires.

Goals & Deliverables Statement

For the first semester of this project, the team consulted with Kerry Major and Lauren Duncan, who are affiliated with the City of Golden and Trout Unlimited respectively. Using the expertise and resources of the clients and technical advisors, the team identified potential locations and methods to restore sections of the Missouri Creek sub-basin. The potential problems looked at include flood risks, wildfire risks, and water quality analysis. To identify such problems, Stream Team conducted four site visits throughout the spring and fall semesters. Stream Team collected data on mechanical stream characteristics, soil quality data, and water quality parameters (heavy metals, pH, stream slopes, stream classification, etc.). The clients have requested a 50% design of this solution completed by the end of the fall 2022 semester, which includes a preliminary set of drawings that can be included in a grant application and possibly given as an outline to construction contractors. The requested 50% design encompasses this drawing set as well as material suggestions and structural specs.

Types of Wildfire Treatment

One of the key issues that the Stream Team will address during this project is wildfire mitigation and treatment. Wildfire treatment can come in multiple forms and there are many techniques that can be used to mitigate wildfire vulnerability. This may include stream health restoration but is more clearly known by methods such as hand thinning, mechanical thinning, and mastication.
A potential wildfire treatment could be hand thinning. With hand thinning, small-diameter trees are removed by using a chainsaw. The benefits of implementing hand thinning could include an improved habitat, a reduction in forest density, and reduced wildfire hazards [1]. For our project, this method may be attractive since it is not too expensive or dangerous; and can be easy to implement.

Mechanical thinning is another option to consider. With mechanical thinning, heaving equipment is used to reduce tree densities. This method can be more helpful than using hand thinning because with mechanical thinning it is possible to reduce any size tree density at a quicker rate. Other benefits of mechanical thinning can include an improved habitat [1]. A disadvantage is getting the required equipment into a high-density forest.

Types of Stream Restoration

Stream rehabilitation is one of the largest ways to protect an area from wildfire. One of the largest concerns when considering the deterioration of streams is how they are impacted by erosion. Stream banks can be stabilized and protected through the use of vegetation, which then holds bank soil together. Increased vegetation can also increase overall stream health. Beyond decreasing the suspended sediment, herbaceous vegetation can work as a filter for contaminants as well as a habitat for organisms. One study that quantified the impact of riparian vegetation on streambank stability found that vulnerability to erosion is significantly decreased as more vegetation is rooted in the bank [2].

Bank restoration is a necessary component to examine when looking at stream health. The deterioration of streams leads to an unbalanced ecosystem and an increase of sediment and other materials in the water. One course of action to amend these issues is to use reclaimed biomass to rebuild the stream where the most restoration is required. An example of this is using dead trees from the site to build a structure that is like a beaver dam. This allows the stream to naturally begin to rebuild itself and keeps larger sediments from impacting the stream's ecosystem.

Proposed Solutions

For this project, Stream Team has a few main proposed solutions to both the water and soil quality issues, as well as the wildfire prevention methods. This area is in an area of low flood risk based on the FEMA Floodplain Management system (Appendix 1A), which makes it unlikely to flood along the reach. That opens possibilities for making the river more serpentine at select locations. One of the selected locations is near the pooling pond halfway down the reach, where Missouri Creek is due east.

This pooling pond is currently heavily polluted with iron (3960 ug/L) with extremely low dissolved oxygen (1.27 mg/L) based on the water quality data. The soil quality data revealed pollution with aluminum (0.406 mg/L), copper (0.0152 mg/L), and phosphorous (0.8256 mg/L). This requires dredging of the soil and sludge inside it to start the remediation process. Dredging is also required of the soil in between the creek and the pond, as there is an old, large mine waste pile contaminated with many different heavy metals that flow into the pooling pond whenever a storm event occurs. While this dredging occurs, wattles with stakes should be placed along the creek to reduce the contaminated sediment flowing into the river. Once these two things occur, Missouri Creek can be laterally moved closer to the pooling pond. The flowing water will increase the dissolved oxygen content, help filter out pollutants, and create a mating area for fish.

Overall, the Missouri Creek river needs to be less obstructed (Figure 1). Another proposed solution would be to take the dead logs perpendicular to the river and put them on the side of the stream bank (Appendix 2A). This would also help reinforce the bank so less erosion occurs, and less sediment gets deposited into the creek. Missouri Creek and North Clear Creek also need to be deepened for trout to prosper more [3]. The first step to this process would be to remove dead, obstructive, plants and wood material from the river and then reinforce the side of the stream bank with that matter. After this occurs, there would a higher flowrate in the creek to wash excess sediment or rocky materials downstream or towards the side of the creek. A more invasive next step would be to widen the river, which would be completed before reinforcing the bank with trees and logs [4]. This widening of the river should be completed after monitoring the river for a season and determining that the natural flowrate of the creek is not sufficient to increase the river height. Stream Team recommends that clearing out the river takes place over the length of the reach, and the widening processes can occur in segments upstream if necessary.

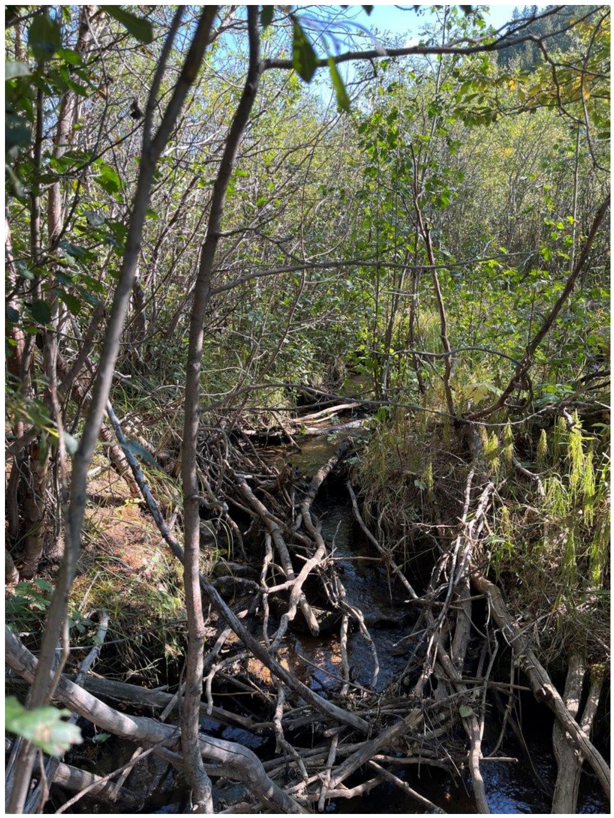


Figure 1. Missouri Creek obstructed with dense trees

To help reduce wildfire risk, hand-clearing is prescribed for the length of the river, and within 50 feet of the edge of the banks. As discussed earlier, hand-clearing reduces forest density while minimizing invasive procedures to the forest [1]. The cut trees can be used as material for stabilizing the stream sides, which reduces unnecessary waste. Stream Team is currently working on solutions to excess hand-thinning waste and where that material could be reimplemented into the forest. With less forest density, fires cannot burn as fast and destructively, and this helps protect the creek from excessive soot and deposited ash.

One radical method to achieve less density surrounding this reach of Missouri creek would be the removal of 65-80% of trees. The primary tree habitats in the area are Lodgepole pine trees, mixed conifers, and Aspens. Lodgepole pines are somewhat problematic in this area due to their dense-growing patterns, thin bark vulnerable to fire, shallow root systems, and relatively fast rate of growth [2]. As a species, they rely on fire to thin their forests [2]. This thinning could be achieved by copious hand thinning or through strategic and careful mechanical thinning. By selectively thinning many Lodgepole pines and preserving mixed conifers and Aspens the fire resilience of the area can be increased significantly.

To achieve this goal, it was recommended by Nate Goeckner, a member of the Boulder Watershed Collective, to follow the steps outlined below:

1) Delineate the areas of operable slope and terrain.
2) Delineate the bounds of treatment.
3) Break area into habitats based on tree population:
    a. Mixed Conifers (Ponderosa, Spruce, Limber pines)
    b. Lodgepole stands
    c. Aspen forests
4) Plan the elimination of 65-80% of stem density in patch cuts, prioritizing >5” diameter Lodgepoles, Mixed Conifers, and Aspens.

To implement this suggestion in the Missouri creek project it may be necessary to use a less drastic or scaled-down version. Currently, this would mean using a different bound of treatment than was first intended. This area of focus would be the same as mentioned above—within 50 feet of the stream edge.

For the excess hand-thinned trees that will not be used for stream bank stabilization, wood chippings will be scattered around the forest floor within 50ft of the river. There are many researched positives and negatives to this design, outlined in Table 1 below.

Table 1. Advantages and implications to spreading wood chippings onto the forest floor

Advantages	Implications
• Make trails to the creek	• Increased acidification
• There is less waste to be transported	• Expensive to transport the vegetation
• Decrease excess nitrogen in water	• There will be a lot of chippings
• Chipping yard in Gilpin County	

This stretch of Missouri Creek will generate a significant amount of wood after the hand thinning, more than what is needed to stabilize the bank. The team looked at what could be done with the chippings following the removal. It was discovered that wood chippings tend to lower the pH of the soils they are deposited on. Since the soil at the site ranges from 5-6, adding the chippings would lower the pH even more. This increased acidity could decrease the nutrients found in the area and lead to toxic elements having a greater impact [5]. It would also be very costly to get the trucks and equipment up to chip the wood on site, not to mention that if only 50ft of the bank had the chippings there would still be an excessive amount to transport off the site.

However, the wood chippings could also be used to create trails at the site that could be utilized by campers and school children. This would allow the creek to be used for recreational activities in the future and for the restoration project to be enjoyed by all. The use of wood chippings to create trails would also decrease the number of chippings that need to be transported off the site, lowering the costs associated with hand-thinning. In the case of extra wood not being used at

Missouri Gulch, Gilpin County has a chipping yard. This would be a close location to utilize chipping off-site, not to mention the fact that the county holds chipping days where it would be free to chip the wood [6]. It was also pointed out to the team that Gilpin County may use the chippings to heat a utility building. If this were the case, all excess chippings would be put to use and would not have to be transported outside of the immediate area. The chippings could also be handed out to private residences for heating homes.

At the upstream part of the creek, there are outlet culverts that are caved-in and need replacement (Figure 2 and Figure 3). These calculations are still a work in progress, but drawings of what the updated culvert pipes should look like are shown in Appendix 3A. The team is also looking into who owns the rights to the culvert replacement since they are on the boundary between the Forest Service and Gilpin County. At the last site visit, a sign was discovered that indicated the Forest Service owned the land upstream of the pooling pond. It would be necessary to reach out and confirm before replacement occurs.

Figure 2 & Figure 3. Current culverts at the upstream section of Missouri Creek off Missouri Creek Road

III. Path Forward, Risk Mitigation, Detailed Design Critique

Path Forward

In the next three months, Stream Team will take the data from the four site visits and use them to finish the analysis needed to determine the water quality of the creek, areas of the creek that need to be deepened, areas near the creek that need to have some form of deforestation, and where and how much of the creek bed should be raised. Using the data, Stream Team will also determine if it is feasible to use reclaimed biomass from the site for stream restoration practices. Once this data has been collected and analyzed, Stream Team will use this data to design a stream channel restoration plan. Within this design, drawings and other documents will be made to Kerry and Lauren detailing what needs to be done to the stream in a clear and precise manner. Calculations and justifications will also be made to explain why the design was made the way it was. During this design phase, the Stream Team will regularly check in with their clients, the City of Golden and Trout Unlimited, providing updates and receiving client feedback (Table 2).

