Erosion Control and Trail Condition Improvements at Chimney Rocks Park in Blair County

Team: Chimney Rock 'n' Roll

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Executive Summary

The trail located at Chimney Rocks Park in Hollidaysburg, PA has experienced erosion control problems over the past several decades due to stormwater runoff. Because of these problems, some parts of the trail have become very uneven and difficult to navigate. That is why the Blair County Planning office has enlisted the help of Penn State to develop a site plan that will hopefully minimize the erosion and stabilize the trail in the problem areas. This detailed plan will incorporate recommended best management practices for the trail while maintaining the natural look of the landscape and keeping the cost to a minimum. The hope is to allow three season access and minimal maintenance once everything is complete.

Our team has been working with our sponsors, Tina Enderlein, the Regional Planner for Blair County, and Thomas Shaffer, the Penn State Altoona Coordinator for Academic Internships and Community-Based Studies, over the past two semesters to learn about this problem. By visiting the site several times this past year and collecting survey data, we were able to understand the problem better and how we wanted to solve it. After doing extensive, external research and meeting with two faculty members of Penn State's Center for Dirt and Gravel Road Studies, we were able to gather a significant amount of information on how to combat erosion and runoff problems. From all our research, we narrowed down all the concepts to the three we will most likely be using. These are broad-based dips, grade breaks, and waterbars.

During the spring semester, the survey data was analyzed using ArcGIS, Virginia Tech and Penn State Urban Hydrology Model (VTPSUHM), and AutoCAD Civil 3D. The current erosion and stormwater volumes were determined for the entire trail. The volume of runoff that would need to be controlled by each structure was also calculated. These volumes will be used to help design the proper sized structures to divert the stormwater off the trail surface. The final design structure that the team came up with was to utilize a combination between broad-based dips and modified waterbars using fill material. The team was able to generate these structures using AutoCAD Civil 3D, and model them in the EPA's SWMM software to test their feasibility and efficiency in diverting the necessary water. The final design solution met all the initial customer needs and the target specifications, so the team was successful in designing structures for Chimney Rocks to utilize in the future.

Table of Contents

1.0 Introduction

Water, being one of Earth's main constituents in all aspects of life, cycles throughout Earth and its atmosphere. One part of the hydrologic cycle is precipitation, which is when the water in the atmosphere travels back down to Earth, either in the form of rain, sleet, snow or hail. When these precipitation forms reach Earth as water, they are then referred to as stormwater. This stormwater can either soak into the soil, stay on the surface and evaporate, or runoff and travel to nearby streams, lakes or other bodies of water. The state of Pennsylvania receives an average of about 39 inches of rain per year; as of October 2018, PA rainfall has already exceeded this average for the year ("Climate", 2018).

As this stormwater moves across surfaces, it creates erosion. Erosion is the surface movement of soil, rock, and other sediment from one location to another. This natural movement of materials can be a problem for several reasons. Once soil or other sediment erodes, it can take many years for it to return naturally. Also, if this eroded soil and sediment ends up in bodies of water, it can cause poor water quality due to the suspended solids content. This is why there are practices and methods that attempt to control and reduce the amount of erosion.

Not only do natural storm events cause erosion, but humans can impact these natural landscapes as well. Areas with concentrated foot traffic, like a trail, can lead to soil compaction in that pathway. This soil compaction can reduce vegetation and the ground cover. Because of this, more stormwater interacts with the surface and bare soil, so this can cause more erosion during storm events.

Fortunately, there are lots of methods and practices that can be used to reduce and control the amount of erosion on areas, like trails. Best Management Practices (BMPs) are certain control practices that are aimed at reducing and controlling erosion and sediment movement. By controlling water at the higher parts of the trail by using BMPs, the amount of water that is allowed to affect the rest of the trail will be reduced. This will reduce the amount of erosion over the entire trail.

1.1 Initial Problem Statement

The sponsors for this project, Tina Enderlein, who is the regional planner for Blair County, and Tom Shaffer, who is a Penn State Altoona professor and the coordinator for Academic Internships and Community-Based Studies, have tasked us with solving the issue at Chimney Rocks Park. Chimney Rocks Park, located in Hollidaysburg, Blair County, PA, is having a problem with their trail system eroding away in some sections. These parts of the trail are very uneven and difficult to walk through due to the erosion. Our task is to implement erosion control practices for this trail that are inexpensive to install and maintain in the future. The erosion control practices that we design are going to continue to keep the trail looking natural, so there will be no addition of outside materials, such as pavement. Blair County wants to have this trail be used for three seasons out of the year, once the erosion problem has been solved. Because they want to spend little to no money on this trail, they want it to require little maintenance throughout the year, if any. This problem is fairly important since the solution is going to incorporate Blair County's two existing initiatives, which are promoting community health and wellness, and managing stormwater. By having easy access to trails and parks, the residents of Blair County are able to maintain an active lifestyle. Also, the county is in the process of updating its stormwater management plan. The current plan for solving the erosion problem at the park is to focus on the main trail to the top overlook and one of the side trails to the chimney rocks. If we have time to develop a plan for the other half mile trail, we would make the whole trail about a mile loop.

1.2 Objective and Description of Design Problem

The objective of this project is to design an erosion control plan to fix the current conditions of the Chimney Rocks trail while preventing further negative impacts of erosion due to the stormwater that is generated at the Park. The design should improve the safety and increase the usability of the trail system while maintaining the natural look of the landscape. The cost of implementation and maintenance should be kept to a minimum. The design will only require maintenance after each major storm event, following snowmelt, and if needed when the trail reopens in the spring. The design will incorporate Blair County's health initiative by bringing the community together to implement the control practices and for the future enjoyment of this trail system.

2.0 Sponsor Needs Assessment

2.1 Gathering Input

The team met with the sponsors for the first time at Chimney Rocks Park on Monday, September 10. The weather of the previous few days had been very rainy and when we arrived at the park it was still raining. We walked the main ½-mile trail of interest and the small side trail that leads to two of the chimney rocks. Meeting on a rainy day was a perfect way to see where the erosion problems were occuring. It also gave the team a look at what there is to work with on the site and an idea of what could potentially work and not work with respect to finding a solution.

The sponsors are looking for a trail system that can be maintained for the safety of the hikers. They are not looking to implement any unnatural trail foundations such as pavement or soil amendments to improve the trail. The trail should stay as natural as possible in the proposed plans. Since no resurfacing of the trail is wanted, it was said that the trail is not expected to be in a condition where it could be handicap accessible. They prioritize safety and liability and feel that the steep slopes of the trail system are not safe to be handicap accessible.

The main concern of the trail is the extensive erosion that is occuring. The erosion was most prominent at the trailhead and the first stretch of the trail but that is because the stormwater seems to become more concentrated in these areas. The peak of the trail has the least erosion since it is relatively flat and the ground cover is still intact. Descending down the trail from the top overlook, the erosion issues gradually worsen. The volume of stormwater accumulates forming a concentrated flow path as compared to the sheet flow at the onset of the slope. The erosion issues on the first ½-mile of the trail that leads to the top overlook are the top priority. The small side trail that leads to the chimney rocks is also a high priority. The ½-mile trail that creates a loop back to the lower overlook should be considered if there is time. An additional outcome of the project that Tom suggested was to possibly add an update to the trail that loops back to the lower portion of the park. This would provide a mile loop of walking trail rather than just a ½-mile stretch where hikers walk back and forth. We also feel that if it was a loop then the amount foot traffic and compaction effects could potentially be reduced.

Other concerns that the sponsors expressed were in respect to implementation, cost, and maintenance. As part of the county's health initiative they hope that this project can be implemented by volunteers. They would really like to avoid the use of heavy equipment on the trails. They would much rather the erosion control practices be implemented by the labor of community volunteers. This would allow for the least amount of destruction to the trail and surrounding vegetation that could result from the use heavy equipment. It would also help to bring the community together. Using volunteers for implementing the erosion control practices could also help with the cost of the project. Renting equipment or hiring a contractor could end up being very expensive. The county does not have a lot of funds to use towards the implementation of the trail restorations. They want both the implementation costs and future maintenance costs to be very low or almost nothing. This means that the control practices selected should be durable. This should allow for the county to only have to do minimal maintenance and will help for future costs to be less if the control practices last for years to come. The sponsors explained that minimal maintenance should be defined as only having to conduct maintenance in the spring after the winter snow melt and if there is a large storm that causes great issues on the trail. Currently there is not much maintenance performed and it would be best, for the county's sake, to keep it that way.

They want to incorporate this project into the following Blair County initiatives: health and improvement of stormwater quality. As mentioned above, one way they want to accomplish this is by asking community volunteers to help with the implementation of the erosion control practices. The implementation of erosion control practices on the trail can also help improve the water quality of the stormwater that is generated in the Chimney Rocks Park. The sponsors also explained that this feasibility study and the future trail restoration project on the Chimney Rocks Park is a small part of a larger project in the county. The plan is to make improvements at other parks nearby to give the community beautiful natural parks for purposes of education, recreation, and promoting a healthy lifestyle.

The reduction of erosion and impact of the suspended sediments that are being washed from the trail into Blair County's stormwater needs to be addressed. In making plans to reduce the erosion and promote a safe trail system, there are a few resources the team will be utilizing to ensure there is compliance with existing stormwater regulations. First, in the State of Pennsylvania the occurrence of a storm event is on average every 72 hrs, or every 3 days. The erosion control practices will be designed to be able to convey the amount of precipitation that occurs at the Park during these events. The design will be prepared based on the proper design storms that are instructed for use in the Blair County and Pennsylvania Stormwater Management manuals. The proper design will be chosen based not only on the regulations of the state and county, but also for the allowance of a factor of safety. The reason for a factor of safety is to encompass the safety of hikers, durability and lifespan of the erosion control structures, comparison to existing practices, and cost of the design. There will also be a Erosion and Sedimentation Control Plan (E&S Plan) developed to be used to help reduce erosion during any construction practices if the design covers more than 5000 square feet of disturbed area. Any construction or improvements conducted on the trail will be done efficiently and in a timely fashion to reduce the chance of erosion. They will also be implemented by following an E&S plan, if applicable.

2.2 Weighting of Customer Needs

Following the visit with our sponsors, the team compiled a list of the needs that the sponsor has for our erosion control project proposal. From the list of needs we will be able to identify the most important specifications for the design. The goal of meeting the specifications is to be able to encompass most, if not all the needs of our sponsors. At our initial visit of Chimney Rocks Park, we were able to witness the erosion from stormwater first hand. The trail was at prime conditions of saturation and it was still raining allowing for the team to see where the erosion was the worst. The areas of high concentration of flow were observed and documented. Figure 2.1 shows the trailhead and the gully that has formed on the bank for large volumes of stormwater exiting from the trail. Figure 2.2 shows the gully that has formed on the steepest part of the trail. This is located on the first stretch of the trail. This part of the trail not only has a large gully forming, but the part of the trail that is still flat is also very slippery when wet. Figures 2.3 and 2.4 show the start of the gully at the switch back near the bench along the trail. This is the onset of the large gully that is shown in figure 2.2. Figure 2.5 shows the conditions that exist on the trail leading to the first few chimney rocks. This is a side trail that leads to the main trail of concern. The last figure, figure 2.6, is a map of the trails and it indicates where the pictures in figures 2.1 through 2.5 were taken. It also gives a few other observed trail conditions. The main trail of concern is shown as a red dashed line. The side trail to the chimney rocks is shown as a pink line and the trail that would create a loop back to the lower portion of the park is shown as dashed green line.

Figure 2.1. Erosion and gully forming at the trailhead

Figure 2.2. Major erosion at the start of the trail. On the left is looking up the trail. On the right is the same location in the trail but looking down the slope.

Figure 2.3. Erosion near the bench at the switchback on the trail

Figure 2.4. Lower erosion after the switch back

Figure 2.5. Side trail to the chimney rocks. Looking down the trail (left). Looking up the trail where roots hold the trail in place (right).

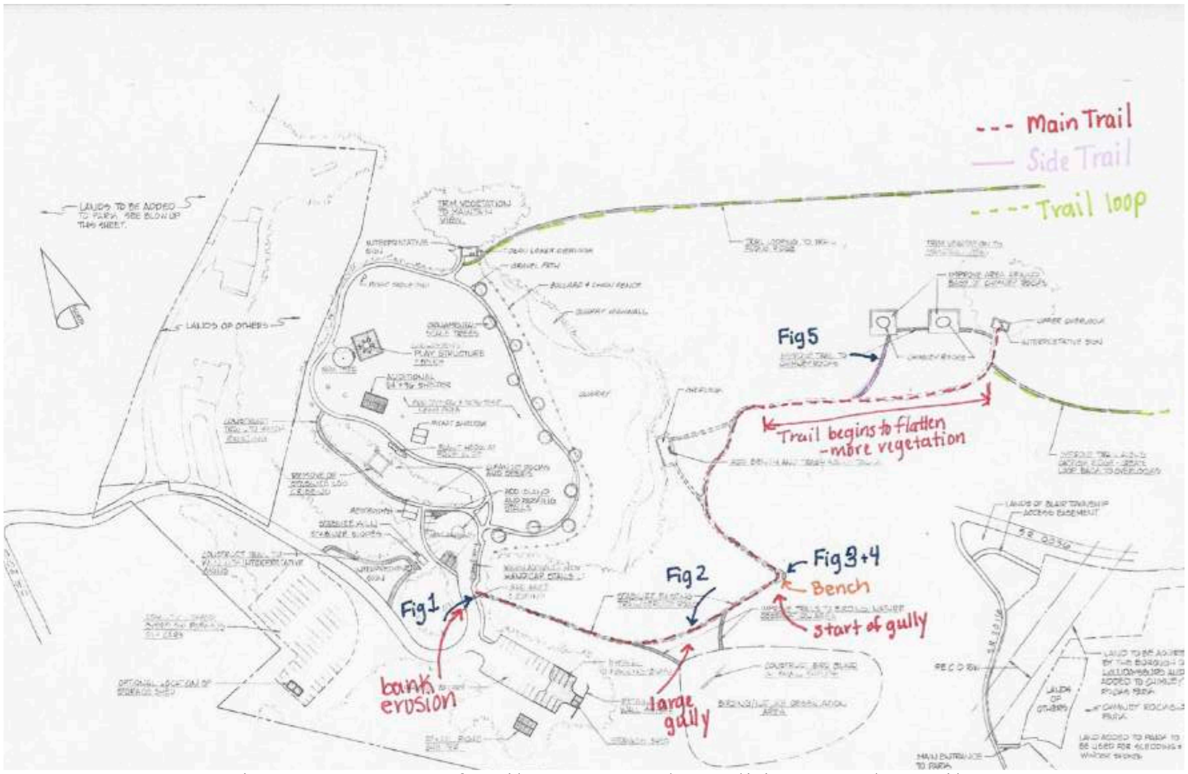


Figure 2.6. Map of trail system and conditions on the trail

Based on the site visit and the meeting with the sponsors, the team developed a list of customer needs and assigned a weight to each need (Table 2.1). The team decided that making the trail natural was a very important need. Making the trail natural was weighted as a 4 since we do not want to pave it, but in places we might need to add outside fill material. The need of the trail being safe was weighted as a 5 since the sponsors expressed safety and their liability as very important. Since there are regulations and Blair County has an improvement of stormwater initiative, the environmental impact of the trail improvements was marked as a high importance need with a weight of a 5. The sponsors expressed in our first meeting that they would like for the trail improvements to be done by volunteers so there was no need for large equipment use. After some research and team discussion, we think that some of the improvements are going to need equipment for sake of the safety of the workers/volunteers and time and money. This caused the team to rank the use of labor implementation as a 3. To reduce future costs and need for maintenance the team decided that the sustainability/durability of the trail after improvements had a weight of 4. The team did not see how this project could cause any cultural impacts unless you looked at it as a way to bring the community together but having an improved trail does not mean there is going to be an increase in use necessarily. This caused the cultural impact need to get a weight of a 2. The sponsors expressed, during our hike, that Blair County wants to use this project as a way to promote its health initiative. The team believes that getting the public involved with helping to implement the project in someway will help align the project with the ethics/values of Blair County and its health initiative. This need was weighted as a 3. Since the trail needs to meet the Pennsylvania regulations this need was weighted as a 5; we should follow and comply with all regulations throughout the design and future implementation of the improvements. Lastly the cost of the improvements to the trail was weighted as a 4 since the sponsors said that the county does not want this project to have a high cost.

Table 2.1. Customer needs table, where 1 = less critical need and 5 = essential need.

Customer Needs	Weight (1-5)
Environmental Impact - Reduce/control erosion and stormwater discharge at end of trail	5
Cost - have no funds and do not want it to have a high cost for initial implementation and future maintenance	4
Meet Regulations - of both Blair County and the State of Pennsylvania	5
Labor implementation - volunteers from community to implement the erosion control practices	3
Safety - three season access and liability	5
Sustainable / Durability - Last for a long time with minimal maintenance	4
Make it Natural - no paving of trail	4
Cultural Impact	2
Alignment with ethics/values - getting community involved with health and exercise and improving stormwater quality	3

3.0 External Search

3.1 Journal Articles

3.1.1 Reducing Erosion from Forest Roads and Skid Trails by Management Practices

The article focuses on how forest roads and skid trails can lead to an increase in erosion and contribute to negative environmental effects. The erosion can eventually reach a stream, which will decrease the quality of water. There are numerous variables that affect the amount of erosion of each case, like climate, surface material, and slope length. The best way to reduce erosion as much as possible is to use management practices. This article looks at how water diversion and vegetative cover affect soil erosion. Water diversion, like water bars for example, are extremely effective at rerouting water from the trail path into more forested areas, reducing erosion. The frequency of these diversions depends on the climate, surface material, and slope length, as previously mentioned. Vegetated cover is extremely important in keeping the stability of soil, especially sections that have steep slopes. Vegetated cover also plays a big role in reducing erosion as water moves over a surface and raindrops displace soil. These two practices are essential for mitigating erosion (Akbarimehr, 2012).

3.1.2 The Influence of Use-Related, Environmental, and Managerial Factors on Soil Loss from Recreational Trails

Unsurfaced trails inevitably will have erosion. The amount of erosion depends on soil texture, topography, climate, trail design, trail maintenance, trail use, etc. The research in this article investigates the influence of use-related, environmental, and managerial factors on soil loss on recreational trails and roads. After analyzing the trails and roads at Big South Fork National River and Recreation area, research showed that trail position, trail slope, alignment angle, grade, water drainage, and type of use significantly impacted the amount of soil loss a specific road/trail would have. This research led to a better understanding of what trail management actions are most effective; these actions include avoiding "fall line" alignments, steep grades, and valley bottom alignments, installing and maintaining adequate densities of tread drainage features, and reducing horse and all terrain vehicle use. Another element to this research was developing a more efficient Variable Cross-Sectional Area (CSA) method for assessing soil loss on trails. This was made possible by incorporating the CSA measures in a representative sampling scheme applied to a large sample of the park's 526 km trail system (Olive, 2009). Once we gather enough data from the survey of our own trail, it could be possible to implement the CSA method to determine soil loss.

3.1.3 Assessing the Influence of Sustainable Trail Design and Maintenance on Soil Loss

Trail systems are an essential part of people being able to access remote destinations that would otherwise be unreachable. The condition and usability of trails are vitally important for the managers tasked with maintaining the trail. Sustainable trails are designed, constructed and managed to accommodate their intended types, amounts, and seasons of use to provide high quality visitor experience while protecting trail infrastructure and natural resources. This journal article focused on how trail grade, slope alignment, trail drainage, and trail substrates affect soil loss through regression modeling and analysis of trail datasets. The research revealed that trail grade and slope alignment have the greatest influence on soil loss. If segments of trails are identified as "unsustainable", then the managers can either reroute the trail to decrease grade, or implement rockwork, graveling, and other additional drainage features that decrease soil trail loss (Marion, 2017).

3.1.4 Quantifying Short-Term Surface Changes on Recreational Trails: the Use of Topographic Surveys and 'Digital Elevation Models of Differences'

The objectives of the study done in this journal article were to analyze the spatial aspect of surface changes in microscale and to quantify the short-term rate of soil loss and deposition. The measurements were taken on trails characterized by different slopes, types of vegetation, and types of use. Electronic total stations and digital elevation models (DEMs) helped to provide precise elevation data and assess the sediment budget of the surface changes. During a two year period in which the study was conducted (2008-10), soil loss dominated 10 out of 12 testing sites, with a predominance of deposition in the other two. The average net volumetric change of trail surface varied from -0.035 m^3m^{-2} to +0.005 m^3m^{-2} per year. Local geomorphic conditions, morphology of the trail tread and soil properties seemed to be the most important factors contributing to the relief transformation. No connection was demonstrated between the amount of use (i.e. number of visitors) or type of use and the amount of soil loss or deposition (Tomczyk, 2013). The values found for the average volumetric change in the trail surface, which equates to how much sediment transport occurred, will be used as a way to set the specification for how much soil erosion is allowable after control structures are implemented.

3.2 Engineering Standards and Regulations

3.2.1 Blair Township Stormwater Management Ordinance

In order to comply with the stormwater regulations of Blair County, this ordinance was reviewed. This manual gives specific details on how stormwater must be managed during earth disturbance activities. The selected erosion and sediment control Best Management Practices (BMPs) must be designed, implemented, operated, and maintained to meet the requirements outlined in the ordinance. The ordinance requires that a Stormwater Management site plan must be approved, the plan must meet water quality goals of the chapter, and the use of design storm volumes and peak rates of discharge must be obtained from the NOAA database. It is required that the post development total runoff volume of any storm size cannot exceed the two-year twenty-four-hour duration precipitation. It also requires existing, pre-development non-forested pervious areas to be modeled as a meadow in good condition. The post-development discharge rates are also not allowed to exceed the pre-development discharge rates for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-yr, twenty-four-hour storms. This requirement is only met when the peak discharge of each storm post-development is shown to be less than or equal to the peak discharges of the pre-development analysis.

For the analysis, storm frequencies of the USDA NRCS twenty-four-hour, Type II Rainfall Distribution shall be used in both the stormwater calculations of pre and post-development conditions. When computing runoff hydrographs and finding the peak flow rate, Technical Release (TR) 55 or 20, HEC I or Penn State Runoff Model (PSRM) or Modified Rational Method should be used. The use of detention/retention facilities for the routing of hydrographs should have the designs modeled utilizing the Modified-Puls Method or other reservoir routing methods that are approved by the Township Engineer ("Chapter 338", 2011).

3.2.2 Pennsylvania Code 25 Chapter 102: Erosion and Sediment Control

This chapter is required to be followed by a contractor or person who is going to conduct earth disturbance activities. They are required by this chapter to develop, implement, and maintain BMPs to help minimize the potential of accelerated erosion and sedimentation from such activities. This chapter also requires there to be management of post construction stormwater. The purpose of the BMPs is to help protect, maintain, and restore the water quality of the stormwater that will occur on the site and end up in nearby storm drains and eventually the streams ("Chapter 102", 1972).

3.2.3 Pennsylvania Department of Environmental Protection Erosion and Sediment Pollution Control Program Manual

This manual is a reference for any individual who is proposing any earth disturbance activity that will be 5,000 square feet or more. They are required to develop and implement a written Erosion and Sediment Control Plan (E&S Plan). The main focus of this manual is to minimize the accelerated erosion and the resultant sedimentation during human earth disturbance that is regulated by the Pennsylvania DEP under Chapter 102. The purpose is to minimize the duration of the earth disturbance, maximize protection of existing drainage features and vegetation, minimize soil compaction, and to prevent or minimize the generation of increased runoff from stormwater (PADEP, 2012).

3.3 Existing Products or Design Approaches

3.3.1 USDA Trail Construction and Maintenance Notebook: Surface Water Control

Diverting surface water off of a trail is very important to maintaining trail health. Whenever water does not naturally run off of the trail, there are a few design practices that can be implemented to help divert water. A grade reversal involves increasing the grade before and after the trail, promoting the water to simply flow perpendicular to the trail. However, once water gets onto the trail, it will likely want to follow the trail path, which could form gullies, puddles, or other negative structures. Knicks (Figure 3.1) are helpful in eliminating puddles along a trail. A knick essentially creates an out-sloped drain that allows the water to flow off of the trail and into the surrounding forestry. For problem areas of the trail that cover a longer distance, rolling grade dips (Figure 3.2) are very effective. They involve building up one side of the trail and downsloping the other side of the trail to promote water to flow off of the trail. The steeper the trail, the more rolling dips are needed. This method could be very helpful with our design at Chimney Rocks due to the steep slope of the trail. Another common drainage structure is a waterbar (Figure 3.3). It involves putting material, like a log, into the trail to create a bump, which the water will not be able to go over and instead will flow off to the side. The efficiency of this practice depends on how steep the slope is and how much water is flowing into the waterbar. This practice could also be helpful in our designs at Chimney Rocks (Hesselbarth, 2007).

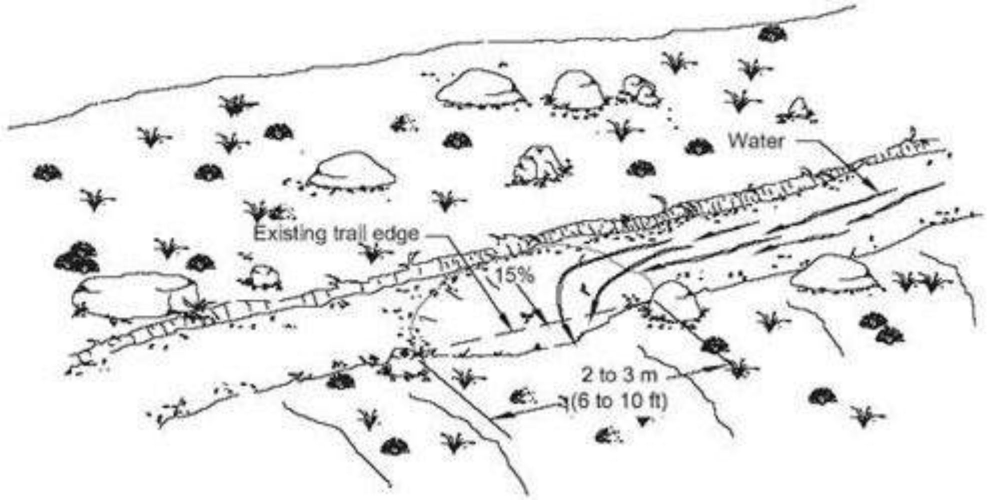


Figure 3.1. Knick Schematic (Hesselbarth, 2007)

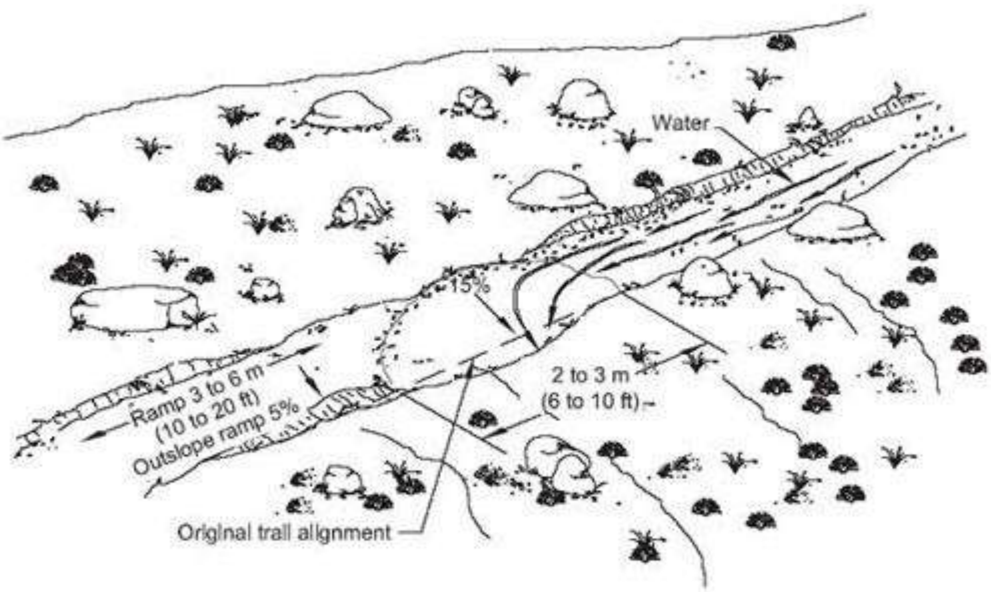


Figure 3.2. Rolling Grade Dip Schematic (Hesselbarth, 2007)