Table 2. Client Needs

#	*Date Added*	*Demand/ Wish*	*Need Statement*
1	2/15/22	50% drawings	The drawings can be given to a contractor and be able to start building from the given drawing set
2	2/15/22	Field Data	Gathering of sufficient field data for further stream restoration and wildfire mitigation analysis
3	2/15/22	2-3 Project Ideas	A few main ideas will help establish what the best course of action is
4	3/10/22	PDR	Concept exploration/selection, readying for next semester
5	4/29/22	1st Site Visit	Flow measurements, data collection, familiarize team with area
6	5/12/22	Presentation	May 12th presentation to Clients and Blackhawk stakeholders, site visit with stakeholders
7	7/28/22	3rd Site Visit	Water quality collection, flow measurements
8	9/8/22	4th Site Visit	Soil quality data collection, water quality data collection
9	10/4/22	Intermediate Design Review	Show clients intermediate drawings and proposed solutions, solicit feedback, and prepare for final design review on November 29
10	10/4/22	Community Engagement	Engage with stakeholders about the Pickle Gulch Campground & human recreational requirements of the design
11	11/17/22	BLM Soil Levels	Human health standards for the soil at Missouri Creek can be used to gain further support for the project

Water quality analysis was completed through the City of Golden's laboratory methodologies, and soil quality testing was done with the CDMG methodology through the Colorado School of Mines' laboratory. A fifth and final site visit occurred on October 20th to conduct forestry measurements and calculations. This allowed Stream Team to predict more implications around wildfire prevention through forest thinning. At the October site visit, GPS coordinated were taken next to the culverts and a second soil control was taken.

Stream Team is also planning to obtain more stakeholder feedback. This would include engaging with the city of Black Hawk about the project and considering how the design could affect recreational activity near the stream. This stakeholder feedback may include taking surveys of campers near the site and holding a community meeting for the citizens of Gilpin County in 2023.

These meetings and surveys may change some aspects of the design and recommendations going forward.

Risk Assessment

Stream Team acknowledges that undertaking any engineering task may lead to impacts that were not originally intended or were unthought of when the design was first introduced. Therefore, the team will look at societal risks, safety risks, and technical risks to ensure that the final design will be ready for implementation. For a restoration site project, the best analysis tool was found to be an ecological risk assessment (ERA). Since the stream is near a campground and many people will use that area for recreation, a human health risk assessment will also be conducted. ERA consists of three main parts, problem formulation, analysis, and risk characterization [5]. The bulk of the risk assessment will focus on these three steps, but risks that were not easily assessed under this format will also be analyzed. A human health risk assessment will focus on four steps which include hazard identification, dose-response assessment, exposure assessment, and risk characterization.

The most pertinent ecological risks discovered at the site were the high amounts of iron found in the water, the mine waste piles, and the high turbidity levels. These risks all pertain to the health of the aquatic life that the team is hoping to create habitats for with the restoration of the stream. Other risks that were observed were the water rights of the people below the site since the final design may impact flow, the financial risks of insufficient cost allocation, and a potential technical failure of the culverts.

Mitigating the risks discussed above is a crucial part of the group's tasks this semester and in creating the final design. There is a risk of the pool’s water quality contaminating the rest of the stream if the stream is redirected through the radical lateral movement of the streambed. To reduce this risk, the team proposes dredging the pool before the stream’s path is changed. The mine waste piles on the site from previous mining activity could pose a more constant risk. While the piles did not have high levels of iron, they did have high levels of aluminum, copper, and phosphorous that could leach into the soil and contaminate the site. To mitigate that risk the team recommends more dredging and further observation to be aware of any drastic changes to the quality of the mine waste piles. Since the team’s proposed design solutions only seek to increase the flow in the stream it is not expected that water rights will pose an impactful risk. When the new culvert is constructed, the flow could be affected, and communicating with stakeholders during that time will be crucial to avoid legal issues. The risk of not enough funds being allocated to the project can be mitigated by stakeholder engagement that encourages community involvement. With increased support comes increased funding for the final designs in Missouri Creek. Further cost issues can be avoided by following the project budget and communicating with project leads if spending is significantly higher than planned.

Stream Team created a risk rating to easily describe the major risks that may occur in the restoration of Missouri Creek (Table 3). The most impactful risks to the site were given a ranking on a scale of one to five, with five representing the greatest risk.

Table 3. Major risks and mitigation action plans

Risks	Rating	Mitigation
Mine Waste Piles	3	Observations and further dredging
High Turbidity	4	Bank stabilization
Iron Levels	5	Dredging of the pooling pond
Water Rights	4	Stakeholder engagement
Culvert Failure	3	Multiple design reviews and thorough testing
Insufficient Cost Allocation	2	Public awareness to increase funds

An ecological risk assessment was used since it allowed risk analysis on the most crucial parts of the project. Step one of an ERA deals with problem formulation. Risk assessors and stakeholders get together to determine what is occurring at the site and how human actions will impact it. For example, frequency, toxicity, and intensity are a few characteristics that may be examined at each potential risk site. If one risk is continuous while another occurs only once, it would be more important to target the continuous risk first. Another key aspect of problem formulation is the assessment endpoint. An assessment endpoint identifies what in the environment needs to be protected and why that species or ecosystem needs to be protected [6]. This allows the risk assessors to stay on the necessary analysis plan.

The risk assessors are the key people in the analysis step of the ERA and their main tasks are to create an exposure profile and stressor response profile. The exposure profile will detail how likely it is for the risk to occur and where and why it will happen. While the stressor response profile uses gathered data to summarize the effects of the stressor. Both will be combined to move on to the final step of the ERA. In the end, the risk characterization is performed which details uncertainties and allows the necessary conclusions to be drawn.

An ERA was ideal for the project since ecological concerns are the main issue at Missouri Gulch. The tool has few limitations since it looks at countless parts of the project and focuses on the ecological issues that are occurring and why they need to be prevented. The tool does not account for financial issues or property rights issues. However, these are risks that can be evaluated without the tool. The team has accepted that multiple risk assessments may have to be performed to better prepare the final outcomes of this project.

For the human risk assessment, the biggest risks discovered at the site were tripping and falling hazards, isolated areas, severe weather conditions, dangerous animal encounters, and undrinkable water conditions within the stream. All these risks could potentially harm the people and campers who use this area for recreational purposes.

It is of the highest priority to create the safest environment for the humans that will use this area for recreational purposes. The risk of tripping and falling throughout the site already exists and future development could increase those risks. To reduce the risks of tripping and falling, Stream Team proposes moving dead vegetation and tree limbs and putting up signs that alert campers of the risks of falling and tripping. This may impact how potential tree thinning will be carried out since it could add more risks to tripping and falling. This may mean that when tree thinning is carried out, there will be a procedure in place to make sure that the results of the tree thinning do not increase this risk.

Due to the location of this site being in the mountains of Blackhawk, there are potential scenarios where someone could get lost and not be able to contact another person. To reduce this risk, the team suggests putting up some maps near the stream and advising future campers to bring their cell phones with them or travel with friends. The location of the site tends to have severe weather, especially during the winter. This severe weather can pose potential threats to future campers through extreme cold and being stuck in snowy conditions. To minimize these risks, the team suggests having that area closed off during severe weather conditions, and informing future campers about the risks, potentially through signages.

The site area is also at a higher risk for animal encounters. Bears and other aggressive animals are known to be seen around the site. To reduce the risks of future campers being attacked by animals, it is suggested that the site has signs warning campers of the risks and encouraging campers to travel with friends and take equipment that could help save their lives, such as bear spray.

After conducting water quality tests and observation of the stream, it is apparent that the water in the stream is not of drinking quality, Future campers and stakeholders who will use the site could be at risk from drinking the river water. Drinking untreated water can lead to sickness or death. To reduce this risk, the team will propose putting up signs telling campers that the water is not of drinking quality.

Stream Team also created a risk rating table (Table 4) describing the major risks posed to human health. This is also ranked on a scale going from one to five with five having the most negative impactful risk.

Table 4. Major human health risks and mitigation action plans

Risks	Rating	Mitigation
Tripping and falling	4	Clearing out dead vegetation and limbs, warning signs
Isolated areas	4	Warning signs, encouraging people to travel together
Severe weather conditions	3	Closing the site during a storm
Aggressive animals	2	Stakeholder engagement
Poor water quality	3	Multiple design reviews and thorough testing

The human health risk assessment through the EPA was used since it was the best way to assess the potential human health risks that are present at the site that could be impacted by future design and development. The first step of the human health risk assessment is hazard identification. The goal of hazard identification is to identify adverse health risks that could occur from a site's exposure [7]. This could include exposure to chemical or physical risks. This hazard identification also analyzes how likely an adverse event will occur and how severe that event could be.

The second step in a human health risk assessment is the dose-response. A dose-response assessment will analyze and describe the likelihood and severity of health effects given a certain amount of exposure to the risk being assessed [7]. Typically, the more a person is exposed to a risk the more likely an adverse health effect will occur. This dose-response assessment looks at a human's exposure to harmful chemicals, but can also be used in assessing physical risks like animal attacks.

The third step in a human health risk assessment is conducting an exposure assessment. This assessment looks at how much risk people are exposed to during a specific time and how many people will be exposed to that risk. Like the dose-response assessment, this assessment is typically used for chemical risks and pollutants, but this model can also be used for physical risks [7].

The last step for a human health risk assessment is the risk characterization assessment. The risk characterization assessment conveys whether a risk is present or not. It is broken into two major components, risk estimation, and risk description. Risk estimation compares the estimated exposure level for each stressor and community [7]. Risk description provides information about how to interpret the risk result.

Team Safety

The safety of the team is of the highest priority when working on the site. A hazard assessment and safety plan have been performed and are shown in Appendix 4A.

IV. Engineering Calculations and Analysis

The team took four soil samples at the September 8th site visit (Table 5). The control sample was taken off the Pickle Gulch campground and the side of the road. Due to the high levels found in the initial control sample, the team went back to the site and took a different control. The first “control” sample was found to be a source of contamination for the site and is labeled Upstream 1 (Table 5). Differing heavy metals were compared to the Environmental Protection Agency’s (EPA) and the Colorado Department of Public Health’s (CDPHE) acutely or chronically toxic levels to aquatic life. To exceed the acute measurement means that the toxicity is immediately affecting the health of the aquatic life, and to exceed the chronic measurement means that long-term exposure would negatively impact the health of the aquatic life.

Table 5. Soil quality data & what standards they exceed

Location	Aluminum	Copper	Chromium	Iron	Nickel	Phosphorous
Control	EPA Chronic	CDPHE Acute	--	--	EPA Chronic	CDPHE Chronic
Upstream 1	EPA Acute	CDPHE Acute	EPA Chronic	EPA Acute	EPA Chronic	CDPHE Chronic
Upstream 2	EPA Chronic	CDPHE Acute	---	---	---	CDPHE Chronic
Downstream	EPA and CDPHE Chronic	CDPHE Acute	---	---	---	CDPHE Chronic

Pooling Pond	EPA and CDPHE Chronic	CDPHE Acute	---	---	---	CDPHE Chronic

Based on these soil testing results, Stream Team calculated the loading rate per year of Aluminum (Al), Copper (Cu), and Phosphorous (P):

$$flowrate = velocity\ x\ area \qquad \text{(Equation 1)}$$

$$flowrate\ of\ Missouri\ Creek = 0.0116\ fps\ x\ 4ft\ x\ 0.41667\ ft = 1670.4\ \frac{ft^3}{day}$$

$$loading\ rate\ of\ contaminants = concentration\ x\ flowrate \qquad \text{(Equation 2)}$$

$$\text{Aluminum loading} = 14.2629\ \frac{mg}{ft^3}\ x\ 1670.4\ \frac{ft^3}{day}\ x\ \frac{kg}{10^6\ mg} x \frac{365\ days}{year} = \mathbf{8.6960}\ \frac{\boldsymbol{kg}}{\boldsymbol{year}}$$

$$\text{Copper loading} = 0.68465\ \frac{mg}{ft^3}\ x\ 1670.4\ \frac{ft^3}{day}\ x\ \frac{kg}{10^6\ mg} x \frac{365\ days}{year} = \mathbf{0.4174}\ \frac{\boldsymbol{kg}}{\boldsymbol{year}}$$

$$\text{Phosphorous loading} = 9.90735\ \frac{mg}{ft^3}\ x\ 1670.4\ \frac{ft^3}{day}\ x\ \frac{kg}{10^6\ mg} x \frac{365\ day}{year} = \mathbf{6.0404}\ \frac{\boldsymbol{kg}}{\boldsymbol{year}}$$

The loading rates were calculated from the soil concentration data because, in a storm event, that would be the amount of contaminant flowing into the river. Only Al, Cu, and P were analyzed because they were the only heavy metals present in the farthest downstream location along Missouri Creek's specified reach.