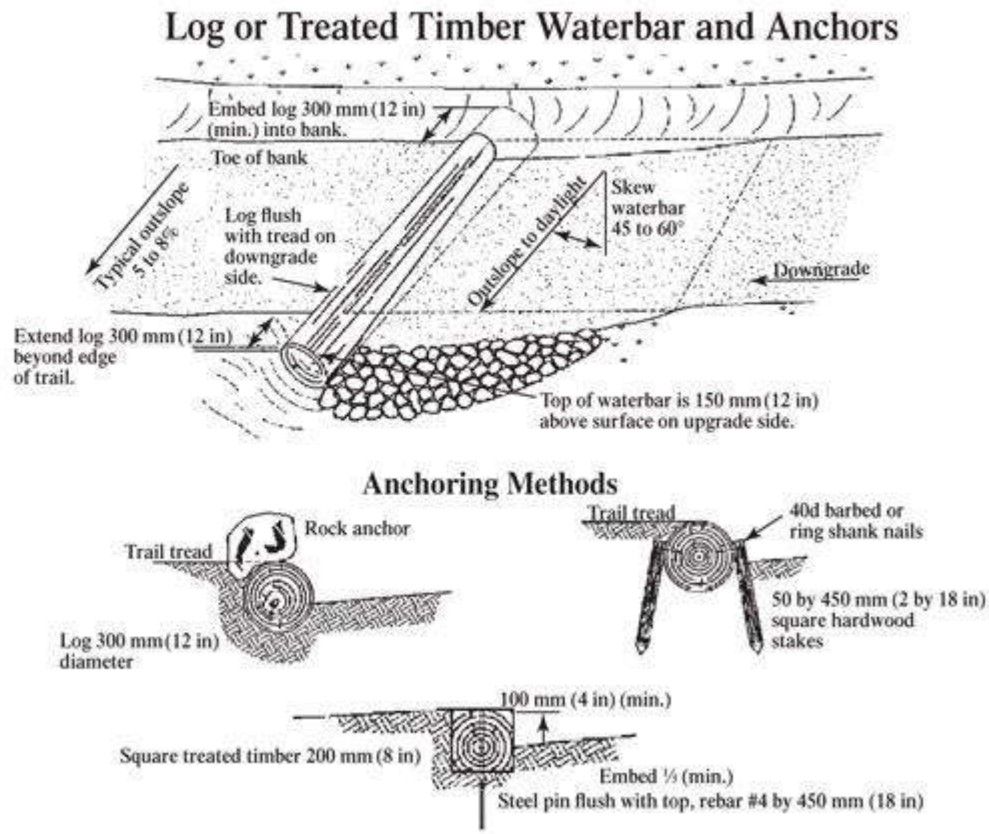


Figure 3.3. Waterbar Schematic (Hesselbarth, 2007)

3.3.2 Pennsylvania Department of Environmental Protection BMP Manual

Not only will the design have to comply with the county regulations, but it will also have to comply with the regulations of Pennsylvania. The purpose of the Pennsylvania Stormwater Best Management Practices Manual is to give guidance, options and tools to help prevent water quality issues related to construction and stormwater conveyance. The manual also provides planning concepts and design standards for the use in planning, designing, reviewing, approving, and constructing land development projects. The manual strives to prevent or minimize stormwater problems through comprehensive planning and development techniques. It also gives ways to mitigate potential problems by employing structural and non-structural BMPs. Useful BMPs mentioned that might be utilized for erosion control on a trail system would be non-structural BMPs such as limited earth disturbance and minimal soil compaction. Structural BMPs that could potentially be utilized are a vegetative filter strip, soil amendment and restoration, and BMPs for dirt and gravel roads. The BMPs for dirt and gravel roads that could be useful for the project are waterbars (figure 3.4) and broad based dips (figure 3.5). The manuals provide the maximum recommended spacing for water bars (table 3.1) and for the broad based dips (table 3.2) (PADEP, 2006).

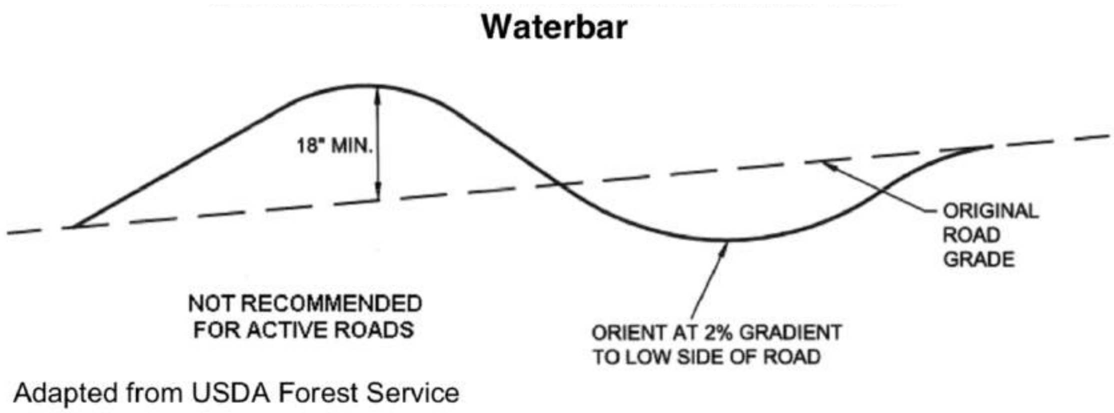


Figure 3.4. Waterbar Standard Construction Detail #3-5 (PADEP, 2006)

Table 3.1. Maximum Waterbar Spacing (PADEP, 2006)

PERCENT SLOPE	SPACING (FT)
<5	250
5 - 15	150
15 - 30	100
> 30	50

Adapted from USDA Forest Service

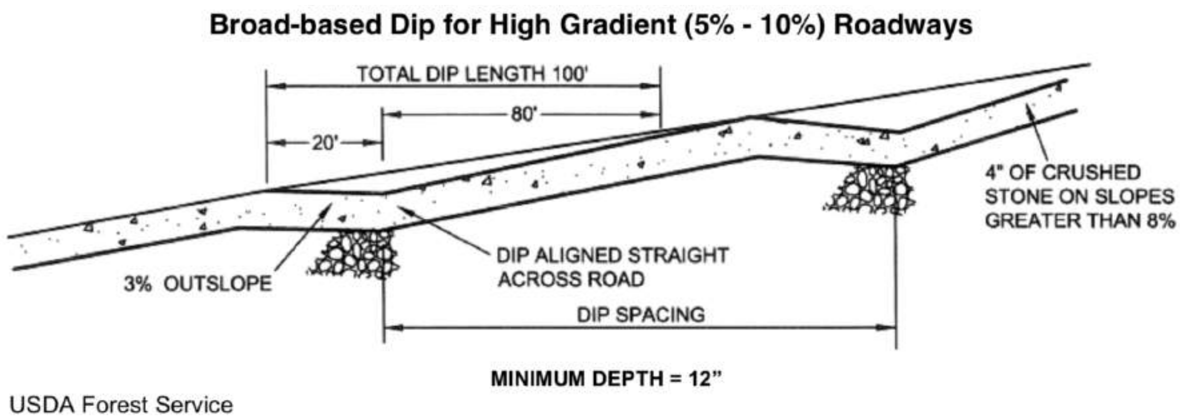


Figure 3.5. Broad-based Dip for High Gradient Roadways - Standard Construction Detail #3-7 (PADEP, 2006)

Table 3.2. Maximum Spacing of Broad-based Dips, Open-top Culverts and Deflectors (PADEP, 2006)

Road Grade (Percent)	Spacing Between Dips, Culverts, or Deflectors (feet)
<2	300
3	235
4	200
5	180
6	165
7	155
8	150
9	145
10	140

USDA Forest Service

3.3.3 Penn State Center for the Dirt and Gravel Road Studies Department

The team met with Eric Chase and Eric Nevel from the Penn State Center for Dirt and Gravel Roads department at the University Park campus. They gave us a brief presentation and provided booklets with useful information on implementation and maintenance of proper dirt/gravel roads and trails. Their department deals mostly with dirt roadways and their improvement with erosion control and surface amendments. But they were able to show us that most of the practices could be applied to hiking trails. Three erosion control practices that they suggested were adding grade breaks (figure 3.6), crowning or out-sloping the trail surface (figure 3.7), and adding rolling dips (figure 3.8). The figures provided below were in the technical guide books that the team were provided by the Center for Dirt and Gravel Road Studies department. They also showed us the benefit of adding a trail surface aggregate and provided us with a cost calculator and fact sheet for typical deliverables on dirt, gravel, and low volume road projects (PSU Center for Dirt & Gravel Studies, 2017).

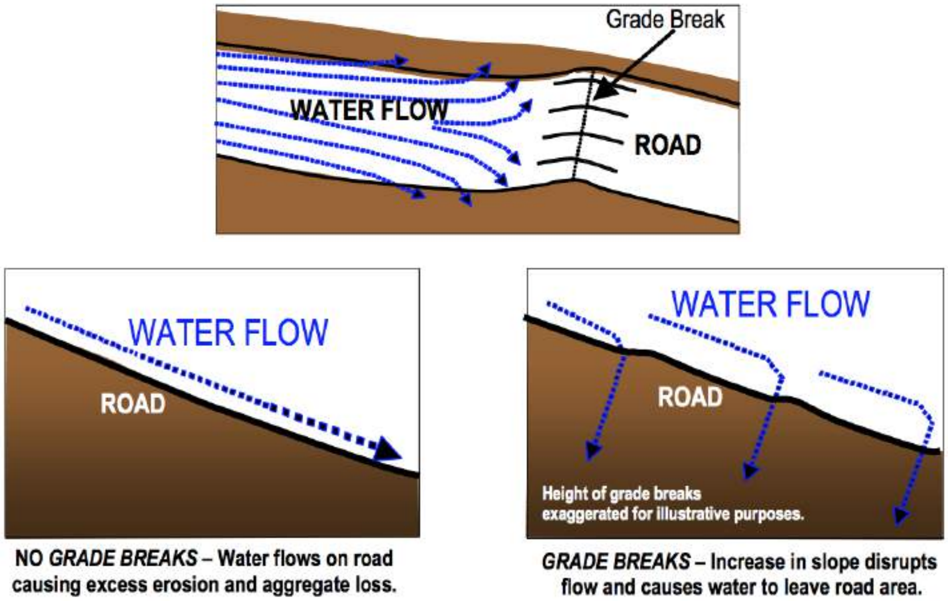


Figure 3.6. Grade Breaks used to divert water off a road or trial (PSU Center for Dirt & Gravel Studies, 2017)

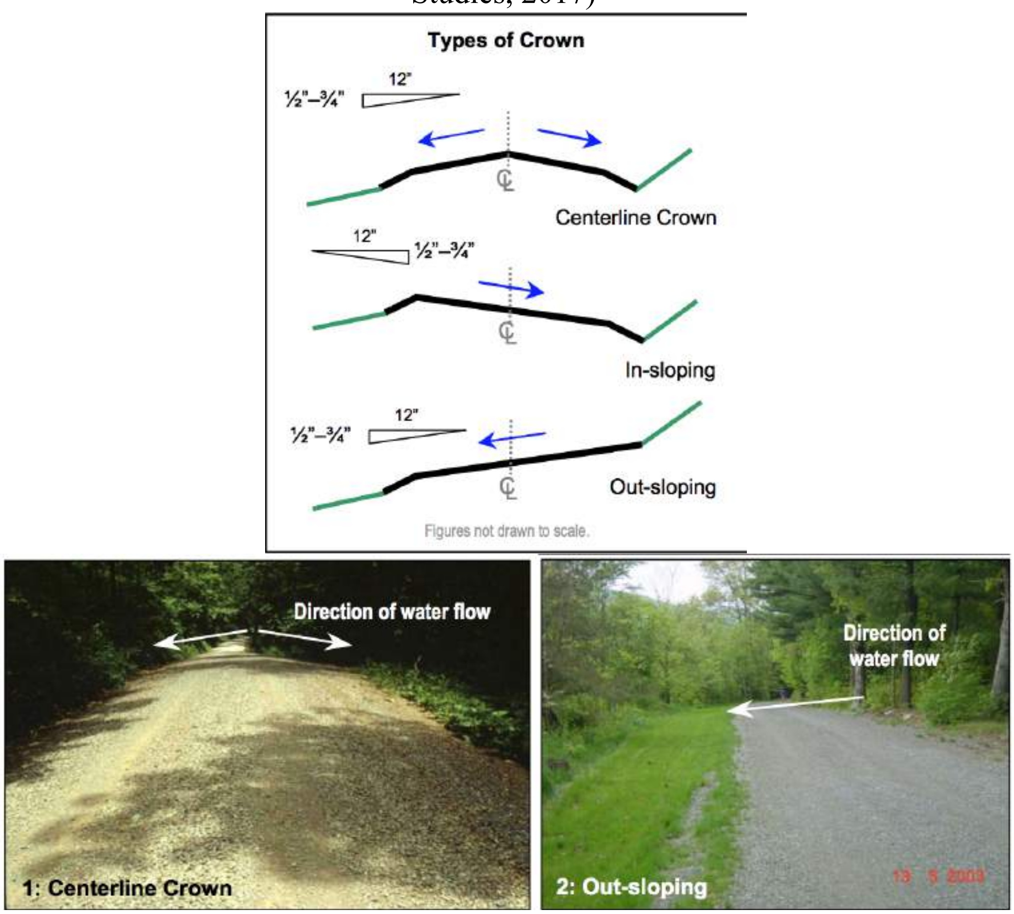


Figure 3.7. Crown and Cross-Slope cross sectional shapes of roads and trails used to drain water (PSU Center for Dirt & Gravel Studies, 2017)

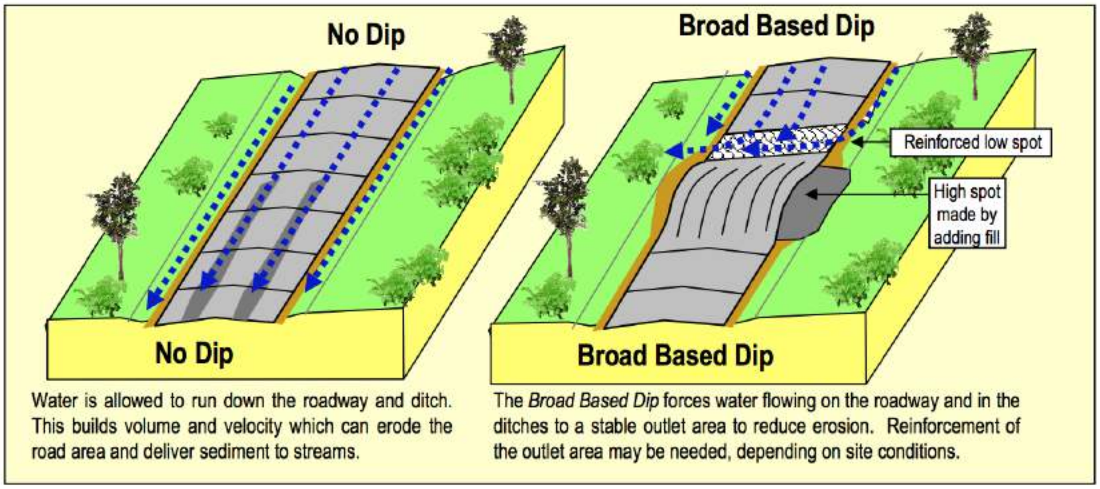


Figure 3.8. Broad Based Dips or Rolling Dip used to convey water off roadway or trail (PSU Center for Dirt & Gravel Studies, 2017)

3.3.4 Trail Surface Aggregate Technical Bulletin

The implementation of a Trail Surface Aggregate was proposed by the Center for Dirt and Gravel Roads. They suggested that this is a great way to improve a trail and have long lasting effects on the trail system. The technical bulletin gives an overview of what a trail surface aggregate mixture is, specifications on the materials in the mixture, and specifications on how to apply the material on a trail or road (PSU Center for Dirt & Gravel Studies, 2013).