It is recommended that future soil testing be completed to compare the site to the BLM human health screening levels. Since the CDMG method was used by Stream team, the soil samples were mixed with water and the water quality was then tested for metals. This meant the soil results were presented in mg/L and they need to be in mg/kg for BLM screening. These standards can be found in Appendix 16A.

There were four water quality results that stood out to Stream Team as an issue on the September 8th site visit. The dissolved oxygen of the pooling pond was found to be 1.27 mg/L. The CDPHE standard for this section of the creek is 6 mg/L and fish spawning can only occur at 7 mg/L (Table 5). Other notable results in the pooling pond were turbidity readings of 17.4 NTU which is significantly higher than the standard for aquatic life at 3 NTU. Iron levels were found to be 3.96 mg/L which exceeds the 1 mg/L standard and phosphorous was 0.16 mg/L which exceeds the standard of 0.11 mg/L. These results all support the fact that the pooling pond needs to be dredged before Missouri Creek can be connected to it. The turbidity at all locations on Missouri Creek is higher than the acceptable standard (Table 6). Bank stabilization will help decrease the amount of erosion in the stream and provide future fish with a more stable habitat. Screenshots of the water quality results can be found in Appendix 11-15, and the entirety of the spreadsheets will be handed off with the final deliverables.

Table 6. Water quality results impacting stream health on September 8th

Location	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Total Fe (mg/L)	Total P (mg/L)
Upstream	7.47	4.53	0.315	ND
Downstream	7.61	3.51	0.231	ND
Pooling Pond	1.27	17.4	3.96	0.16

During the first site visit, the team identified five different reaches, upper, middle, lower, downstream, and pond locations. The lengths and flow categories for each reach are listed in Table 7. For flow categories, flow A refers to a stream with low sinuosity, relatively high slope, and steep banks causing a small floodplain. Flow B is similar to flow A but with slightly more sinuosity, a less extreme slope, and a wider floodplain. With an even wider floodplain, flow category C is ideal for pooling and a slower flow. This project seeks to widen the floodplain of this reach of the Missouri Gulch to have all portions of the stream fit into B or C categorization. This can be attained by clearing debris, widening floodplains, and adding sinuosity [8].

Table 7. Length and flow categorization by each reach of Missouri Creek

Reach	Length (ft)	Flow Category	Comments
Upper	230	B to C	Includes Culverts, some pooling
Middle	610	A	Interruption of flow
Pond	-	-	High interruption of flow, high iron levels, ~750 sqft
Downstream	135	B	Interruption of flow
Lower	240	A	Interruption of flow, lower O_2 levels

Stakeholder engagement is crucial when implementing any engineering project. It allows designers to stay on track with the project and achieve desired results. With the last two semesters of work, the following feedback was given, and the proper adjustments were made to keep the Missouri Creek restoration project moving forward (Table 8). The most notable actions the team took between the intermediate design review and the final design review were community engagement and a risk assessment for human recreation. These were completed in the hopes that the Forest Service will feel more engaged in the project since Missouri Creek lies on their property boundary.

Table 8. Stakeholder feedback and adjustments made

Project Stage	Description	Stakeholder Feedback	Adjustments Made
Letter of Intent	Defining the problem and developing ideas of solutions and their scope	N/A	N/A

Preliminary Design Report	Compiling research and preliminary decision making	More site visits, need to collect soil quality data & more water quality data	Planned site visits for April and May
Field Testing 1	First look at the site, deciding the reaches of focus for restoration, tested water for mechanical and chemical properties	Need to revisit site another 3 to 5 times to collect more data. Due to inclement weather the team was unable to collect all planned data	Needed to plan more site visits with water quality and benthics. Readjusted expectations of scope of work and river
Field Visit & Presentation to Blackhawk Community Council	Site exploration led to more concrete solution ideas and more testing	Continue to engage with community and water rights authority	N/A (left for summer break)
Letter of Reengagement	Reengaging with Clients after summer break: outline next steps and dates	N/A	N/A
Field Testing 3	Collect water quality data and benthics	The pool discovered should be included in solution designs	Next site visit, soil and water quality analysis of this pond will be included
Field Testing 4	Collect soil quality data and last water quality data	Heavy metals in soil. Culverts deformed can wash out nearby road. High iron in water.	Care needs to be taken when moving stream or soil due to pollution.
Intermediate Design Review	Intermediate design drawings, calculations, and client feedback	Need more community engagement. Figure out what to do with hand-thinned trees. Forest service and human recreation needs to be considered.	Risk assessment for human recreation needs to be completed for Forest Service. Community engagement is starting to be planned.

V. Preliminary Drawings

For the need of erosion and sediment control, sediment control logs are recommended anytime there is construction or disturbance near or on the stream. Typical details of sediment control logs are shown in Figure 4. In addition, a complete set of preliminary drawings can be found in the Appendix.

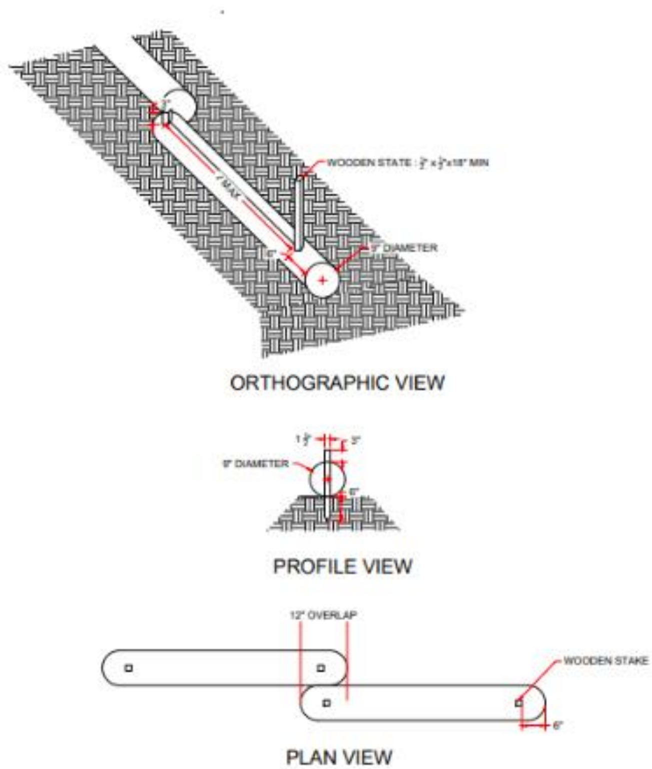


Figure 4. Sediment control log details

The current culvert at the very upstream part of the river in the section being analyzed has started to break down. The Stream Team believes that it is beneficial to replace the current culvert with a new galvanized steel culvert. Figure 5 shows the details of a potential replacement.

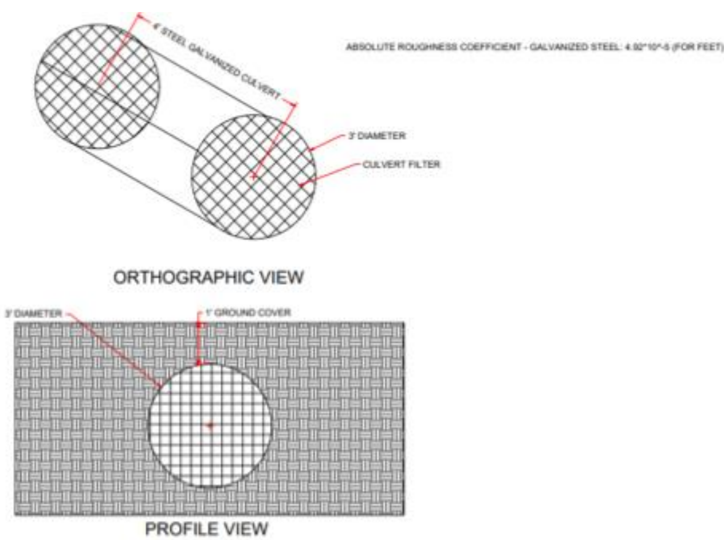


Figure 5. Galvanized steel culvert design

Getting the site laid out was validated by using a comparison of aerial photos and Lidar data, by the melding of the elevation data and photos of the given extrapolated surface (Figure 6). The site has three focus areas along the reach of the stream, the upstream, downstream, and pooling pond (Figure 7). The size of the site that the stream is part of is approximately 570 linear feet with an elevation change of 100 feet. The pooling pond has an approximate volume of 2 cubic yards and a water surface of 16 square yards. These areas will be the primary focus for the total a la carte for site remediations. Furthermore, the stream as a whole has some larger focus areas for moving the stream as part of the remediation (Figure 9). The path of the stream was chosen on by avoiding the mining waste piles to keep from disturbing them. The curves of the stream were set by locations from the topography that had close to the same slope and would allow for the stream to flow without interruption due to a large change in flow in the steam.

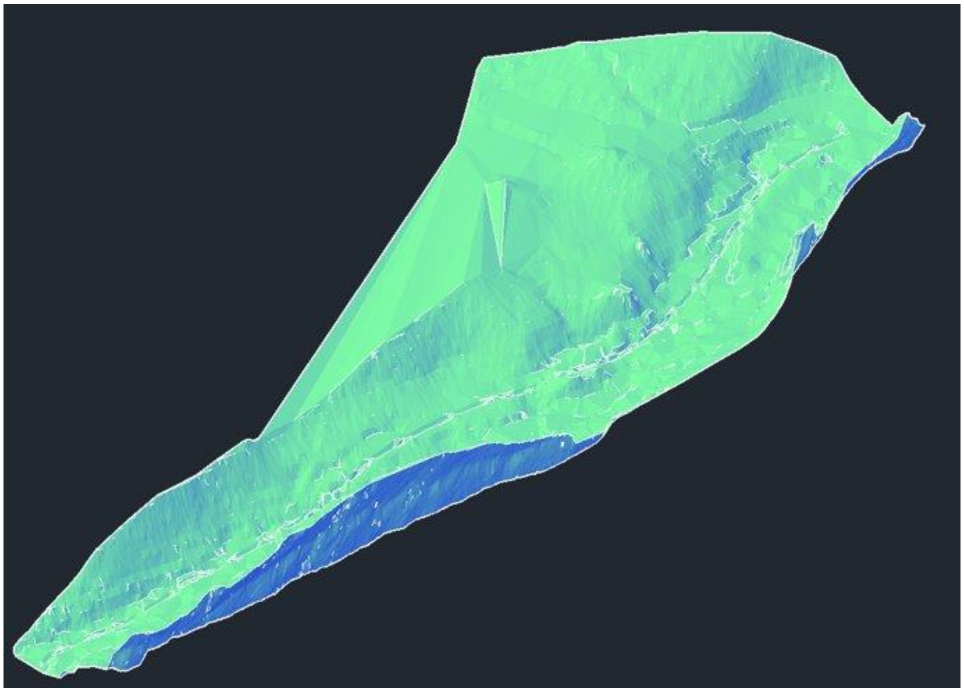


Figure 6. Site Computer Generated Surface

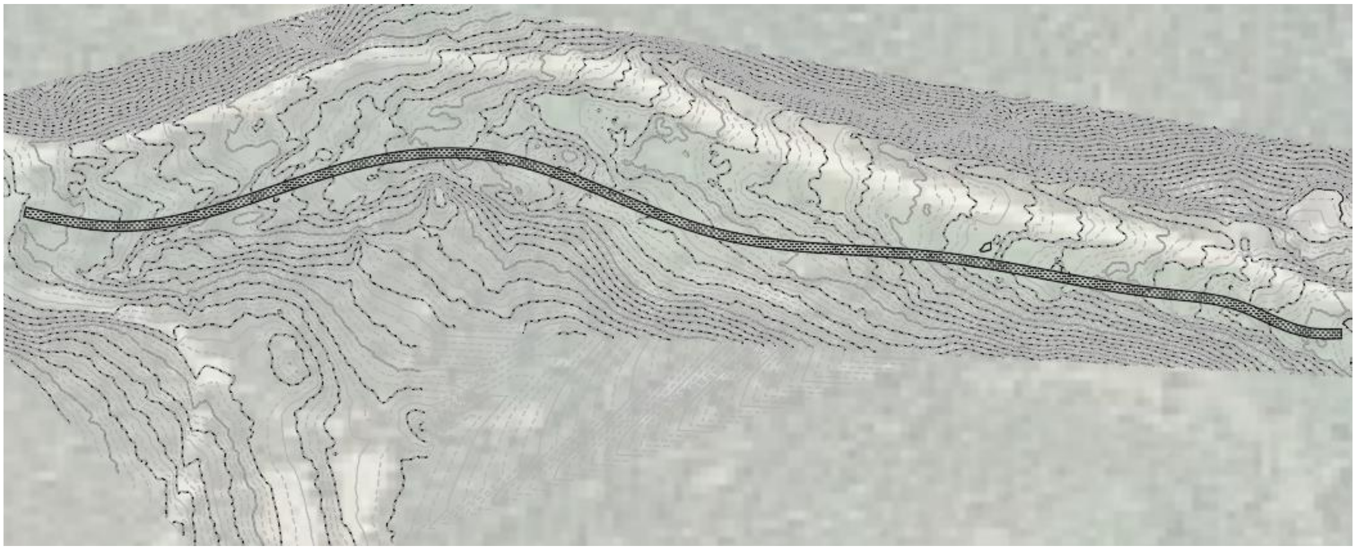


Figure 7. Existing Surface

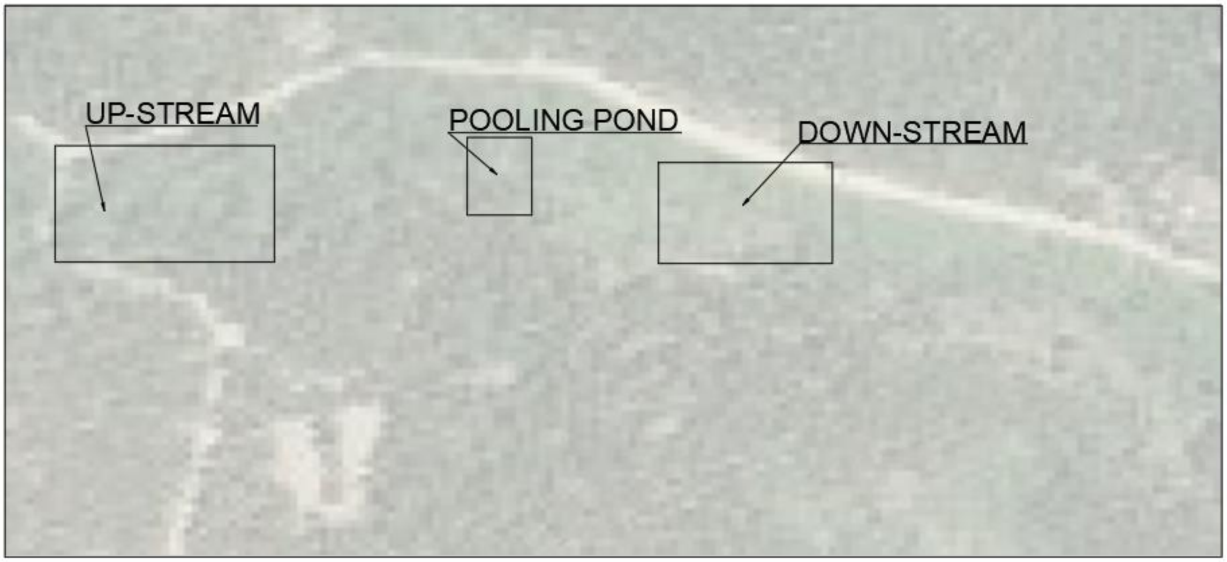


Figure 8. Site areas of focus

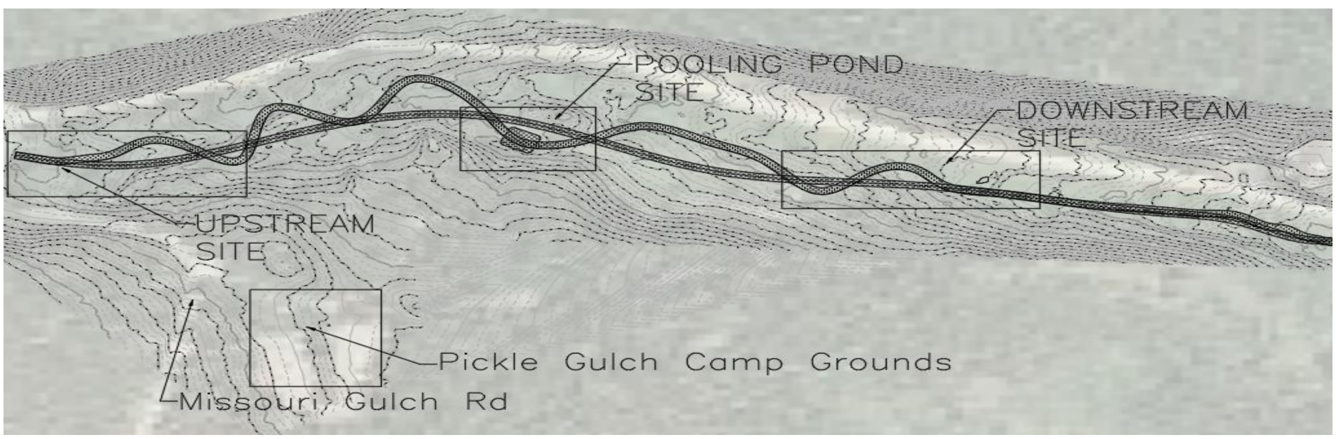


Figure 9. Stream existing & Proposed

VI. Project Management

Design Validation

In the making of this design, there was input and advice from many experts in their field. Lauren Duncan and Kerry Major—the Clients—were essential in water and soil quality research and remediation tactics. Through the City of Golden, Stream Team was able to conduct all water quality measurements, and the Colorado School of Mines conducted all soil quality measurements. Sam Zrust led the team in soil collection and water quality remediation. Community engagement was completed through the Blackhawk City Council: Diane Kietly and other board members guided Stream Team's work towards more community-based thinking. They gave contacts for different agencies to reach out to for clarification about land boundaries, regulations, and culverts, which helped the depth of the final design.

There were many helpful advisors throughout this design process. Yosef Allam and Scot Allen, Stream Team's project advisors (PAs), facilitated reviews and design work to help the team stay on track. The PAs were crucial in developing the creativity and technicality of Stream Team. Kate Spangler, the environmental lab technician for Colorado School of Mines, helped Stream Team interpret data and became an invaluable technical advisor. Jeffrey Holley, an AutoCAD expert from Colorado School of Mines, gave feedback and design clarifications for all Civil3D work completed and was another essential technical advisor for Steam Team. Nate Goeckner, a member of the Boulder Watershed Committee, assisted Stream Team in identifying and researching tree variations around Missouri Creek and how they affect wildfires.

Project Tasks and Scheduling

The Stream Team implemented sprint reviews every other week with their PA and Clients. This enabled the team to hold each other accountable for completing tasks to further the design process. Since there was inclement weather in the first semester, not allowing the team to visit the site until the end of April 2022, the first part of the second semester was heavily focused on site visits with water and soil analysis. Trello was the main tool used to keep the team on track while logging future and past work.

Luke Kimsey-Biglen of Stream Team was the main contact for budgeting. The City of Golden used $3,000 for three separate water quality analyses, and Stream Team used $282 of the allotted Colorado School of Mines budget for soil quality testing and the final poster print (Appendix 7A).

Lessons Learned & Next Steps

Throughout this senior design project, the Stream Team has learned a lot. We learned from our clients, our technical advisors, and from our mistakes. All the members of Stream Team have developed new skills and strategies they will take into their future careers. The process of having a preliminary, intermediate, and final design report allowed Stream Team to have a first look at how the design process in engineering is conducted. It also allowed the Stream Team to learn from our mistakes in each phase and how to address and fix those mistakes and/or updates. During the last two semesters, the Stream Team has developed better skills in how to work as a team. This includes better communication with each other, along with putting into place better ways of assigning specific tasks to each team member, and the expectations of when those tasks will be completed. One of the biggest lessons that the Stream Team learned was how valuable the skill of effectively communicating design specifications to stakeholders is. Being able to effectively communicate to a client or to a stakeholder the concepts and specifications of a proposed design is one of the most important skills an engineer can learn. Moving forward, the Stream Team members will reflect on the past two semesters, learn from mistakes, and implement the lessons learned for future projects and challenges.

For this project, the Stream Team has identified future work that would be beneficial beyond the final design report. This includes dredging the pooling pond and dredging the mine waste piles between the pond and the river. The Stream Team also suggests using hand-thinned trees to reinforce stream banks. Replacing outlet culvers near the Pickle Gulch Campground is also suggested. Future water quality tests and flowrate measurements within Missouri Creek would provide insight into how much the stream has been improved once the design recommendations have been put into place. Future stakeholder feedback around human recreation is also advised, as it could lead to a more human-friendly area. Since this final design report only contains 50% drawings, it is recommended that the continued work on the drawings is completed to at least 90%.

VII. Conclusion

Overall, there are many plans in place for stream remediation and wildfire prevention for Missouri Creek and North Clear Creek. As discussed in the design narrative, Stream Team suggests dredging the pooling pond and the old mine waste piles in between the creek and the pond, using hand-thinned trees in the stream bank stabilization, and maintenance of the outlet culverts near Pickle Gulch Campground Road. With these plans, 50% drawings have been given to the Client as well. The Final Design Report will be completed by December 1, 2022 and sent to the clients before the Showcase on the Colorado School of Mines' campus on December 1, 2022. As referenced in Appendix 7A, Stream Team has $290 remaining of funds to complete this work in a timely manner.

VIII. Works Cited

[1] Types of forest treatments, Northern Colorado Fireshed Collaborative, 2021.

[2] J. W. L. M. J. D. J. Kirchner, "Effects of Herbaceous Riparian Vegetation on Streambank Stability," 1998. [Online]. Available: https://escholarship.org/uc/item/70q7678r .

[3] Yoshi, "Do Trout Like Deep or Shallow Water?," Fast Cash Rods, 2019. [Online]. Available: https://fastcastrods.com/do-trout-like-deep-or-shallow-water/. [Accessed 19 January 2022].

[4] S. Nelson, "Stream and Drainage Systems," University of Tulane, 2015. [Online]. Available: https://www2.tulane.edu/~sanelson/eens1110/streams.htm . [Accessed 20 January 2022].