3.3.5 Effectiveness and Costs of Overland Skid Trail BMPs

The objectives of the study discussed in this paper were to evaluate the effectiveness and implementation costs of erosion control practices used on skid trails. Specifically this study focused on waterbars as an erosion control practice. Different types of waterbars were compared for their effectiveness and cost. The five waterbars compared where a waterbar constructed of only soil/gravel material, a seeded waterbar, a seeded waterbar that was mulched, a waterbar with hardwood slash and a waterbar with pine slash. The study found that the waterbar that was seeded and mulched most effectively controlled erosion. The table below (table 3.3) shows the cost estimates for the different components of the waterbar implementation on a skid trail. This will help the team estimate the cost for the implementation of erosion control practices (Sawyers, 2012).

Table 3.3. Cost Estimates for Specific Components of
Skid Trail BMPs Installed (Sawyers, 2012)

Component	Information	Equipment - Supply Costs ($/mile)	Operator - Labor Costs ($/mile)	Total Installation Costs ($/mile)
Water Bar	$18.75/bar	$1,320	$660	$1,980
Seed	265 lbs/acre @ $1.11/lb	$442	$33	$475
Mulch	2 bales/50 feet @ $4.99/bale	$1,054	$ 220	$1,274
Lime	1 ton/acre @ $200/ton	$300	$33	$333
Fertilizer	200 lbs/acre @ $0.259/lb	$78	$33	$111
Slash	Cover 100 feet/hour	$2,790	$1,320	$4,110

3.4 Other Sources

3.4.1 NOAA Hydrometeorological Precipitation Frequency Data Server

NOAA Precipitation Frequency Data Server (PFDS) is a database that was developed to provide precipitation frequency estimates and associated information. A specific location can be selected and the database will display the precipitation frequency estimates for that particular location. The estimates and associated information are displayed in either tables or graphs. The associated information includes temporal distributions of heavy rainfall, time series data from the site with data collection equipment, hydrographs, and ASCII grids of the estimates that can be exported for use in GIS. Table 3.4 gives the 24-hour precipitation depths for design storms that were determined for the Chimney Rocks Park area (NOAA, 2014).

Table 3.4. Precipitation Frequency for Chimney Rocks Park (NOAA, 2014)

Average recurrence interval (years)	24-hr Precipitation Depth (inches)
2	2.66
5	3.31
10	3.84
25	4.61
50	5.24
100	5.98

3.4.2 Web Soil Survey

Web Soil Survey is an online resource that provides soil data for the entire United States. It was developed by the USDA Natural Resource Conservation Service and is constantly being updated. The soil data for Chimney Rocks Park were found on here to be used in calculations. It will be useful to have the type of soil known for use in runoff calculations. Table 3.5, below, gives the soils that were determined to be on the trail and the full soils report is given in Appendix A (USDA:NRCS, 2018).

Table 3.5. Soils Report of the Trail

Soil Map Unit	**Soil Description**	**Hydraulic Group**
HeD	Hagerstown-Rock outcrop complex, 8 to 25 percent slopes	B
Qu	Quarries-Dumps complex	Not Given
OxF	Opequon-Hagerstown-Rock outcrop complex, 25 to 50 percent slopes	D
OuD	Opequon silty clay loam, 15 to 25 percent slopes	C
MnD	Mertz channery silt loam, 15 to 25 percent slopes	C

3.4.3 FEMA Flood Map Service Center

It was a requirement in the Blair Township Stormwater Management Ordinance that the one-hundred-year floodplain boundaries have to be identified on the development site. These floodplain boundaries are to be based on the maps on FEMA Flood Study. This resource is an official public source of flood hazard information. The Flood Map Service provides official flood maps that are continuously updated, access to a range of flood hazard products, and tools that allow for better understanding of a flood risk (DHS, 2017). The FEMA flood map generated for Chimney Rocks Park is given in Appendix B.

3.4.4 DCNR Trail Funding Grants

One of the goals of the project is to have the restoration be as inexpensive for Blair County as possible. One of the ways to decrease the cost is to seek grants from nonprofit organizations or governmental agencies. The Department of Conservation and Natural Resources awards grants for Park Rehabilitation projects each year throughout Pennsylvania. While there is not a set amount of money that the fund awards, it could potentially cover the total cost of the rehabilitation. Each county has a regional advisor that oversees the applications for the grant. For Blair County, the contact is Jay Schreibman. His phone number and email are listed on the website, so he would simply need to be contacted about the feasibility of awarding a grant for our project.
The website is: http://www.antis-township.com/_pdf/community/useful-documents/Trail%20Grant%20Apllication.pdf

4.0 Ethics

4.1 Sustainability Ethics

Sustainability is one of the many important values that pertain to agricultural and biological engineers. There are several professional organizations that offer both ethics and codes pertaining to sustainability, such as the World Federation of Engineering Organizations (WFEO), the International Society of Sustainability Professionals (ISSP), the National Association of Environmental Professionals (NAEP), and there is also guidance from the American Society of Agricultural and Biological Engineers (ASABE). These organizations adopt these codes to ensure that they are conducting their work in a way that respects their ethical and sustainability-focused beliefs. This team's sustainability ethics are as follows:

- Promote planning, design, management and review of activities in a scientifically and technically objective manner.
- Incorporate the best cost-effective principles for the mitigation of environmental harm and enhancement of environmental quality.
- Research & determine the most effective method that meets the needs of our customer without compromising regulations and/or safety.
- Create and implement engineering solutions for a sustainable future that require minimal maintenance/upkeep.
- Be mindful of the economic, societal and environmental consequences of actions or projects.
- Promote and protect the health, safety and well being of the Blair County community and the Chimney Rocks Park environment.

4.1.1 Identify Sustainability Issues

The sustainability issues that could potentially affect this project are related to economic, environmental, durability, and social problems. The team must ensure that the final design is economically viable for Blair County to implement and maintain. If the final design becomes too expensive, Blair County might never implement it and their trail at Chimney Rocks might never be fixed. This would conflict with their community initiative for promoting health and wellness. The final design must also be environmentally sustainable and sound. If the final design does not meet environmental regulations, then it cannot be implemented. We also might want to do more than just having regulatory compliance so that our design will improve environmental impacts further. Also, if the final design creates more environmental harm than good, then the design defeats the purpose of the project, which is not ethical. The final design must also be durable enough to not require that much maintenance. If the final design creates a lot of upkeep after it has been implemented, then the team failed in fulfilling that customer need. The final design also needs to be socially sustainable, in that the design needs to work for people to use it and have it be socially acceptable. If our design does not end up working, then the community will not be able to use the park trail, and Blair County will be in conflict with their health initiative. Also, some of the BMPs we might use could lead to the trail being more difficult to use; for example, bumps, tree logs, and other diversions becoming tripping hazards.

Table 2. Summary of Sustainability Issues

Sustainability Issue	Impact on Design
Economic sustainability	Needs to be cost-effective for Blair County, but still expensive enough to work when implemented
Environmental sustainability	Needs to meet environmental regulations, also not harmful to the environment
Durability	Needs to not require much maintenance once it has been implemented
Social sustainability	Needs to do what it was intended for once implemented for community to be able to use it

4.2 Ethics analysis

4.2.1 Ethical issue

The biggest ethical issue that can arise during this project is if it is ethical to rely solely on labor for implementation of recommended trail restoration practices. If we prioritize cost, then the simple, inexpensive implementation method would be to use volunteers. We do not want to jeopardize the worker's safety, but we also do not want to choose practices that are less likely to work, and therefore, would further jeopardize the environment. After extensive, external research, our team thinks that the trail might need a more costly method for it to be safe and effective. For Blair County, our team thinks that if they pay more upfront now, the trail will be better in the long run. If they are not willing to put more money into the project now, then they might be spending more money later for maintenance or new methods. Our team just needs to have a conversation with our sponsor about what we feel is right.

4.2.2 Stakeholders

The main stakeholders in this project are our sponsors, us, the Blair County offices, the Blair County residents, the workers/volunteers/contractor that might implement the final design, and regulatory agencies. Our main sponsor, Tina Enderlein, is the Regional Planner for Blair County. She wants us to fix the trail at Chimney Rocks Park as part of the bigger community wide health and wellness initiative. She is relaying this information to us from the county and our information back to them. She might be harmed by the fact that the methods that we present to her might not be inexpensive, or if we do not do a great job of solving the erosion problem. Our other sponsor is Tom Shaffer, who is the Coordinator of Community-Based Studies at Penn State Altoona. He unites students at Penn State to work with the surrounding communities, and tries to make sure that Penn State students receive good publicity from the community. He could be harmed if we do not create a good solution for their erosion problem. The three of us as a team are another form of stakeholders since we will be gaining real world experience by helping Chimney Rocks restore their trail and control their erosion problem, and we will greatly benefit from this experience. The Blair County offices are a part of this project because they are the ones that originally wanted us to solve this problem for the county-wide initiative. They might be harmed by the fact that they should put more money up front for the project if implemented, since it will be safer and more effective in the long run. They might be harmed as well if they only want volunteers to implement the methods, but it is not exactly safe for them to do it, so there could be a liability issue. Also, the Blair County residents will benefit from a nice, safe hiking trail, but could be harmed if the erosion is not controlled or the implemented practices fail. The workers and volunteers that implement the methods are stakeholders as well since they could be harmed if the equipment is too heavy or dangerous. Also, Blair County might want to hire a contractor that could come in and complete the implementation process if it proves to be too dangerous for just the volunteers. Regulatory agencies are another big stakeholder because if Blair County went ahead with our final design for Chimney Rocks trail, they would have to consult with the PA Department of Environmental Protection and other county agencies before implementing. These agencies would check to make sure everything we design would comply with the necessary regulations.

4.2.3 Values

The main values that are being jeopardized by the ethical issue include honesty, safety, unity, environment, and profit. We want to be honest with our sponsor about the fact that the methods we present to the county might not be exactly what they were envisioning at first. Also, we want to value the safety of the local community members since they are going to be the ones potentially implementing the methods, and they might need more equipment than just a shovel. The value of unity is important since this entire project is part of a larger initiative for the community to come together and focus on their health and wellness. The environment is fairly important to us since we are ultimately trying to reduce and control the erosion on the trail at Chimney Rocks Park, so we can restore the environment there. Also, money/profit could potentially play a large role in this project since Blair County wanted something very low cost at first, but it might make more sense to invest more money now, so there is less maintenance.

4.2.4 Potential solutions

The best solution for our ethical issue is finding a compromise that still allows for volunteer engagement, but also using equipment. We need to continue the honest communication that we have going on now and tell our sponsors any changes or problems that arise. We also might tell Tina in our customer specifications that there could be a maximum of three pieces of machinery that are needed for implementation. Also, we will let her know that they can still have volunteers assist with the implementation, but they just should not handle the heavy machinery. While there is a limited amount of machinery to do the larger, heavier jobs on the trail, the rest of the smaller tasks can be done by the volunteers. If the cost is too much of a problem, then possibly Blair County could do a phased implementation, where they would start at the highest elevation and do some projects over the course of a few years. This might lead to more erosion problems, so it might be more beneficial to do all of the construction at once. This situation will be monitored in the future by explaining what could happen with the combination of machinery and volunteers in our final design.

5.0 Engineering Specifications

5.1 Establishing Target Specifications and Specification Analysis

The team first took the established needs that we collected from our sponsor and regulation research in Section 2 and found quantified values for each that would allow for a measurable unit. The measurable units were based off our GIS analysis and research of regulations and common allowable values. When the ideal range of values and their associated units were established, the team was able to define proper specifications for the future design.

Table 5.1, below gives the specifications that will be used to address the customer needs with their ideal range values. The table also defines the units that are associated with the given values. Most of the values defined below were determined through different analysis methods given in sections 5.2 through 5.4.

Table 5.1. Target Specifications

Specification	Limits of range	Ideal range or value	Units
Environmental Impact			
Erosion Reduction		< 714.57 ft3/acre	Amount of soil (ft3/acre)
Reduction of gully formation - no deeper than existing	0" - 5"	< 3	Inches (gully depth)
Maximum Cost (materials, equipment, labor)	10,000 - 20,000	< 15,000	$
Meet Regulations (PA E&S Control Manual, PA Code 25 Chapter 102, Blair Township Stormwater Management)			
Control practices meet design storm volume (25 yr storm)	See Table 5.2 for each structure		ft^3
Post -development runoff does not exceed pre-development runoff	See Table 5.2 for each structure		inches
Annual Maintenance	0 - 48	< 24 (2 hours/month of year)	Time (hrs)
Lifespan	5 - 25	8 - 10	Years
Implementation			
Percentage of implementation conducted by volunteer labor	0 - 100	< 50	%
Weight of hand equipment/tools	10 - 75	< 50	lbs
Pieces of Equipment	0 - 5	3	Amount
Safety			
Maximum height obstructing erosion control practices	< 10	< 6	Inches
Maximum slope of control practices	Location Dependent (see Table D.1)	< 10	(ft/ft), %
Trail can be accessed for 3 seasons	1 - 3	3	Seasons
Natural Trail surface material similar to existing	1-5	< 1.5	diameter of stone (inches)

The reduction of erosion to the trail and suspended sediment in the stormwater being discharged from the trailhead are main concerns that need to be addressed as defined by the sponsor. The volume of runoff caused by the stormwater must be reduced. This could be achieved by implementing erosion control practices at multiple locations along the trail. Also following a well written Erosion and Sediment Control Plan to ensure these structures can handle and reduce the erosion during and post construction will help to achieve the reduction of the trail erosion. The reduction of erosion can also be achieved by following already pre-existing state and county regulations. One very important regulation that any type of construction/development has to follow is not causing an increase in runoff in the post-construction volumes as compared to the pre-construction conditions. Also, for the trail and reducing erosion, the hope would be to greatly reduce the post-construction runoff volumes well below the pre-construction volumes to reduce or even eliminate any possible erosion from occuring.