[5] P. M. Homyak, R. D. Yanai, D. A. Burns, R. D. Briggs, and R. H. Germain, "Nitrogen immobilization by wood-chip application: Protecting water quality in a northern hardwood forest," *Forest Ecology and Management*, vol. 255, no. 7, pp. 2589–2601, Apr. 2008, doi: 10.1016/j.foreco.2008.01.018.[Accessed 11 November 2022].

[6] "Community Chipping Days," *gilpincountysheriff*. https://www.gilpincountysheriff.com/community-chipping-days [accessed Nov. 11, 2022].

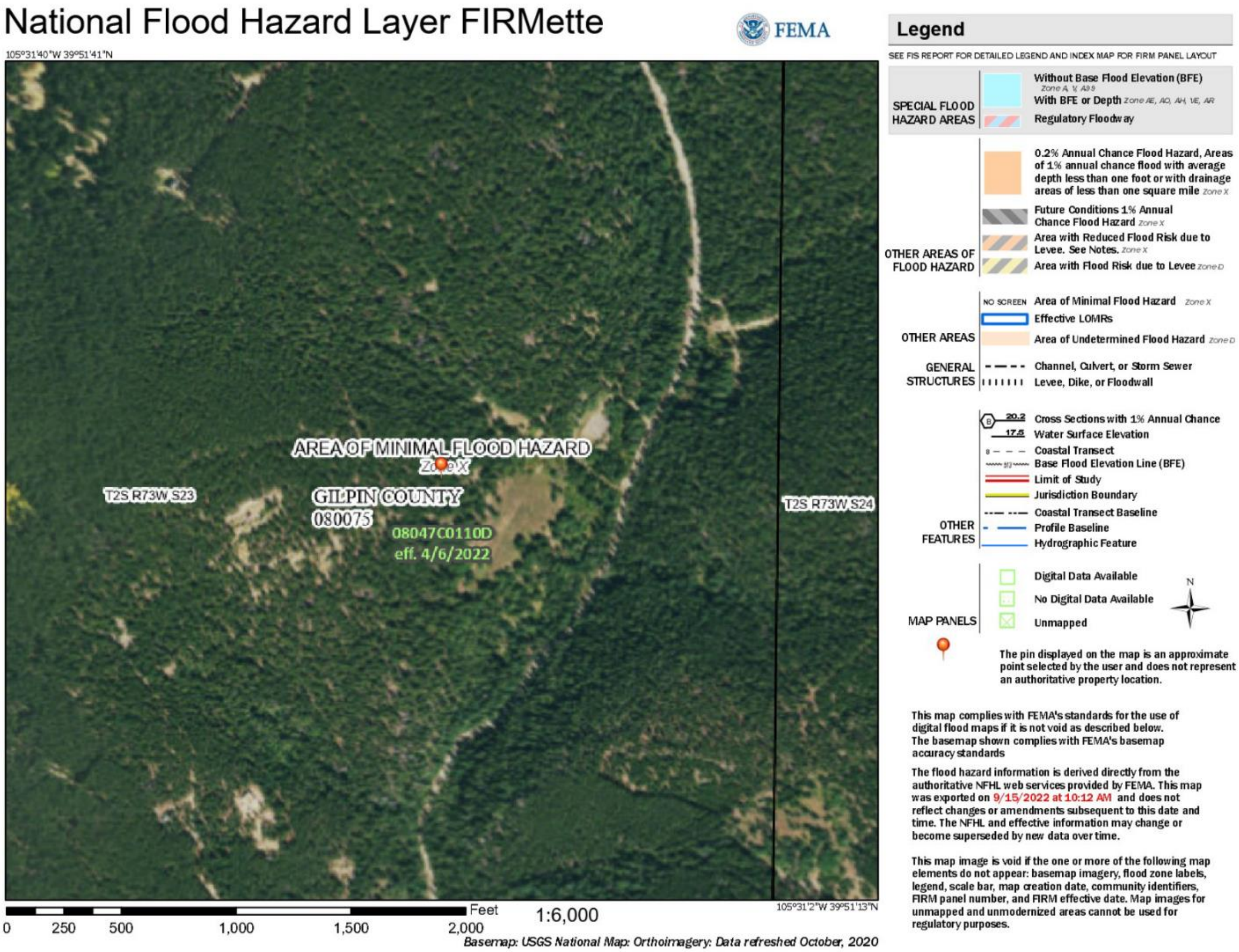
[7] "EPA EcoBox Phases of ERA," EPA, 2021. [Online]. Available: https://www.epa.gov/ecobox/epa-ecobox-phases-era . [Accessed 27 September 2022].

[8] "Phases of ERA – Analysis," EPA, 2021. [Online]. Available: https://www.epa.gov/ecobox/phases-era-analysis . [Accessed 27 September 2022].

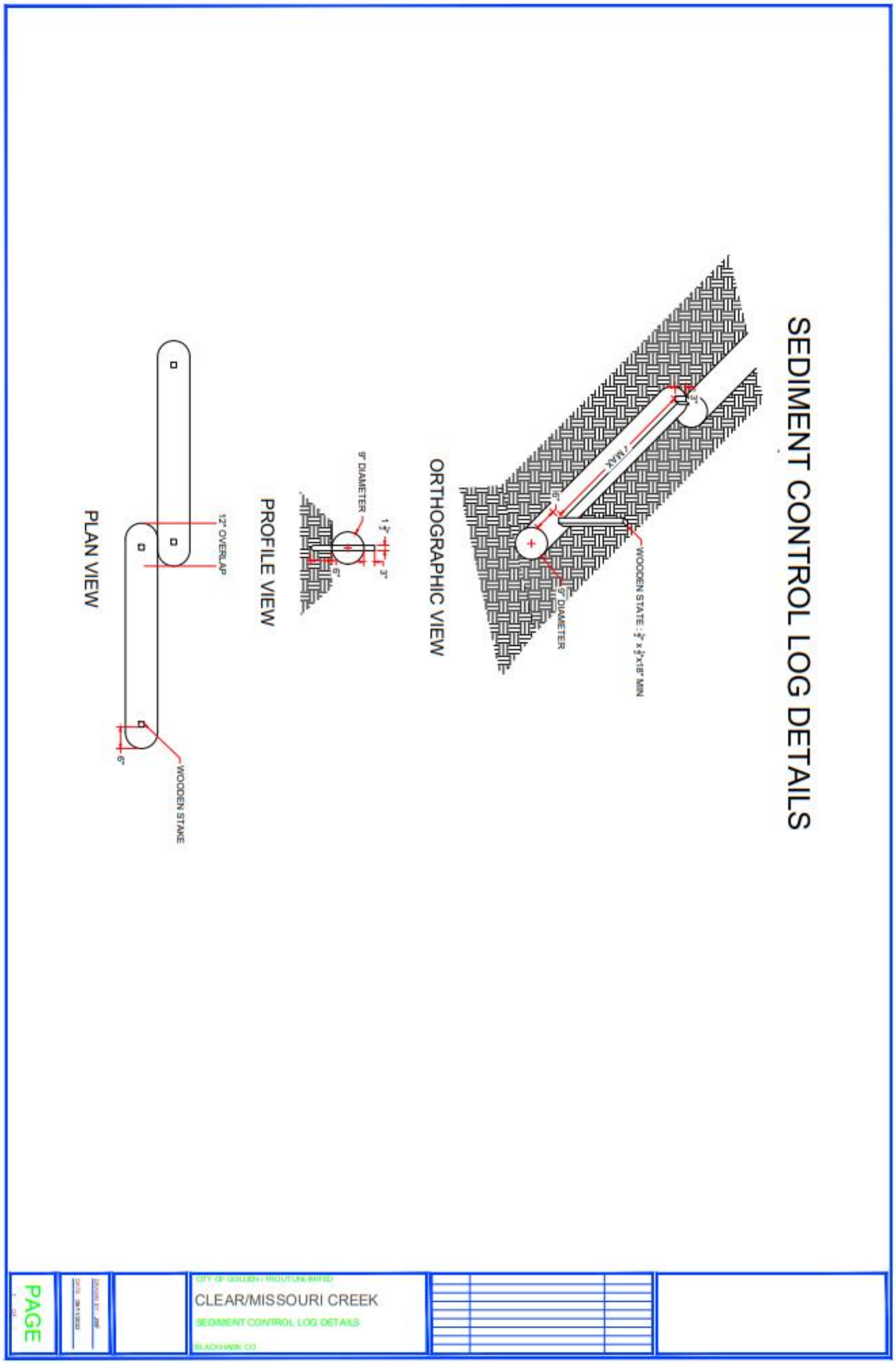
[9] "Human Health Risk Assessment," EPA, 2022. [Online]. Available: https://www.epa.gov/risk/human-health-risk-assessment. [Accessed 5 October 2022].

[10] D. Rosgen, *Applied River Morphology,* Pagosa Springs, CO, US: Wildland Hydrology, 1994. [Print].

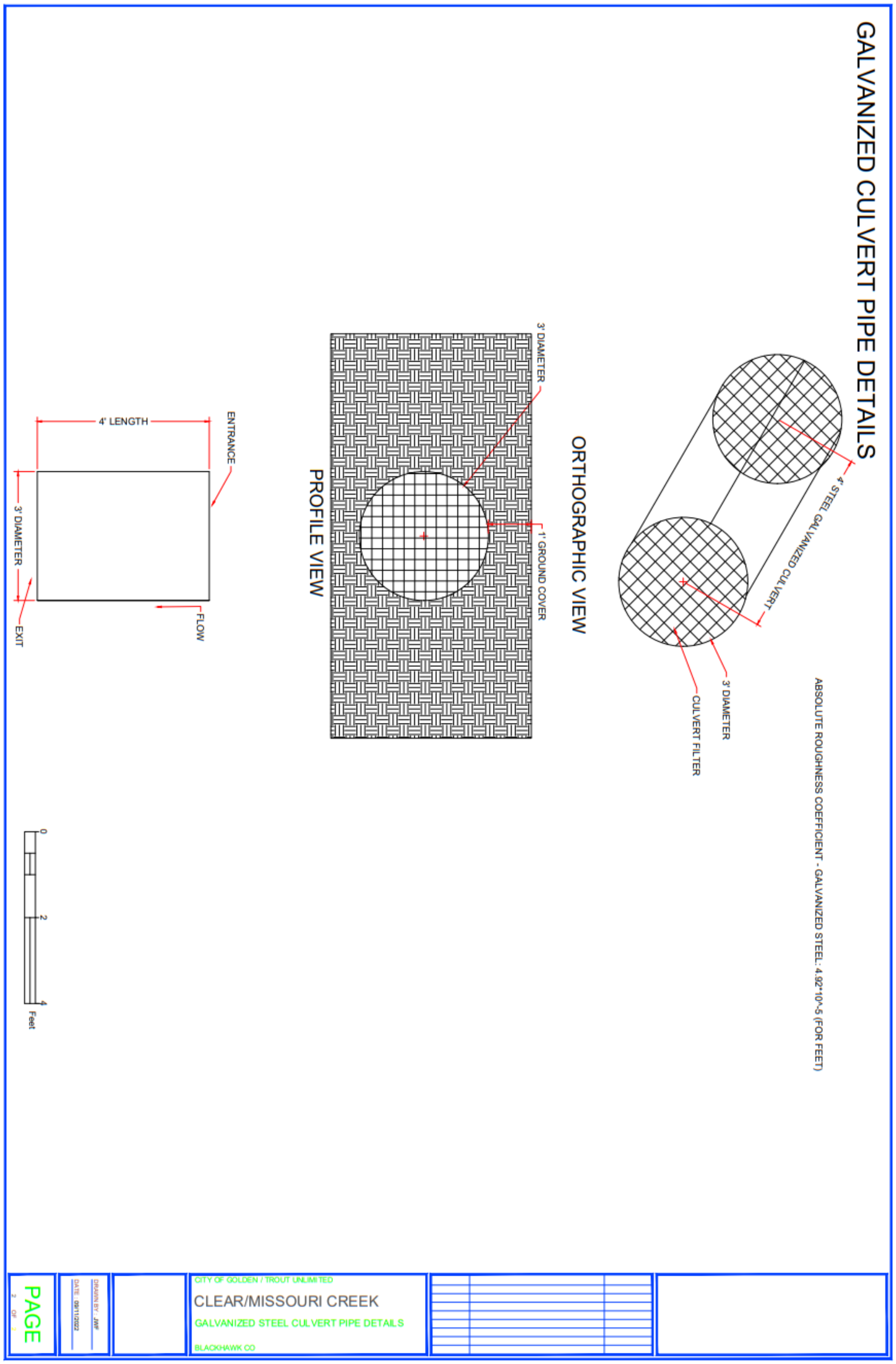
IX. Appendix



Appendix 1A: FEMA floodplain management



Appendix 2A. Stream bank stabilization



Appendix 3A. Culvert design

Appendix 4A. Existing Stream & Preposed

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CAPSTONE/SENIOR DESIGN HAZARD ASSESSMENT AND SAFETY PLAN

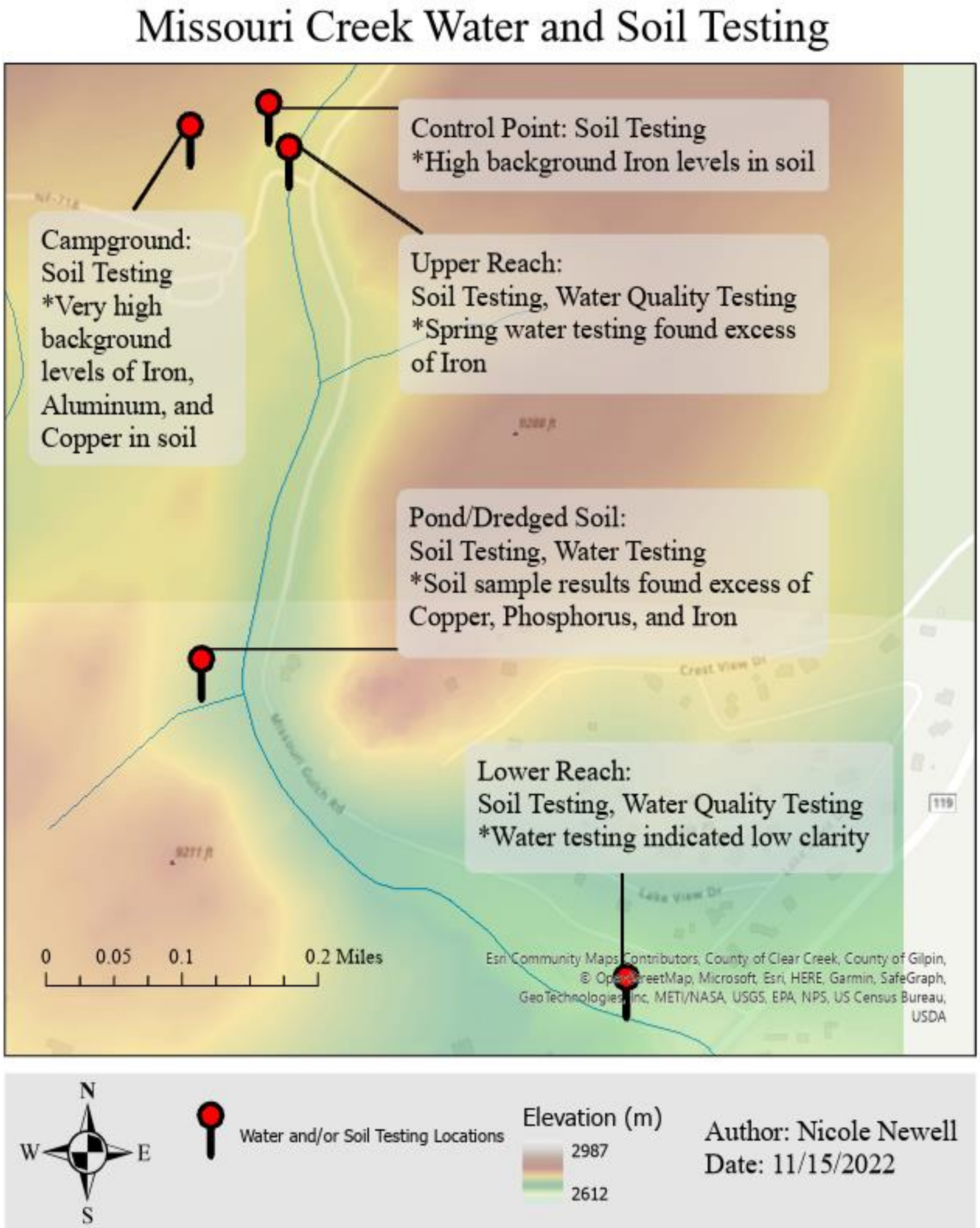
Project Title: Missouri/Clear Creek stream restoration	Program Advisor: Yosef Allam
Team members: James Felmlee, Luke Kimsey-Biglen, Nicole Newell, Erin Taggart, Amanda Zeutzius	
Brief project summary: Examining Missouri/Clear creek water quality, soil quality, and tree density	
Locations where field work will take place: Missouri/Clear Creek near Pickle Gulch Campgrounds	
Equipment Used: Shovels, flow meters, water quality testing equipment, tape measurer, flowrate testing equipment	
Personal Protective Equipment list: Hiking boots, safety goggles, gloves	
List of the things that might go wrong: Get lost in mountains, slips & trips, fall in the creek, run into dangerous animal	

Possible Sources of Harm		
Hazard	**Present?**	**Control method**
Sun Exposure?	Yes	Sunscreen and hats
Trip Hazards?	Yes	Careful assessment of surroundings
Wind?	Yes	Jackets, appropriate clothing
Rain/snow?	Yes	Jackets, appropriate clothing
Animal bites/encounters	Yes	Work in pairs, bear spray
Uneven Terrain	Yes	Hiking boots
Driving to/from the field	Yes	Traveling together
Visibility at night	No	
Heavy Equipment	No	
Sharp Tools	Yes	Careful handling of tools, working with a buddy
Long Hair	Yes	Hair tied up and away
Encounters with the general public/community	No	
Hand Injuries	No	
Other Bodily Injuries	No	
Noise	No	
Having an emergency out in the field	Yes	First aid kit, traveling together
Getting lost	Yes	GPS location, traveling together

General Safety (a checklist)		
I have a buddy working with me?	Yes	
Emergency contacts saved in phone?	Yes	
First aid kit?	Yes	
Sunscreen, hiking shoes, appropriate PPE?	Yes	
Water?	Yes	
Clothing appropriate for the weather?	Yes	
Equipment to use in working order?	Yes	
Checked the weather forecast?	Yes	
Ensure the vehicle being used is in working order?	Yes	
Educated on how to use the equipment being used?	Yes	
I have notified a buddy that I will be on the field and how long I plan to be out at the field?	Yes	
I am being careful of where I walk at the field so that I do not trip?	Yes	