It was asked of the team to find a way to implement the erosion control practices with the use of labor and not with the use of heavy equipment. Through much consideration it was determined that the use of labor for the whole implementation process could pose liability issues for the county and the durability of the erosion control practices could be negatively impacted. Requiring volunteers to carry heavy tools and materials up the trail to implement the structures could cause people to get injured in an array of ways. Most of the erosion control structures need to be compacted to insure they function properly. Labor implementation most likely will not be able to compact these structures so they last their full expected lifetime. To overcome this issue it is proposed that less than fifty percent of the implementation will be completed by the help of labor such as volunteers, although it would be ideal to have the whole project completed by labor. Since some of the implementation will be done with labor, the weight of the tools needed for this work should not exceed 50 lbs. There are locations of the trail were there is no substrate, rather the trail is just on the bedrock material. These locations will have to utilize equipment for implementation of the structures since labor is not going to be able to drill or dig in these areas to implement any type of erosion control.

The maintenance of the trail was also an important need mentioned by the sponsors. The sponsor told us that the county conducts trail condition observations every few weeks by walking the trail. The trail currently receives minimal maintenance throughout the year and it would be best to stay that way for the county's responsibility sake. The best scenario would have a trail that would only need minimal maintenance after each major storm event and after the snow melt in the spring. The maintenance efforts should be kept to less than twenty-four hours per year.

The trail and the erosion control practices have to be able to withstand specified design storms to meet the regulations of Pennsylvania and Blair County. After running watershed analysis using ArcGIS to determine current runoff volumes for each design storm, it was decided that the structures would be built to be able to control the volumes up to a 25-year storm. The 50 and 100 year storms will not happen as often and if the structures were to be built for those size of storms they would be much larger and more costly. Designing for a 25-year storm may also be much larger than what is needed on a walking trail but it will allow for the smaller storms to be controlled properly while at the same time having little to no effect on the structural integrity of the design. This will allow for reduced requirements of maintenance after a smaller storm event which is more likely to occur.

The erosion control practice should be able to be in place for between 8 and 10 years without major adjustments or updates. The lifespan of the erosion control practice will not only help reduce the necessary maintenance each year but will also help with cost and time that is needed in the future for updates. The lifespan and ability to convey the proper stormwater volumes that are normal for the trail also plays a role in the durability of the erosion control practices.

The whole cost of the project should not exceed $15,000. However, the amount of money Blair County would have to spend could be decreased by seeking funding in the form of grants and other endowments. Section 3.4.3. outlines a possible resource for funding for a trail rehabilitation project. The total cost would include planning, materials, and implementation of the erosion control BMPs and trail restoration efforts. Also related to cost would be the cost of maintaining the trail post-construction. The implemented control practices should be durable such that minimal maintenance is needed meaning the maintenance cost of both time of labor and materials does not exceed $1,000 per year.

The safety of the trial is another important need. The safety of the trail can be achieved through reducing the size of the gullies that form along the trail and by reducing the amount of water that saturates the trail. Also the safety of the people implementing the trail erosion practices and maintaining the trail in the future is important. The weight of equipment/tools, and weight and size of the materials needed for improvement and maintenance need to be considered with safety kept in mind. The safety of the hikers also needs to be considered when designing the erosion control practices. The slope of the trail and the BMPs, and the height of the BMPs should not cause obstructions on the trail that could cause hazardous tripping or falling. The slope of the newly constructed erosion practices should not exceed 10 % and their height should not exceed 6 inches if they will obstruct someone’s step. The height can exceed 6 inches if the constructed practice is built having a natural incline that is not an obstruction to walking.

The last need that has to be addressed is the requirement by the sponsor to have the trail stay natural. The trail is not to be paved or have any improvements that are unnatural to the current landscape. The use of the contour of the land and existing outslope of the trail to address the stormwater issues and possible implementation of trail surface material that resembles the existing trail surface can help the team achieve making the trail as natural as possible.

5.2 Survey of the Trail

A preliminary survey of the trail was conducted on October 14, 2018. The team visited Chimney Rocks and walked the trail. During the walk we assessed the trail and the condition on different sections to locate possible places where we thought diversions or other erosion control practices could be implemented. We measured the length of the different sections that could be used in our time of concentration calculations. We also measured the depth and widths of the gullies for use in calculating how much fill material would be needed in areas. The notes from the walk of the trail are included in Appendix C. The team determined seven locations where the trail is in need of a control practice (figure 5.1). Further calculations will have to be conducted to ensure that only seven structures in these selected locations will adequately control the stormwater and reduce erosion.

A second survey was conducted on November 11, 2018 with the use of a Total Station. Data points were taken to document the outer edges of the trail and the centerline. Other points were taken to document locations where there were gullies in the trail or where there was a berm on the outer edge of the trail. These data were processed and then used in GIS to generate the proper watershed for the area in which the trail is located. Subwatersheds were delineated for each of the selected locations as well to determine the volume of water each structure has to control. The subwatersheds delineated for the trial are given as figure 5.2. The results from the GIS analysis are given in section 5.3. The survey data are given in Appendix C. This analysis will help the team determine the existing slope of the trail and will help with determining which structures would be better suited for each location on the trail.

Figure 5.1. Proposed Locations of the Erosion Control Practices

5.3 Analysis with ArcGIS

ArcGIS was used to delineate watersheds, create a land use and soils map, find the curve number for runoff calculations and find runoff amounts for each subwatershed.

5.3.1 Delineating Subwatersheds

The GIS subwatershed analysis is given as figure 5.2. These watersheds were created using the USDA Soil and Water Assessment Tool (SWAT) within ArcGIS. This tool allows for one to use an existing elevation and a GIS geospatial format Digital Elevation Model (DEM) file to determine the flow accumulation and direction of flow of water. This tool can then be told where the outline in which an unknown watershed is to be found. It then generates the watershed boundary for that outlet point. For this project each location where a structure will be placed was considered to be an "outlet point." This helped to determine the volume of water needed to be controlled by each structure.

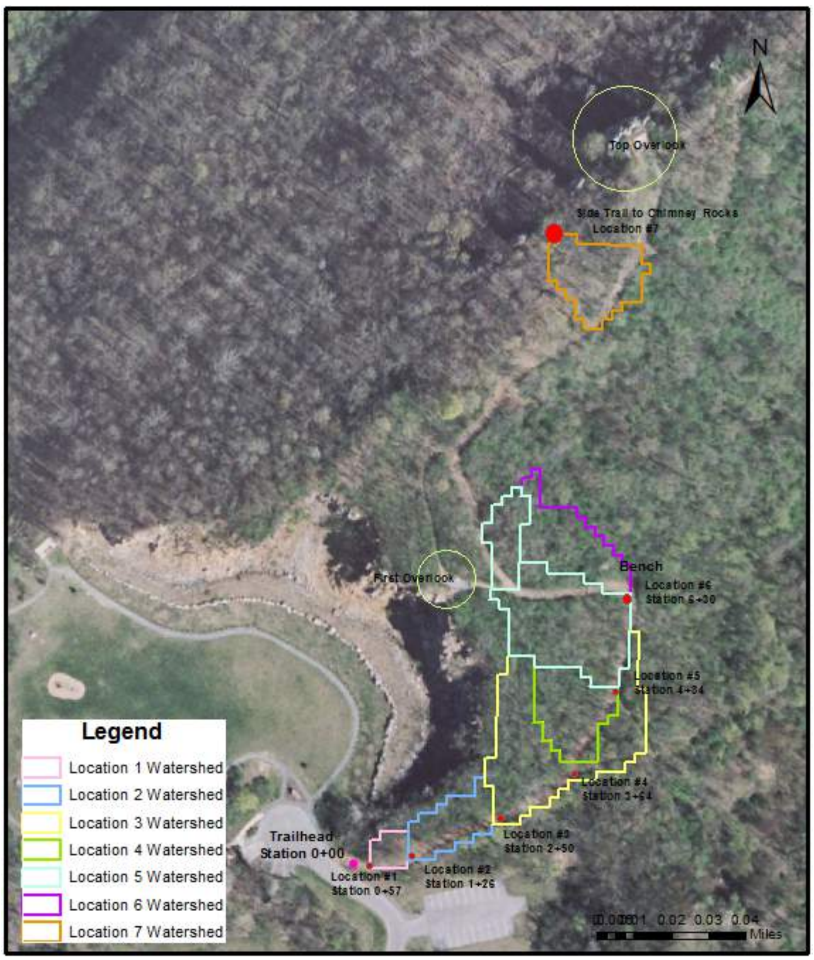


Figure 5.2 GIS analysis: Trail Control Structure Subwatersheds

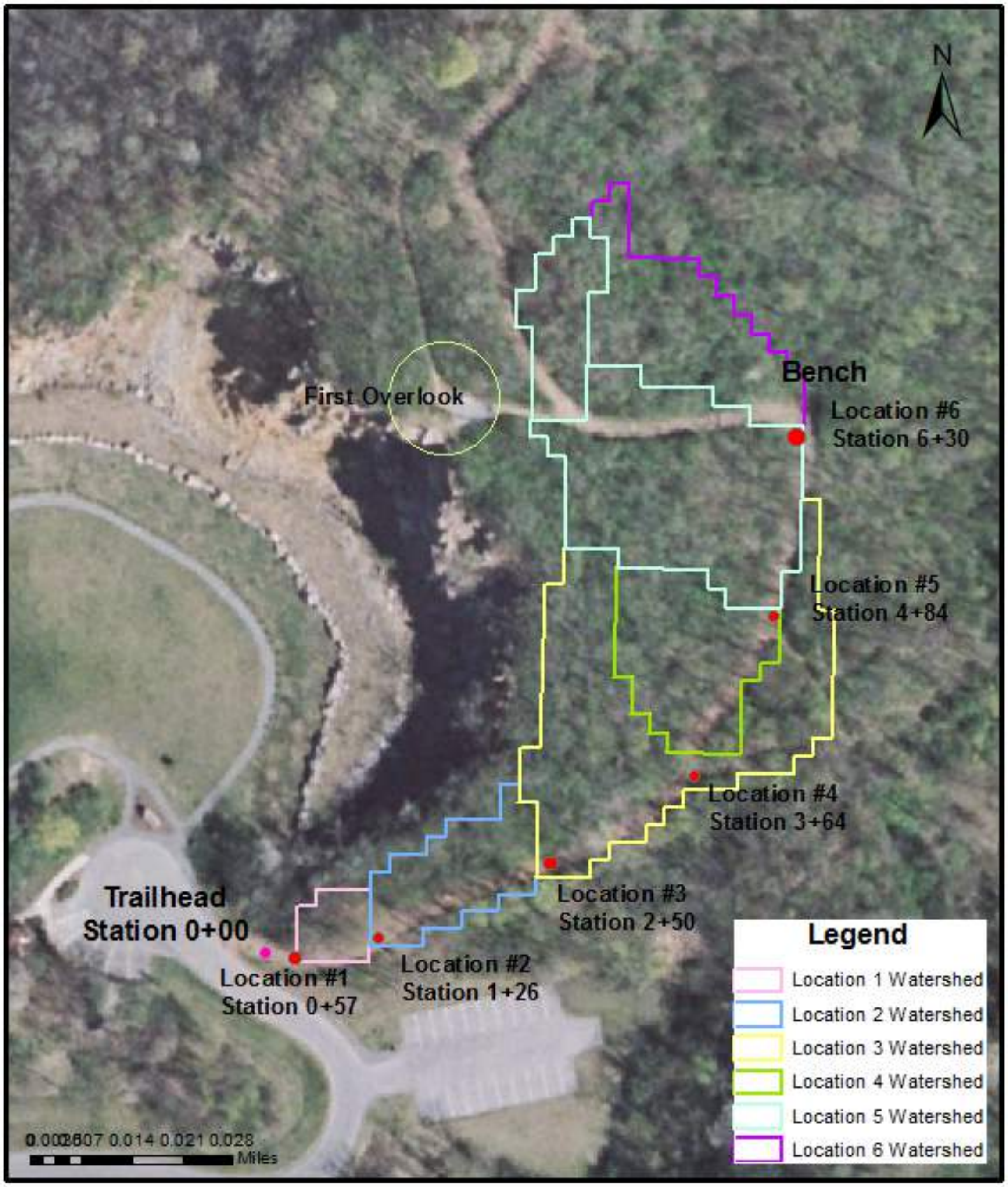


Figure 5.3. GIS analysis: Trail Control Structure Subwatersheds of Main Trail

5.3.2 Determining Runoff with ArcGIS

After the watershed boundaries were determined, the runoff was calculated within each of these subwatersheds. The runoff was found by using GIS land use and soil layers for the Chimney Rocks location. The "raster calculator" tool within ArcToolbox was used to calculate the curve numbers for use in runoff estimation. The SCS Curve Number (CN) method was used and the equation is given as equation 1. This equation was used to calculate the amount of runoff that would occur for each precipitation event (P, in inches) given in table 3.4 in section 3. The "S" variable represents the potential maximum retention after runoff begins (in inches). The maximum potential retention must be calculated first (equation 2) before the runoff (Q, in inches) can be calculated. Table 5.2 gives the results of runoff calculated using the SCS Curve Number method within ArcGIS, the runoff calculated with a weighted curve number generated using ArcGIS, and the total runoff volume calculated by taking the SCS CN method runoff and multiplying it by the watershed area. The SCS CN method runoff was used to calculate the total runoff volume since it estimated the most runoff as compared to the weighted curve number method. The runoff results for the other precipitation events for each of the subwatersheds are given in Appendix D.

$$Q = (P - 0.2S)^2/(P + 0.8S) \qquad \text{Equation 1}$$

$$S = 1000/CN - 10 \qquad \text{Equation 2}$$

Table 5.2. ArcGIS Runoff Results for Each Watershed 25-yr Storm (4.61 inch 24-hour precipitation depth)

Locations	Runoff from GIS (SCS CN method) (in)	Runoff from weighted curve number (in)	Runoff Volume (cu ft)
Location 1	2.85	2.82	3652
Location 2	2.85	2.76	1117
Location 3	2.80	2.60	3476
Location 4	2.85	2.63	1635
Location 5	2.46	2.38	3474
Location 6	1.71	1.64	1046
Location 7 (side trail)	2.85	2.82	1717

5.4 VTPSUHM (Virginia Tech, Penn State Urban Hydrology Model) Analysis

Once we had acquired the slope and curve numbers from ArcGIS, we were able to start our VTPSUHM analysis. VTPSUHM is a hydrologic software that helps in both calculations and modeling. For the purpose of this project, we were aiming to establish the peak flow rates (Table 5.3) for each of the seven locations that were identified on the trail. In order to calculate the flow rates, we first needed to calculate the travel time each watershed experiences. Using the travel time calculator in VTPSUHM, each watershed's travel time was calculated (Table 5.3). Some of the watersheds had not only sheet flow, but also channel flow since the flowpath was greater than 100 ft. Next, time of concentration needed to be calculated in order to obtain the peak flow rates. Time of concentration is the time it takes for water to get to the watershed outlet from the most hydraulically distant point. Figure 5.3 was the equation that was used to quantify time of concentration. Once we had these values, we were then able to establish peak flow rates for each watershed. Using the TR55 tabular method, both peak flow rates (Table 5.3) and hydrographs (Figure 5.4) were developed for 2, 5, 10, 25, 50, and 100 year storms. Since we are basing our design on a 25 year storm, only the 25 year hydrograph was included in the body of the report; the rest can be found in Appendix D.