Need a consult, call EHS at 303-273-3316 or email us at EHS@mines.edu

Appendix 5A. Stream team's safety plan

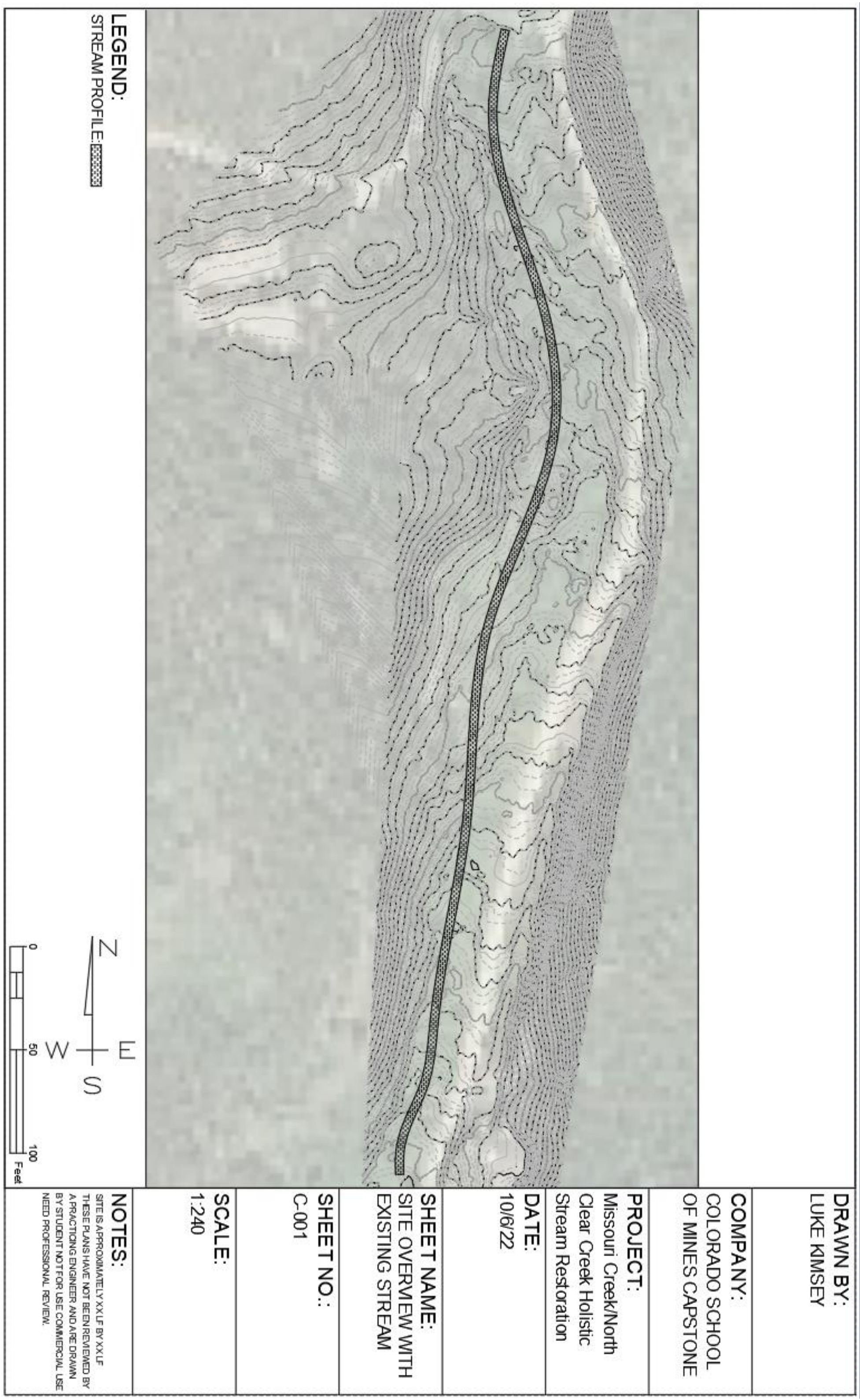


Appendix 6A. Map of water and soil quality data along Missouri Creek

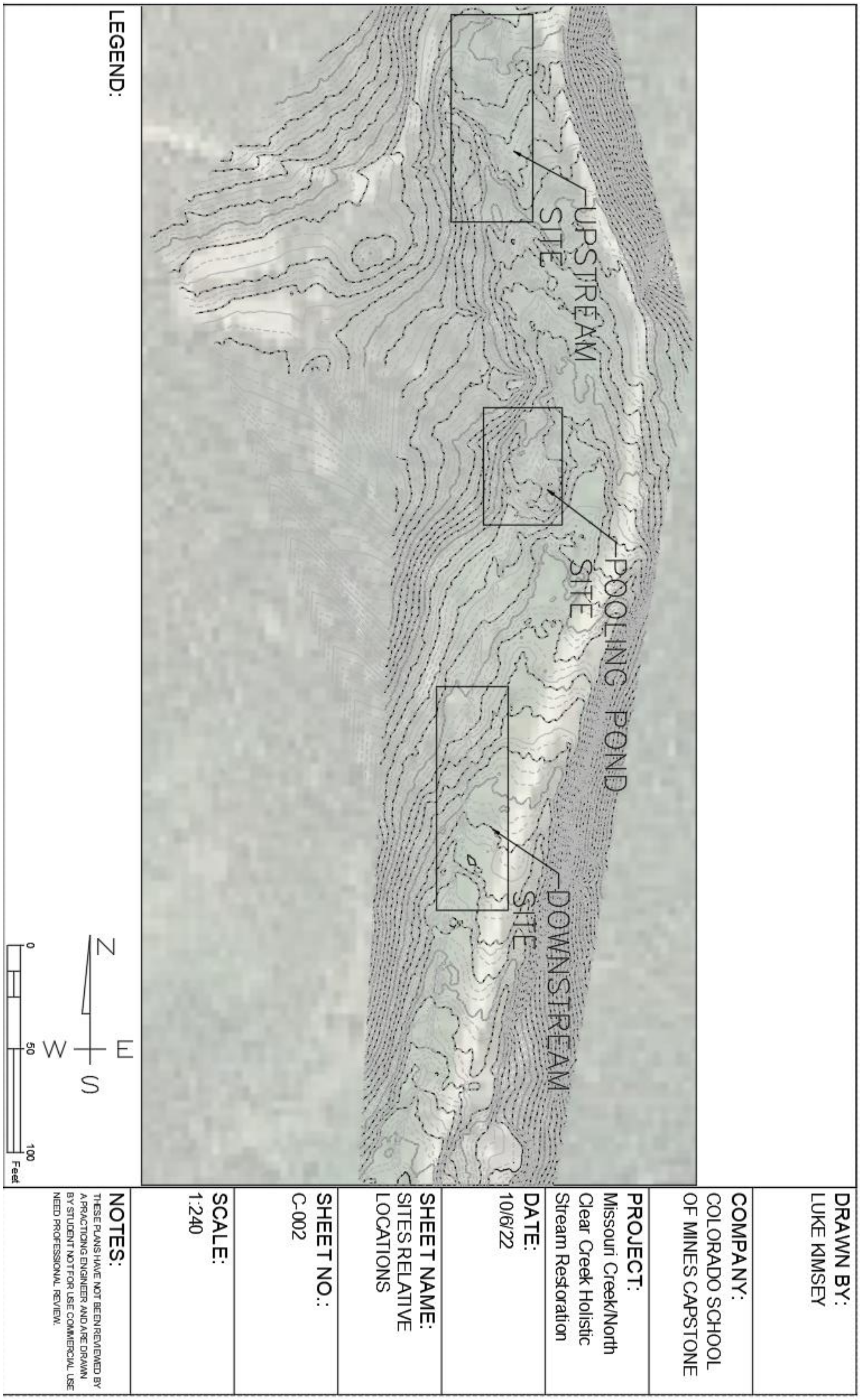
	Date	Source	Total
Starting Budget	2/10/2022	CAPSTONE	600
Additional funds			
		Total Funds	$ 600.00
		Total Spend	$ 278.50
		Remaining Funds	$ 321.50

Date	Company	Item	*Payment Method	Item cost	**Shipping cost	Total cost	Reimbursement Request Date	Return Date	Refund Amount	Notes:
		January								
						$ -				
					Total:	$ -				
		February								
					Total:	$ -				
		March								
					Total:	$ -				
		April								
					Total:	$ -				
		May								
					Total:	$ -				
		September								
9/14/2022	Mines	Lab Testing 8x samples	Internal	25$	0.00$	$ 172.00				PAID
					Total:	$ 172.00				
		October								
10/25/2022	Mines	Lab Testing 1x samples	Internal	$ 21.50	$ -	$ 21.50				UNPAID
					Total:	$ 21.50				
		November								
11/22/2022		Poster Printing	Internal	$ 85.00	$ -	$ 85.00				UNPAID
					$ -					
					Total:	$ 85.00				
		December								
					Total:	$ -				

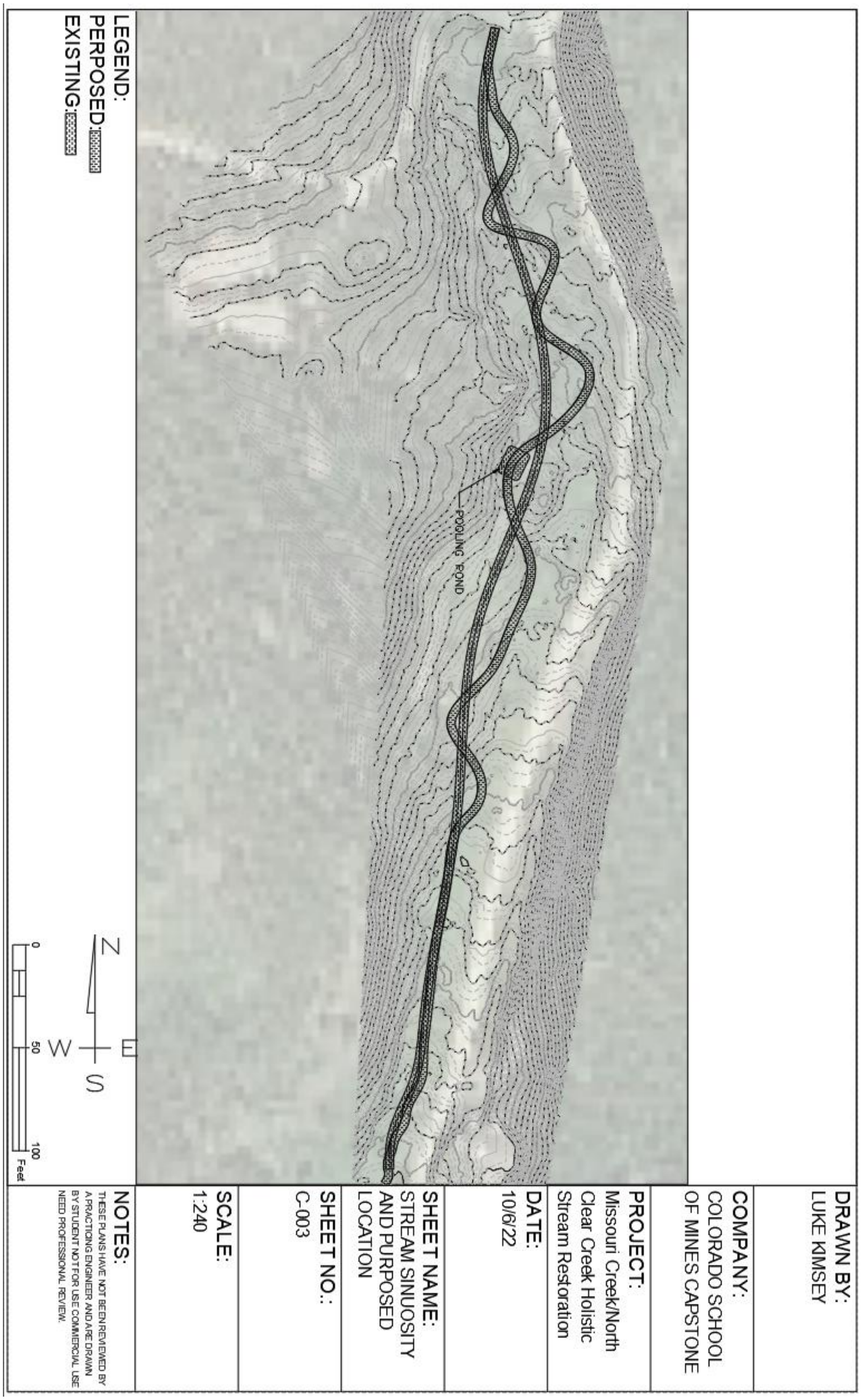
Appendix 7A. Budget tracking



Appendix 8A. Preliminary Drawing



Appendix 9A. Preliminary drawing



Appendix 10A. Preliminary Drawing

April 2022 Results							
Analyte	**Upstream**	**Downstream**	**Units**	**MCL - aquatic life**			
Phosphorous, Total	ND	ND	mg/L				
Total Kjeldahl Nitrogen	ND	ND	mg/L				
Total Organic Carbon	1.94	1.92	mg/L				
Ammonia as N	ND	ND	mg/L				
Aluminum- Total	124	72.8	ug/L		140 ug/L ish CDPHE standard		
Antimony-Total	ND	ND	ug/L				
Arsenic-Total	<1	<1	ug/L				
Barium- Total	18.2	21	ug/L	2000ug/L	domestic water supply		
Beryllium- Total	ND	ND	ug/L				
Cadmium- Total	ND	ND	ug/L				
Chromium- Total	<2	<2	ug/L				
Copper- Total	<10	<10	ug/L				
Iron- Total	358	177	ug/L				300 ug/L
Manganese- Total	36.2	10.3	ug/L				1215.7 ug/L based on hardness
Molybdenum- Total	ND	ND	ug/L				
Nickel- Total	<5	<5	ug/L	610			
Lead- Total	<1	<1	ug/L	50			0.9 ug/L based on hardness
Selenium- Total	ND	ND	ug/L				
Silver- Total	ND	ND	ug/L				
Thalluim- Total	ND	ND	ug/L				
Uranium- Total	ND	ND	ug/L				
Zinc- Total	<10	<10	ug/L	8.2 ug/L	CDPHE Chronic		69.5 ug/L based on hardness

Appendix 11A. Water quality results from the April 29th site visit

Analyte	Upstream	Downstream	Units	MCL-aquatic life	
Phosphorous, Total					
Total Kjeldahl Nitrogen					
Total Organic Carbon					
Ammonia as N					
Aluminum- Total					
Antimony-Total	ND	ND	ug/L		
Arsenic-Total	ND	ND	ug/L		
Barium- Total	18.4	22.3	ug/L	2000 ug/L	
Beryllium- Total	ND	ND	ug/L		
Cadmium- Total	ND	ND	ug/L		
Chromium- Total	ND	ND	ug/L		
Copper- Total	ND	ND	ug/L		
Iron- Total					
Manganese- Total					
Molybdenum- Total					
Nickel- Total	ND	ND	ug/L		
Lead- Total	<1	<1	ug/L		
Selenium- Total	ND	ND	ug/L		
Thalluim- Total	ND	ND	ug/L		
Uranium- Total					
Zinc- Total					
Thorium- Total	ND	ND	ug/L		
Alkalinity	23	25	mg/L as CaCO3		
Alkalinity Phenolphthalein	0	0	mg/L as CaCO3		
Phosphorous, Total	<0.05	<0.05	mg/L	.005 - .05	mg/L
Total Organic Carbon	2.09	2.36	mg/L		
Total Kjeldahi Nitrogen	<0.1	<0.1	mg/L		
pH	7.24	7.49	SU		
Conductivity	99.5	100	uS/cm		
Specific Conductance	99.5	100	uS/cm		
Dissolved Oxygen	7.45	7.24	mg/L		
Temperature	12.4	12.7	C		
Hardness	37	41	mg/L as CaCO3	120	mg/L
Turbidity	10.6	9.28	NTU	3	NTU
Chlorine	-	-	mg/L		
Flouride	-	-	mg/L		

Appendix 12A. The first half of the water quality results from the July 28th visit

Flouride	-	-	mg/L		
Ammonia as N	<0.03	<0.03	mg/L		
Sulfate	20.9	18.8	mg/L	500	mg/L
calcTDS	54.7	55.2	mg/L		
Flow Tracker 2					
Vel Mean	0.2697				
Vel Min	-0.0736				
Vel Max	0.7704				
velocity	0.0116	ft/sec			
uncertainty	47.75%				
largest uncertainty	45.65%				
flowrate	1670.4	ft^3 / d			
depth	0.4166667	ft			
length	4	ft			
area	1.6666667	ft^2			
			mg/d	kg/yr	
		Al	23824.74816	8.696033078	
		Cu	1143.63936	0.417428366	
		P	16549.23744	6.040471666	

Appendix 13A. The second half of the water quality results from the July 28th visit

September 2022 Results						
Analyte	**Upstream**	**Downstream**	**Pool**	**Units**	**MCL- Aquatic Life**	
Specific Conductance (EC)	105	111	117	uS/cm		
Dissolved Oxygen	7.47	7.61	1.27	mg/L	6 mg/L	
Sulfate	19.1	16.6	3.04	mg/L		
Ammonia as N	ND	ND	ND			
pH	7.34	7.55	7.14	SU	6.5-9	
Conductivity	105	111	117	uS/cm		
calcTDS	57.8	60.9	64.5	mg/L		
Phosphorus, Total	ND	ND	0.16	mg/L	0.11 mg/L	
Temperature	10.7	9.4	11	C	21.7 C	CS-1
Total Organic Carbon	2.11	2.54	7.91	mg/L	30 day 50th percentile	
Total Kjeldahl Nitrogen	ND	ND	1.7	mg/L		
Turbidity	4.53	3.51	17.4	NTU	3 NTU	
Alkalinity	32.8	37.2	7	mg/L as CaCO3		
Aluminum-Total	32.1	51.8	9.7	ug/L	125 ug/L	
Antimony-Total	ND	ND	ND			
Arsenic-Total	ND	ND	ND			
Barium-Total	17.1	22	77.7	ug/L	2000 ug/L	
Beryllium-Total	ND	ND	ND			Water
Cadmium-Total	ND	ND	ND			
Chromium-Total	ND	ND	ND			
Cobalt-Total	ND	ND	ND			
Copper-Total	ND	ND	ND		1 mg/L	
Iron-Total	315	231	3960	ug/L	1000 ug/L	CDHPE
Lead-Total	<1	<1	<1	ug/L	50 ug/L	
Manganese-Total	30.1	24.1	344	ug/L	close to 1000 ug/L	
Nickel-Total	ND	ND	ND			
Thallium-Total	ND	ND	ND			
Molybdenum-Total	<2	<2	ND	ug/L	150 ug/L	
Selenium-Total	ND	ND	ND			
Silver-Total	ND	ND	ND			
Uranium-Total	ND	ND	ND			
Vanadium-Total	ND	ND	ND			
Zinc-Total	<10	<10	ND	ug/L		
Thorium-Total	ND	ND	ND			
Aluminum-Dissolved	6.52	5.57	ND	ug/L	1-4800 ug/L	
Antimony-Dissolved	ND	ND	ND			

Appendix 14A. The first half of the water quality results from the September 8th visit

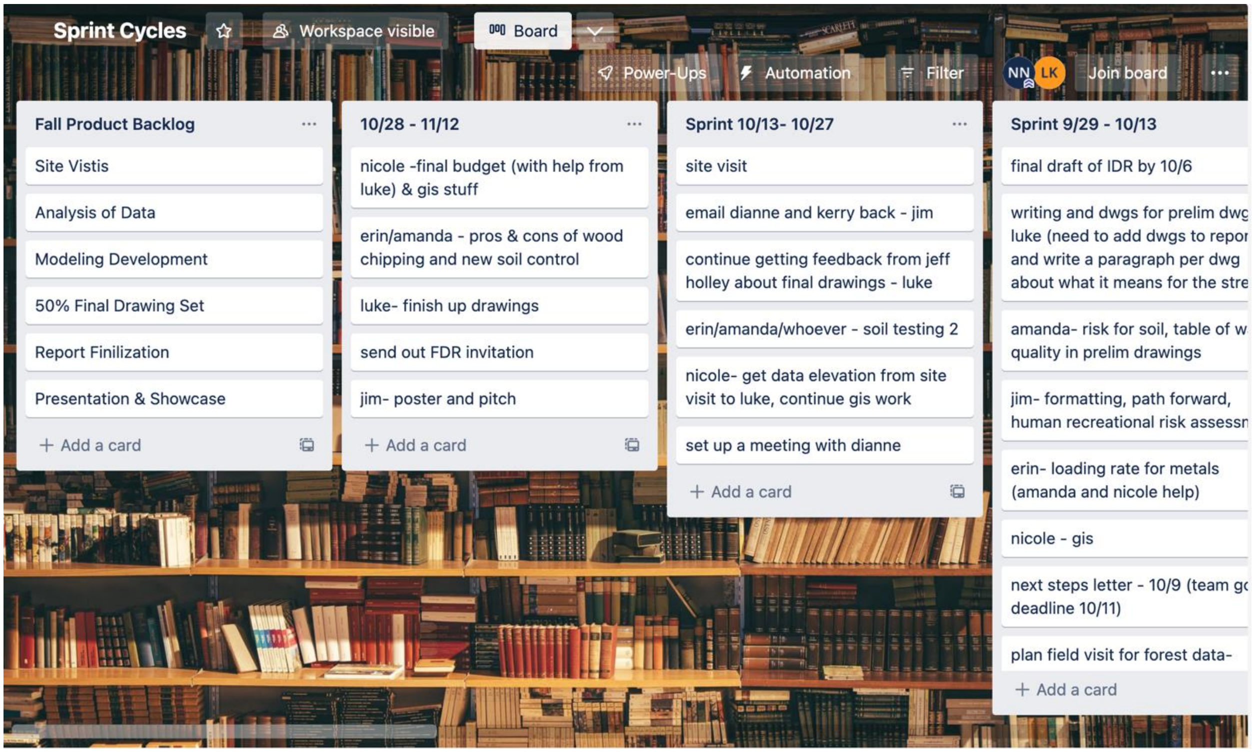
Antimony-Dissolved	ND	ND	ND		
Arsenic-Dissolved	ND	ND	ND		
Barium-Dissolved	17.8	22.6	54.9	ug/L	
Beryllium-Dissolved	ND	ND	ND		
Cadmium-Dissolved	ND	ND	ND		
Chromium-Dissolved	ND	ND	ND		
Cobalt-Dissolved	ND	ND	ND		
Copper-Dissolved	ND	ND	ND		
Iron-Dissolved	95.1	62.3	291	ug/L	300 ug/L
Lead-Dissolved	<1	<1	<1	ug/L	
Manganese-Dissolved	17.3	7.35	<5	ug/L	50 ug/L
Molybdenum-Dissolved	<2	<2	ND	ug/L	
Nickel-Dissolved	ND	ND	ND		
Silver-Dissolved	ND	ND	ND		
Thallium-Dissolved	ND	ND	ND		
Selenium-Dissolved	ND	ND	ND		
Thorium-Dissolved	ND	ND	ND		
Uranium-Dissolved	ND	ND	ND		
Vanadium-Dissolved	ND	ND	ND		
Zinc-Dissolved	ND	ND	ND		

Appendix 15A. The second half of the water quality results from the September 8th visit

Table 1
Human Health Screening Levels (SLs) for Chemicals in Soil At BLM HazMat/AML Sites (mg/kg)

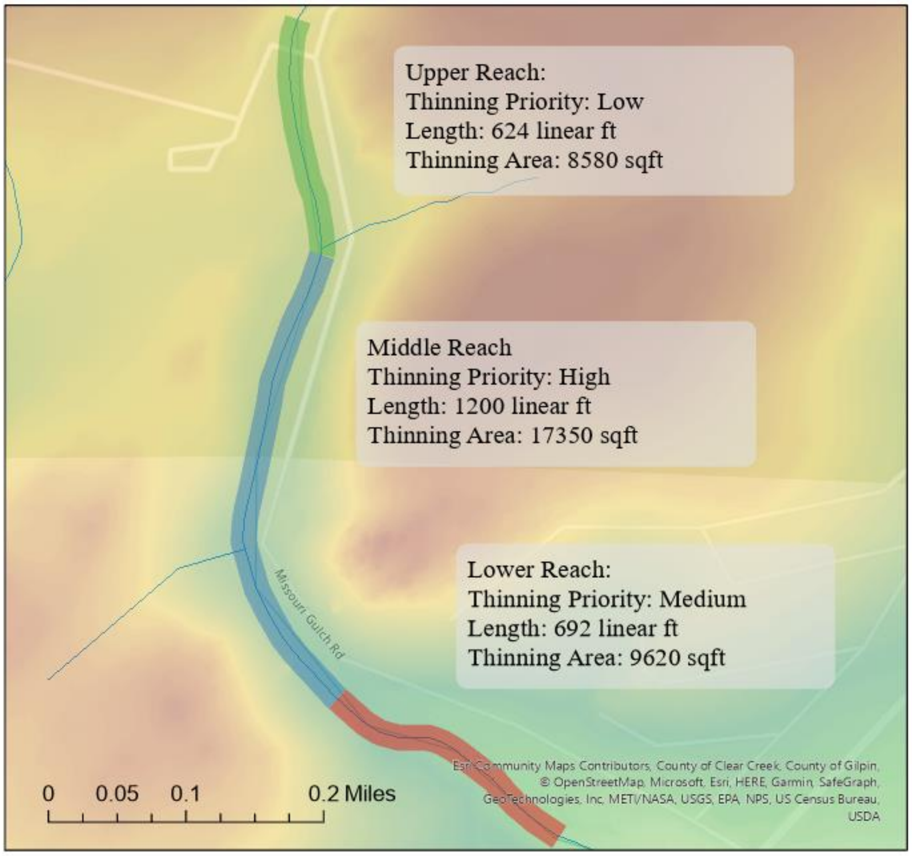
Chemical	BLM Recreational SL	EPA Residential SL	EPA Industrial SL
Aluminum (Al)	>1,000,000	77,000	>1,000,000
Antimony (Sb)	782	31	470
Arsenic (As)	30.6	0.68	3
Barium (Ba)	390,000	15,000	220,000
Beryllium (Be)	3,910	160	2,300
Cadmium (Cd)	1,780	71	980
Chromium (III) (Cr)	>1,000,000	120,000	>1,000,000
Cobalt (Co)	586	23	350
Copper (Cu)	78,200	3,100	47,000
Iron (Fe)	>1,000,000	55,000	820,000
Lead (Pb)	800[a]	400	800
Manganese (Mn)	46,700	1,800	26,000
Mercury (elemental) (Hg)[b]	271	11	46
Molybdenum (Mo)	9,780	390	5,800
Nickel (Ni)	39,000	1,500	22,000
Selenium (Se)	9,780	390	5,800
Silver (Ag)	9,780	390	5,800
Thallium (Tl)	19.6	0.78	12
Uranium (U)[c]	391	16	230
Vanadium (V)	9,850	390	5,800
Zinc (Zn)	587,000	23,000	350,000
Primary Exposure Assumptions	14 days/year, 26 years, adult/child	350 days/year, 26 years, adult/child	225 days/year, 25 years, adult

Appendix 16A. BLM human health screening levels for chemicals in soil



Appendix 17A. Trello board showing how the team managed the project

Missouri Creek Tree Thinning



Appendix 18A. Tree thinning demarcation

OBJECTID *	Shape *	Point	N	E
1	Point	1	39.843114	-105.522815
2	Point	2	39.837872	-105.523989
3	Point	3	39.834641	-105.518084

Appendix 19A. Testing point locations for upstream, downstream, and pooling