Table 5.3. Travel Time, Time of Concentration, & Peak Flow Rates from VTPSUHM for a Watershed 25-yr Storm (4.61 inch 24-hour precipitation depth)

Locations	Travel Time (min) (sheet flow, concentrated flow)	Time of Concentration (min)	Peak Flow Rate (cfs)
Location 1	4.43	4.71	1.18
Location 2	8.42	9.46	0.34
Location 3	10.01, 0.47	27.64	0.66
Location 4	8.72, 0.03	11.21	0.42
Location 5	8.08, 0.39	24.01	0.72
Location 6	9.03, 0.22	26.00	0.20
Location 7 (side Trail)	11.27	17.22	0.42

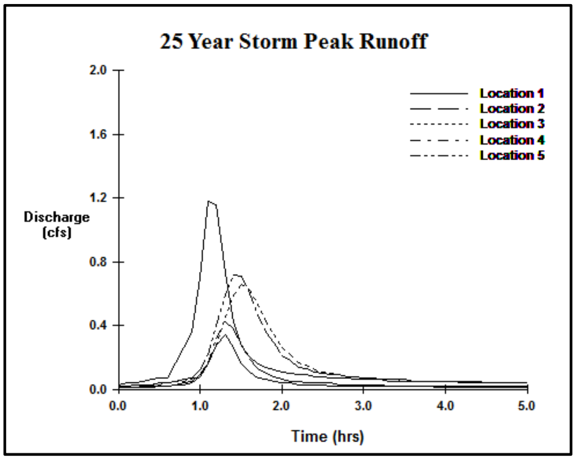
$$T_c = \frac{\ell^{0.8}(S+1)^{0.7}}{1{,}140Y^{0.5}} \qquad \text{(eq. 15–4b)}$$

where:
L = lag, h
T_c = time of concentration, h
ℓ = flow length, ft
Y = average watershed land slope, %
S = maximum potential retention, in

$$= \frac{1{,}000}{cn'} - 10$$

where:
cn′ = the retardance factor

Figure 5.3 Time of Concentration Equation



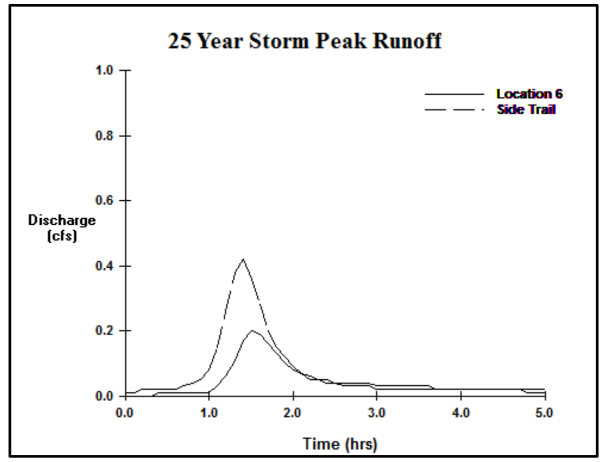


Figure 5.4 Hydrographs for 25 year storm

5.5 Relating Specifications to Customer Needs

Table 5.4, below, gives the matrix that was created to show how the specifications created by the team relate to the needs presented by the sponsors and found during research. Some of the specifications are able to satisfy more than one of the project needs.

Table 5.4. **Need-Specifications Matrix**

	Metrics	Ability to convey design storm volumes effectively	Post -development runoff does not exceed pre-development runoff	Lower amount of soil loss from current trail conditions	Maintain a low flow velocity on trail to eliminate gully formation	Keep implementation cost below $___ (low as possible, only material costs)	Trail BMPs last 8 to 10 years	Maintenace only needed following winter and large storm events	Maintenance can be completed without large equipment	Implementation hand equipment/tools less than 50 lbs	Use of equipment should be limited to 3 pieces of equipment	Height of BMPs should not exceed 6 inches	Slope of implemented BMPs should not exceed 10%	Imported material should be similar to excisting landscape material	Erosion control designed on and with the natrual grade of exisiting trail	Well Written E&S Plan
Needs																
Minimal erosion to the trail			x	x	x								x			x
Reduce stormwater discharge		x	x		x			x				x	x			x
Minimal implementaion cost						x					x					
Meet Regulations			x	x							x					x
Minimal maintenance				x			x	x								
Low maintenance cost							x	x	x							
Man power implementation										x						
Safety			x	x				x	x	x	x	x	x		x	
Liability									x	x		x	x			
Keep the trail natural												x		x	x	
Durability		x	x	x	x		x									
Trail can be accessed in spring, summer, and fall		x	x	x	x			x					x		x	
Cultural impact							x				x					
Alignment with ethics/values											x				x	

6.0 Concept Generation and Selection

6.1 Concept Generation

After surveying and running through calculations for runoff volumes the team was able to determine locations on the trail where it seemed fitting to implement control practices. There were seven locations on the trail that were determined to be suitable for a control practice. There were six locations on the main trail and one location on the side trail to the chimney rocks where a structure could potentially be placed. The team will consider different structures for each location and also determine if all seven locations will need a structure or if the erosion can be controlled with fewer structures. The fewer the structures that have to be implemented means the less time and cost it would take for implementation and maintenance on the trail. But only implementing a few structures would mean each has to control a larger volume of stormwater. Implementing a structure at each of the seven locations would reduce the amount of water that each structure has to control. Controlling less water could help the structures have a longer lifespan and could potentially require less maintenance.

Not only were locations determined for erosion control structures to fix the issues on the trail, but the team also found locations on the trail where fill material is needed or steps would be a good to implement to eliminate the chance of slipping on the trail. Concepts were created for consideration for both the erosion control practices and trail surface improvements. Once the concepts were generated, concepts were selected for each location or stretch of trail. More than one concept was chosen to then be compared to one another for the best concept to be determined. The concepts chosen for each location/portion of the trail are summarized in tables 6.1 through 6.9 provided in Section 6.2: Concept Selection and Analysis.

6.1.1 Concept 1: Waterbar

A waterbar is typically used on access roads or forest skid roads as a means to direct stormwater runoff into a well-vegetated area. They are designed to discharge the runoff to the downslope of the trail or road to force the water away from the road and to ensure it will not flow back on to the surface of the road. Waterbars are recommended to be reinforced with the incorporation of a log or steel pipe to maintain the integrity of the waterbar in high traffic locations. Although this recommendation is for roads and trails in which equipment would be traveling often, it could be a wise consideration for a trail with heavy foot traffic. It is recommended that waterbars be constructed with no more than a 2% gradient to ensure the water controlled by the structure is conveyed properly. The minimum height of the down slope portion of the waterbar structure is recommended to be 18 inches. In Section 3.3.2 the schematic of a waterbar, from the PA Erosion and Sediment Pollution Control Program Manual, was given. Also given in section 3.3.2 is a chart that details the maximum waterbar spacing design requirement based on the slope of the original grade of the trail. In Section 3.3.1, a different method of implementing a waterbar is given as figure 3.3. This waterbar is achieved with anchoring a log to the trail surface that would help divert water to the down slope side of the trail. After surveying and general observations of the trail at Chimney Rocks it was decided that a waterbar might be a proper concept to be implemented at locations 1 through 7.

A waterbar can have both advantages and disadvantages in designs depending on the location in which they are being considered. These structures work best when they are on slopes less than 30% and when they are vegetated. If the vegetation is not well established this can lead to erosion of the waterbar structure and the need for frequent maintenance. With respect to the Chimney Rocks project a waterbar may be a disadvantage since fill material would be needed, equipment would be needed to pack the fill material in place, and the vegetation may not be able to establish on the structure from the frequent foot traffic. The advantages of a waterbar may outweigh the disadvantages in some locations on the trail, though. To achieve a 2% gradient to outslope the trail surface could pose as an advantage. This gradient is needed in front of the structure to force the water to the vegetated area on the side of the trail. In some locations the trail is almost already dug to the bedrock meaning not much gradient change can be accomplished without large heavy equipment that could remove the rock. Since only a 2% gradient is needed to outslope the trail a large alteration in the bedrock substrate would not be needed. Also instead of constructing the entire waterbar about of fill and rock material the center of the waterbar could be constructed with a log that is then covered with the fill material.

6.1.2 Concept 2: Rolling Dip/Broad-Based Dip

A rolling dip or broad-based dip is similar to a waterbar as it is implemented to direct stormwater runoff off of roadways and trails into a vegetated area. The difference though is that broad-based dips are easily traversed by construction equipment and they require much less maintenance to maintain proper function. It is sometimes necessary to reinforce the bottom of the rolling dip and its outlet with larger material to reduce the chance of erosion of the structure. These structures are recommended for trails that have a surface gradient of less than 10%. The stormwater should be discharged to the downslope side of the trail with the use of a maximum slope of 3% in the dip. There are separate standard construction details provided in the PA Erosion and Sediment Pollution Control Program Manual for trail slopes less than 5% and slopes between 5% and 10%. In section 3.3.2 the construction detail for broad-based dips on high gradients (5%-10%) is given. In this section the maximum spacing between the structures is given in table 2 which is based on the original road grade. Two other schematics of a rolling dip are given in section 3.3.1 as figure 3.2 and in section 3.3.4 as figure 3.8.

Following surveying and general observations of the trail at Chimney Rocks it was decided that this structure might be a proper concept to be implemented at locations 1 through 4 and at locations 6 and 7. The advantages and disadvantages of the broad-based dip need to be considered at each of the locations that were determined to be appropriate for this type of control structure. One disadvantage that this trail could pose for this structure is that material needs to be removed from the trail surface to create the grade needed to outslope the structure for water conveyance. This could be an issue in locations where the trail has been eroded all the way to the bed rock. These areas will not be a good location to implement a broad-based dip. Another disadvantage is that this structure can only be used on slopes less than 10%. Some locations on the trail at Chimney Rocks greatly exceed this slope.

When considering concepts the slope may play a great role in the final decision. Take an original slope of the trail to be less than 2%. For broad-based dips on this gradient they can be spaced apart 300 feet. If waterbars were implemented on the same slope they would need to be spaced 250 feet apart. For a long stretch of trail that remained at a 2% grade one could implement a lot fewer structures by choosing to use broad-based dips. This could help save on material costs, construction costs and maintenance requirements.

6.1.3 Concept 3: Grade Break

Grade breaks are very similar to broad-based dips; the only real difference is that the grade break acts as a wall and water is then forced to both sides of the trail. The increase in the slope of the road helps to disrupt the flow on the trail and forces the water off into a vegetated area. A broad-based dip is built so that the intentional increase in the road elevation is on an angle to force the runoff to only one side of the trail. The spacing is critical when designing these types of structures. On steeper slopes more grade breaks are required with shorter straight aways in between them since stormwater will accumulate over the distance in both volume and velocity. It is recommended that this structure be used on gentle-to-moderate slopes that are less than 10 percent in grade. A schematic for a grade break both before and after implementation is given in Section 3.3.4 as figure 3.6. This type of structure will be considered for locations 1, 2, and 4 through 7.

The advantages of these structures on a roadway setting are it is a reliable treatment that is relatively inexpensive and easy to install and maintain. It helps to break up the contributing area of the stormwater to help reduce the potential effects of erosion. Disadvantages of these structures are that it can require large quantities of material to form the proper shape and grade of the structure, and equipment is needed to haul material to the site, up to the location on the trail, and for compaction and shaping of the grade break. Another disadvantage that could be created for this structure is that the slope of the Chimney Rocks trail is very steep.

6.1.4 Concept 4: Crown & Cross-Slope

Crown and cross-slope, both in-sloped and out-sloped, are methods of reshaping and resurfacing a trail to have a surface slope that forces stormwater off the trail as sheet flow to eliminate the chance of erosion of the surface. Crowned roads are effective for roads with gradients 8 percent or more and the cross-slope surface is recommended for use on roads that have a slope 8 percent or less.The schematic for the three different trail surface shapes are given in Section 3.3.4 as figure 3.7. This figure gives both a drawn cross-sectional representation of these structures and pictures of the crown and cross-slope implemented on actual roads. This concept will be considered for parts of the trail that need improvements completed to fix the gullies that have formed. These parts of the trail are located between location 1 and 2, and between locations 3 and 4.

These three trail surface shapes have a few similar advantages and disadvantages with respect to the project at Chimney Rocks Park. An advantage of this concept would be that reshaping the trail to a slope that conveys water off the trail would help remove the stormwater quickly off the trail to reduce concentrated flows down the length of the trail. The sheet flow of water off the trail is much less likely to cause erosion as compared to concentrated flows down the length of the trail. Another advantage would be that the lifespan of the trail could be estimated to last much longer than other trail surfaces if the resurfacing material was the aggregate mixture that the PSU Center for Dirt and Road Studies Department recommends. A disadvantage of this concept could be extensive equipment that would be needed to apply the aggregate mixture or other fill material and equipment that could then compact and shape the trail surface. The steep slopes of parts of the trail could also pose a problem for the ability of equipment to be able to properly implement the material. The slope of the trail could also cause an issue in the effectiveness of road-surface shape conveying water off the trail.

6.1.5 Concept 5: Filling Gully & Material Selection

Another concept to be considered to fix the gullies on the trail would be to just fill in the formed gully with a fill material instead of resurfacing the whole trail (concept 4). The purpose of fixing the gullies on the trail would be to help make the trail surface less uneven and treacherous for safety reasons. Just as with concept 4, concept 5 is being considered for the stretches of the trail between locations 1 and 2, and between locations 3 and 4. The amount of the fill material will be calculated for the cross sections of the trail that will be generated after the survey data from November 11, 2018 are analyzed. This amount of fill material can be compared to the amount of material that would be needed to completely resurface the trail. It is expected that the results will show that just filling in the gully will require a lot less material, equipment, and time. This concept would also be consistent with the fact that the county wants the trail to stay as natural as possible. Although there are these benefits with cost and time, concept 5 has the potential to not be as durable as other erosion control methods.

6.1.6 Concept 6: Walking Steps

Another concept to be considered for the stretch of the trail between locations 3 and 4 is to implement steps. This section of the trail has a very high clay content in its trail surface. When this section is wet the trail surface is very slick that could cause hikers to fall and be injured. The implementation of steps could help reduce the chance of injury on this stretch of trail and could also help hikers traverse this section a lot easier since it is a very steep section of the trail. There could be a few disadvantages associated with this concept. The placement of the steps would have to be done by digging into the existing trail surface. This would not be able to be completed properly if the bedrock material is close to the trail surface as it is on other sections of the trail. You would also need large heavy equipment to get the stones to the location and dug and placed properly.

6.2 Concept Selection and Analysis

Once the concepts were generated, the concepts were each considered for the seven locations along the trail. Two to three concepts were chosen for each location to then be compared for the determination of the best concept at a particular location on the trial. The results of the scoring for each location are provided in table 6.1 through table 6.9. The tables show the score that each concept received for the location and the determination if the concept should be continued to be considered or removed from consideration for the location. When scoring the separate concepts for the locations many factors had to be considered, including the existing dimensions, slope, and natural constraints of the trail along with the requirements of each erosion control practice to ensure a particular structure could be implemented and function efficiently and properly. For example, if a location on the trail had a steep slope certain structures can only be implemented on trails that have a slope of 10 percent or less. This means when scoring the selection criteria of meet regulations or reduce stormwater discharge they would receive low scores. The regulations of the structure cannot be implemented on a steep slope and if not implemented properly then the structure will not properly control the stormwater discharge. Another factor considered when scoring the concepts was the volume of water that each structure had to handle. Each concept varies in its ability to control stormwater. Waterbars are much better at conveying slow moving volumes and grade breaks can handle large, fast moving volumes more effectively. The volume of water that each structure would have to convey was determined with the use of ArcGIS and VTPSUHM analysis conducted with the use of the survey conducted with the Total Station.

At location 1 the concepts of a waterbar, broad-based dip, and grade break were considered (table 6.1). At this location there is already a natural dip in the trail and stormwater following that leads off the right side of the trail. This led the team to believe that a broad-based dip in this location was a proper structure. After scoring the three potential concepts at location 1 it was determined that a broad-based dip was the high scoring concept. The waterbar scored low since at this location the implementation of a waterbar would impede the natural gradient of the trail. The grade break received a low score since there is no way for water to be removed off the trail on both sides. There is a large bank to the left and on the right there is a slightly elevated berm. A broad-based dip could be implemented by incorporating it into the existing dip in the trail and the berm on the right side of the trail could be modified to allow an outlet for the stormwater being conveyed by this structure. The volume of water that needs to be controlled at this location after a 25-year 4.61 inch precipitation event was found to be 3652 ft3 and the peak flow rate was determined to be 1.18 cfs. A broad-based dip would be able to be designed properly to convey this amount of runoff.

Table 6.1. Concept Selection for Location 1

		Location 1					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356	4	0.356
Reduce stormwater discharge	0.089	4	0.356	4	0.356	4	0.356
Minimal implementaion cost	0.072	3	0.216	4	0.288	3	0.216
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	3	0.216	4	0.288	3	0.216
Low maintenance cost	0.072	2	0.144	4	0.288	3	0.216
Man power implementation	0.053	1	0.053	1	0.053	1	0.053
Safety	0.089	3	0.267	4	0.356	3	0.267
Liability	0.072	3	0.216	4	0.288	3	0.216
Keep the trail natural	0.072	3	0.216	4	0.288	3	0.216
Sustainability/Durability	0.072	4	0.288	4	0.288	4	0.288
Trail can be accessed in spring, summer, and fall	0.071	5	0.355	5	0.355	5	0.355
Cultural impact	0.035	3	0.105	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	1						
	Total Score		3.392		3.913		3.464
	Rank		3		1		2
	Continue		no		yes		no

The stretch of trail between location 1 and 2 has major issues with erosion and a gully has formed. For this stretch of trail the concepts of filling in the gully and crowning or cross-sloping the trail surface were considered (table 5.2). The concept of filling material into the gully to bring it back to the natural grade of the trail surface received the high score. The concept scored the highest since it was the most natural approach to solve the issue, was less expensive, and over time would involve less maintenance and maintenance costs.

Table 6.2. Concept Selection for Location between 1 & 2

		Location between 1&2			
		Filling Gully		Crown & Cross-Slope	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	1	0.089	4	0.356
Reduce stormwater discharge	0.089	1	0.089	3	0.267
Minimal implementaion cost	0.072	4	0.288	1	0.072
Meet Regulations	0.089	3	0.267	3	0.267
Minimal maintenance	0.072	3	0.216	4	0.288
Low maintenance cost	0.072	4	0.288	3	0.216
Man power implementation	0.053	2	0.106	1	0.053
Safety	0.089	4	0.356	4	0.356
Liability	0.072	4	0.288	4	0.288
Keep the trail natural	0.072	4	0.288	1	0.072
Sustainability/Durability	0.072	3	0.216	3	0.216
Trail can be accessed in spring, summer, and fall	0.071	3	0.213	3	0.213
Cultural impact	0.035	3	0.105	3	0.105
Alignment with ethics/values	0.053	4	0.212	2	0.106
total	**1**				
	Total Score		3.021		2.875
	Rank		1		2
	Continue		yes		no

At location 2, the concepts of a waterbar, broad-based dip, and grade break were considered (table 5.3). The concept that scored the highest was the broad-based dip, but the grade break was a close second. Since these two concepts scored so close they both will be further considered for this location. The waterbar scored much lower for this location since the implementation of a waterbar would cause a large increase in the natural existing grade. The waterbar would also require a lot more maintenance at this location from the amount of stormwater discharge it would have to control. The volume of water that needs to be controlled at this location after a 25-year 4.61-inch precipitation event was found to be 1117 ft3 and the peak flow rate was determined to be 0.34 cfs. Modeling software will be used to determine whether a broad-based dip or grade break will be able to better manage this runoff volume.

Table 6.3. Concept Selection for Location 2

		Location 2					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356	4	0.356
Reduce stormwater discharge	0.089	4	0.356	4	0.356	4	0.356
Minimal implementaion cost	0.072	3	0.216	4	0.288	4	0.288
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	3	0.216	3	0.216	3	0.216
Low maintenance cost	0.072	4	0.288	3	0.216	3	0.216
Man power implementation	0.053	2	0.106	2	0.106	2	0.106
Safety	0.089	4	0.356	5	0.445	5	0.445
Liability	0.072	3	0.216	4	0.288	4	0.288
Keep the trail natural	0.072	3	0.216	5	0.36	4	0.288
Sustainability/Durability	0.072	3	0.216	4	0.288	4	0.288
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284	4	0.284
Cultural impact	0.035	2	0.07	2	0.07	2	0.07
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	1						
	Total Score		3.5		3.877		3.805
	Rank		3		1		2
	Continue		no		yes		yes

At location 3, the concepts of a waterbar and a broad-based dip were considered (table 5.4). This location on the trail is situated at the bottom of a steep section. The water that will reach this location will have a large velocity but not a large volume since location 4 is situated about 115 ft above, intercepting water before the steep portion of the trail. Since there will not be a large volume, the waterbar concept scored high for this location. Also a broad-based dip may be difficult to implement at this location since the trail is not far from the bedrock material. It would be much easier and more cost effective to implement material to construct a waterbar rather than try to dig a dip in bedrock material. The volume of water that needs to be controlled at this location after a 25-year 4.61 inch precipitation event was found to be 3476 ft3 and the peak flow rate was determined to be 0.66 cfs. A properly built exaggerated waterbar structure would be able to be convey this runoff volume.

Table 6.4. Concept Selection for Location 3

		Location 3			
		Waterbar		Broad-based Dip	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356
Reduce stormwater discharge	0.089	4	0.356	3	0.267
Minimal implementaion cost	0.072	3	0.216	3	0.216
Meet Regulations	0.089	5	0.445	5	0.445
Minimal maintenance	0.072	4	0.288	3	0.216
Low maintenance cost	0.072	4	0.288	3	0.216
Man power implementation	0.053	2	0.106	2	0.106
Safety	0.089	3	0.267	3	0.267
Liability	0.072	4	0.288	3	0.216
Keep the trail natural	0.072	3	0.216	4	0.288
Sustainability/Durability	0.072	4	0.288	3	0.216
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284
Cultural impact	0.035	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159
total	**1**				
	Total Score		3.662		3.357
	Rank		1		2
	Continue		yes		no

The stretch of trail between location 3 and location 4 is very steep. On the right side of the trail a large gully has formed, and the left side of the trail surface is composed of mostly clay which becomes very slippery when wet. For reasons of safety and ease of hiking, the team considered a few different concepts for this section. The concepts considered were filling in the gully with stone material, crowning or cross-sloping the entire trail surface, and implementing stairs. The concept that scored the highest was implementing a fill material of stones into the gully to make the surface of the trail all one elevation. The crowning or cross-sloping scored the lowest since this concept is the least natural option, and on such a steep slope it would not properly convey stormwater off the trail. The stormwater would most likely just run down the trail even faster than before rather than being conveyed to the forested areas on either sides of the trail. This concept would also not be able to just be implemented on a section of the trail. If resurfacing of the trail was considered, it would have to be considered for the entire trail. The concept of implementing steps scored lower than filling in the gully, but the team believes this concept should be further considered. This is because the implementation of stairs could help hikers get up this section much easier rather than on slippery clay material when the trail is wet.

Table 6.5. Concept Selection for Location between 3 & 4

		Location between 3&4					
		Filling Gully		Crown & Cross-Slope		Steps	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	1	0.089	3	0.267	1	0.089
Reduce stormwater discharge	0.089	2	0.178	3	0.267	2	0.178
Minimal implementaion cost	0.072	5	0.36	2	0.144	2	0.144
Meet Regulations	0.089	3	0.267	3	0.267	3	0.267
Minimal maintenance	0.072	3	0.216	4	0.288	3	0.216
Low maintenance cost	0.072	3	0.216	2	0.144	2	0.144
Man power implementation	0.053	3	0.159	1	0.053	1	0.053
Safety	0.089	4	0.356	3	0.267	4	0.356
Liability	0.072	3	0.216	3	0.216	4	0.288
Keep the trail natural	0.072	4	0.288	1	0.072	1	0.072
Sustainability/Durability	0.072	3	0.216	4	0.288	4	0.288
Trail can be accessed in spring, summer, and fall	0.071	3	0.213	2	0.142	4	0.284
Cultural impact	0.035	3	0.105	2	0.07	3	0.105
Alignment with ethics/values	0.053	3	0.159	2	0.106	3	0.159
total	**1**						
	Total Score		3.038		2.591		2.643
	Rank		1		3		2
	Continue		yes		no		yes

At location 4, the concepts of a waterbar, broad-based dip, and grade break were considered (table 5.6). Both the broad-based dip and the grade break score very similarly for this location. The waterbar scored much lower since at this location the trail is too steep for the implementation of a waterbar. The amount of stormwater that needs to be controlled at this location is too much for a waterbar. It would be more cost effective to use either a grade break or a broad-based dip since they would require less maintenance over time. The volume of water that must be controlled at this location after a 25-year 4.61 inch precipitation event was evaluated to be 1635 ft3 and the peak flow rate was determined to be 0.42 cfs. Both a broad-based dip and grade break would be able to be designed properly to convey this amount of runoff volume.

Table 6.6. Concept Selection for Location 4

		Location 4					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356	4	0.356
Reduce stormwater discharge	0.089	4	0.356	5	0.445	5	0.445
Minimal implementaion cost	0.072	3	0.216	4	0.288	4	0.288
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	3	0.216	4	0.288	4	0.288
Low maintenance cost	0.072	3	0.216	5	0.36	4	0.288
Man power implementation	0.053	2	0.106	3	0.159	3	0.159
Safety	0.089	3	0.267	4	0.356	4	0.356
Liability	0.072	3	0.216	4	0.288	4	0.288
Keep the trail natural	0.072	3	0.216	4	0.288	4	0.288
Sustainability/Durability	0.072	4	0.288	5	0.36	5	0.36
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284	4	0.284
Cultural impact	0.035	3	0.105	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	**1**						
	Total Score		3.446		4.181		4.109
	Rank		3		1		2
	Continue		no		yes		yes

At location 5, the concepts of a waterbar, broad-based dip, and grade break were considered (table 5.7). This is located at the point in the trail were there is a bench and the trail takes a sharp turn to the left. At this location the waterbar concept scored the highest. This is because this location is relatively flat and a waterbar would be the only concept that would be effectively implemented and effectively control the stormwater. The volume of water that needs to be controlled at this location after at 25-year 4.61 inch precipitation event was found to be 3474 ft3 and the peak flow rate was determined to be 0.72 cfs. A waterbar would be able to be designed properly to convey this amount of runoff volume.

Table 6.7. Concept Selection for Location 5

		Location 5					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356	4	0.356
Reduce stormwater discharge	0.089	5	0.445	4	0.356	4	0.356
Minimal implementaion cost	0.072	4	0.288	3	0.216	3	0.216
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	4	0.288	3	0.216	3	0.216
Low maintenance cost	0.072	3	0.216	4	0.288	4	0.288
Man power implementation	0.053	3	0.159	3	0.159	3	0.159
Safety	0.089	3	0.267	4	0.356	4	0.356
Liability	0.072	3	0.216	3	0.216	3	0.216
Keep the trail natural	0.072	3	0.216	4	0.288	4	0.288
Sustainability/Durability	0.072	4	0.288	3	0.216	3	0.216
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284	4	0.284
Cultural impact	0.035	3	0.105	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	**1**						
	Total Score		3.732		3.66		3.66
	Rank		1		2		2
	Continue		yes		no		no

At location 6, the concepts of a waterbar, broad-based dip, and grade break were considered (table 5.8). This location on the trail is located at the top of a short incline near the first overlook. A erosion control structure could be implemented to control the water before it goes down the incline and gains momentum to further erode the trail as the water moves down towards the bench. At this location the broad-based dip scored the highest. This is because at this location there is already a natural dip that could be used to control stormwater runoff. If the natural dip was over exaggerated and used as part of the structure then the stormwater could be effectively controlled and conveyed off the trail. The volume of water that needs to be controlled at this location after a 25-year 4.61 inch precipitation event was found to be 1046 ft3 and the peak flow rate was determined to be 0.20 cfs. The creation of a broad-based dip within the existing natural dip in the landscape would be able to be designed properly to convey this amount of runoff volume.

Table 6.8. Concept Selection for Location 6

		Location 6					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	4	0.356	4	0.356
Reduce stormwater discharge	0.089	3	0.267	4	0.356	4	0.356
Minimal implementaion cost	0.072	2	0.144	4	0.288	3	0.216
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	3	0.216	4	0.288	3	0.216
Low maintenance cost	0.072	3	0.216	4	0.288	4	0.288
Man power implementation	0.053	2	0.106	3	0.159	2	0.106
Safety	0.089	3	0.267	4	0.356	4	0.356
Liability	0.072	3	0.216	4	0.288	3	0.216
Keep the trail natural	0.072	3	0.216	4	0.288	4	0.288
Sustainability/Durability	0.072	3	0.216	4	0.288	3	0.216
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284	4	0.284
Cultural impact	0.035	3	0.105	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	**1**						
	Total Score		3.213		3.948		3.607
	Rank		3		1		2
	Continue		no		yes		no

At location 7, the concepts of a waterbar, broad-based dip, and grade break were considered (table 5.9). This location is on the side trail that leads to the chimney rock formations. The trail at this location is relatively steep which could reduce the effectiveness of a waterbar and caused this structure to score as second. The orientation of the trail caused the grade break to score the lowest. At this location the broad-based dip was determined to be the best concept to implement. The volume of water that needs to be controlled at this location after a 25-year 4.61 inch precipitation event was found to be 1717 ft3 and the peak flow rate was determined to be 0.42 cfs. A broad-based dip would be able to be designed properly to convey this amount of runoff volume.

Table 6.9. Concept Selection for Location 7

		Location 7					
		Waterbar		Broad-based Dip		Grade Break	
Section Criteria	**Weight**	Rating	Wgtd Score	Rating	Wgtd Score	Rating	Wgtd Score
Minimal erosion to the trail	0.089	4	0.356	5	0.445	4	0.356
Reduce stormwater discharge	0.089	4	0.356	4	0.356	3	0.267
Minimal implementaion cost	0.072	3	0.216	4	0.288	3	0.216
Meet Regulations	0.089	5	0.445	5	0.445	5	0.445
Minimal maintenance	0.072	3	0.216	4	0.288	3	0.216
Low maintenance cost	0.072	3	0.216	4	0.288	3	0.216
Man power implementation	0.053	2	0.106	3	0.159	2	0.106
Safety	0.089	3	0.267	4	0.356	3	0.267
Liability	0.072	3	0.216	4	0.288	3	0.216
Keep the trail natural	0.072	3	0.216	4	0.288	3	0.216
Sustainability/Durability	0.072	3	0.216	4	0.288	3	0.216
Trail can be accessed in spring, summer, and fall	0.071	4	0.284	4	0.284	4	0.284
Cultural impact	0.035	3	0.105	3	0.105	3	0.105
Alignment with ethics/values	0.053	3	0.159	3	0.159	3	0.159
total	1						
	Total Score		3.374		4.037		3.285
	Rank		2		1		3
	Continue		yes		yes		no

7.0 Safety Analysis

The table below shows the hazards that could be associated with our trail restoration project. This table includes potential effects and injuries for each hazard and their quantitative analysis. This analysis includes the exposure, likelihood and consequences for the potential injuries of each hazard. The values of the analysis are multiplied to get the total hazard value. The higher values are more hazardous to our project and the people involved. Our more significant hazards are the uneven walking path and the heavy materials that might be needed during implementation, while the slippery trail poses the least amount of risk. Waterbars and walking steps might not be the best concept to use based on this analysis, but also broad-based dips or gully-filling might also not be the safest. In order to avoid injury, our specifications in section 5 account for the maximum and target values for both the existing hazards (gullies) and the structures that might be implemented (waterbars, broad-based dips).

Table 7: Hazard Analysis

Hazard	**Factors contributing to hazard**	**Effect/Injury Potential**	**Quantification**			
			Expo.	**Like.**	**Cons.**	**Total**
Uneven elevation & walking path	Eroded gullies & displacement of rock	Hikers tripping or falling; breaking bones	5	5	5	125
Heavy equipment/ materials during implementation	Volunteers won't be able to handle the equipment	They'll get hurt from the machinery or materials	3	5	7	105
Slippery trail	Rainwater and runoff	Hikers slipping & falling down	6	5	1	30
Steep Slope	It is situated on a steep slope	Equipment may be damaged during maintenance	3	4	6	72
Areas of sudden trail height increase	Protrusion from waterbar or broad based dip	Hikers tripping or falling; Broken bones	4	4	5	80

8.0 Special Topics

8.1 Budget and Vendor Purchase Information

For this project, there was no official budget given by our sponsor. However, it was made clear to us from the beginning that the design should be as inexpensive as possible. The vision of the sponsors was to utilize community volunteers to help with the design implementation so that the project would not only bring the community together, but also that labor costs would be reduced. After researching the options suitable to stabilize the trail, it became clear that this was likely not the best option. The main expenditures of our concepts include the machinery necessary to implement the practices, labor costs to run the machines, and the material needed to construct the practices. The material/labor costs can be estimated in different ways. Once we identify the type of material we will need based on our best management practice recommendations, we can identify a supplier of that material and get an estimate directly from them. Also, there is a Dirt, Gravel, and Low Volume Road materials calculator on the Penn State Center for Dirt and Gravel Road Studies website that calculates the cost of a certain material based on the volume the material will take up. Additionally, our contacts in the same department sent us Figures 8.1.1 and 8.1.2, which give estimates for the cost of certain materials as well as costs to rent and operate certain machinery. Travel costs back and forth to the trail are also included in the budget. Since our final deliverable will be a feasibility study, our group is considering making multiple proposals that vary in cost, so that the borough of Hollidaysburg can choose how much they would be willing to spend if they accept our recommendations.

Dirt, Gravel, and Low Volume Road Program

Summary of Typical Costs

April, 2015

Center for Dirt and Gravel Road Studies

This sheet presents rough cost estimates for typical deliverables on Dirt, Gravel, and Low Volume Road Projects. This is intended as a rough price guide only. Prices vary widely around the State. PEMA / FEMA rates may have changed since the date of this publication. Always check current listings.

Item	Unit	Expected Cost per Unit		Typical DGLVR Program Use and Notes
		Material Only	Installed / Completed	
STONE			*Note:*	*Installed cost of stone products is highly dependent on trucking distance.*
Driving Surface Aggregate (DSA)	Ton	$15-$25	$20-$35	Driving surface
AASHTO #1 Stone *(PA #4, ballast)*	Ton	$10-$20	$15-$25	4" top size. Fill for French mattress, road fill to allow drainage, underdrains
AASHTO #3 Stone *(PA 3A)*	Ton	$10-$20	$15-$25	3" top size. Road fill to allow drainage.
AASHTO #10 Stone *(screenings)*	Ton	$10-$20	$15-$25	Pipe Bedding
AASHTO #57 Stone *(PA 2B)*	Ton	$10-$20	$15-$25	1.5" top size. Clean stone for underdrains, road sub-base or fill
2A Stone	Ton	$10-$20	$15-$25	2" top size. Graded, clean. Road sub-base
2RC Stone	Ton	$10-$15	$14-$20	2" top size. Graded, highly variable composition. Road sub-base or fill
Riprap R-3	Ton	$16-$22	$26-$32	6" top size. Outlet stabilization, road base.
Riprap R-4	Ton	$18-$24	$28-$34	12" top size. Concentrated flow stabilization (ditches, outlets)
Riprap R-5	Ton	$20-$26	$32-$38	18" top size. Concentrated flow stabilization (ditches, outlets)
Riprap R-6	Ton	$22-$28	$36-$44	24" top size. Concentrated flow stabilization (stream banks, outlets)
DRAINAGE			*Note:*	*installed cost for pipes includes backfill, inside diameters listed.*
4" perforated	Linear Ft.	$2-$4	$6-$8	Underdrain
6" perforated	Linear Ft.	$3-$5	$7-$9	Underdrain
12" HDPE, dual-wall smooth bore	Linear Ft.	$7-$11	$20-$30	Drainage culverts **(HDPE = High-density polyethylene (plastic pipe))**
15" HDPE, dual-wall smooth bore	Linear Ft.	$8-$12	$40-$50	Drainage culverts
18" HDPE, dual-wall smooth bore	Linear Ft.	$14-$18	$45-$55	Drainage culvert in larger drainages.
24" HDPE, dual-wall smooth bore	Linear Ft.	$18-$22	$50-$60	Drainage culvert, stream crossing.
30" HDPE, dual-wall smooth bore	Linear Ft.	$24-$30	$60-$70	Drainage culvert, stream crossing.
36" HDPE, dual-wall smooth bore	Linear Ft.	$28-$34	$70-$80	Drainage culvert, stream crossing.
Stone Headwall or Endwall	Each	$50-$100	$100-$200	Protect pipes ends from erosion. (price is each, budget two per pipe)
French Mattress (18"D x 20'W x 50'L)	Each	~$2,800	~$4,000	Stone structure wrapped in fabric under a road to allow water to flow freely
GEO-FABRICS				

Figure 8.1.1. Summary of typical costs for materials

Item	Rental	FEMA/PEMA Rate*	Typical DGLVR Program Use and Notes
EQUIPMENT	*Notes:*	*PEMA/FEMA rates do not include labor and do not apply to contracted equipment*	
Dozer, crawler, up to 75 HP	Rental rates are highly variable based on location, for a general estimate, multiply the hourly FEMA/PEMA rate by 10-15 to estimate a daily rental rate. (i.e. small dozer @$31/hr = $310-$465/day)	$31/hr	Spread material
Dozer, crawler, to 105 HP		$40/hr	Spread material
Dozer, crawler, to 160 HP		$65/hr	Spread material
Dozer, wheel up to 300 HP		$55/hr	Spread material
Grader, up to 110 HP and 10' blade		$34/hr	Re-shape road surface.
Grader, up to 150 HP and 12' blade		$58/hr	Re-shape road surface.
Excavator, 1 CY Bucket		$39/hr	Excavate trenches, pits and place material
Excavator, 1.5 CY Bucket		$65/hr	Excavate trenches, pits and place material
Backhoe, 1 CY Bucket		$23.5/hr	Excavate trenches, pits and place material
Backhoe, 1.5 CY Bucket		$33/hr	Excavate trenches, pits and place material
Loader, Skid Steer, (2,000lb cap.)		$18/hr	Loading and moving material.
Trucking (~22 tonTriaxle)		$65/hr	Hauling material
Paver, up to 125 HP		$115/hr	Place asphalt and DSA
Paver, to 175 HP		$125/hr	Place asphalt and DSA
Roller, 8 Ton Vibratory		$25/hr	Compact asphalt, DSA and sub-base material
Roller, 10 Ton Vibratory		$29/hr	Compact asphalt, DSA and sub-base material
Jumping Jack	$60-$80/day	-	Compact pipe bedding

Figure 8.1.2. Costs of various equipment

8.2 Project Management & Ethics Statement

All three members of our team are majoring in natural resources engineering, giving us a broad understanding of soil and water related issues. We all felt very comfortable taking on this project given our backgrounds. We all had experience with surveying equipment from our classwork in BE 307, Principles of Soil and Water Engineering. Molly built on that experience with her internship with the Natural Resource Conservation Service this past summer, where she consistently surveyed different types of landscapes. We leaned on that knowledge when we went to survey the Chimney Rocks trail, which yielded productive results. In order to interpret our data, the software we have used in BE 467, Design of Stormwater and Erosion Control Facilities, will be incredibly useful. VTPSUHM is software that helps to calculate time of concentration, flow duration, and develop hydrographs. Once we are able to analyze the surveying data, we will be able to quantify important aspects of the surface runoff. We have also extensively reviewed BMPs in BE 467, which will help us to pick the most effective ones to use in our design.

Our team has an ethical responsibility to make our design as safe as possible. That being said, we cannot simply pick the least expensive possible design, knowing that it is probably not the safest choice. We must be responsible for making sure all parties involved can safely utilize our design, the people that will construct it as well as the people who will use it. We also have an ethical responsibility to take care of the environment and to leave it in a better condition than when we found it. This includes choosing BMPs that are least invasive the environment and its inhabitants. Our team is aiming to exceed the environmental standards in the design of this project by following the standards set for the state of PA in the Pennsylvania Stormwater Best Management Practices Manual and the Pennsylvania Department of Environmental Protection Erosion and Sediment Pollution Control Manual. Chimney Rocks trail is something that the Hollidaysburg community seems to value. Each time we have went for a site visit, we have seen residents enjoying the trail. Upgrading it and making it safer would definitely be a welcomed change. Following these guidelines will help us to stay focused on our goals while keeping our standards in mind.

8.3 Project Risk Plan

This project's main purpose is to correct the erosion that is taking place, causing the trail to become increasingly unsafe. Our number one priority is to improve the safety of the trial, while also minimizing the erosion as much as possible. Our sponsors have made it clear that money is not an abundant resource and that an expensive redesign of the trail may not be feasible. It is our job to create designs that are safe but also relatively inexpensive. As mentioned in the table, a possible strategy could be to create multiple designs that differ in cost, giving the community board more flexibility in their decision. Now that we have surveyed the trail, it is very important that we are able to translate the data from the surveying equipment to the relevant program that will help analyze it. Since we are unfamiliar with the equipment, it will be important to reach out to people that have experience to guide us. Since our designs will be diverting surface runoff, it will important to quantify how much water will be entering stormwater outlets and whether or not that could lead to flooding. Having relevant software, like VTPSUHM, will help us calculate the stormwater that will be entering the outlets so that we can be sure that we are not causing any issues.

Table 8.3.1 Risk Plan

Description	Risk	Actions to Minimize	Fall Back Strategy
Customer being dissatisfied with final design	Medium	- Keep updated with customer preferences - Cater design to be as customer friendly as possible	- Create numerous designs to choose from - Have a convincing argument as to why our design is necessary
Ability to integrate survey data into GIS	Medium	- Contact faculty that are experienced with software - Research methods to integrate data	- Utilize familiar programs like Excel to interpret data

Design features create a safety risk	High	- Select the most effective design options that are also safe - Detail steps to advertise the risk created from the design	- Select less efficient designs that are safer
Increase in runoff to outlets causes flooding	Low	- Quantify the runoff from 10, 25, 50, and 100 year storms before and after design is implemented	- Suggest creating another outlet to handle the new flow pattern of the water

8.4 Communication and Coordination with Sponsor

Communicating with our sponsor was extremely important to our group. We wanted to make sure that they were constantly aware of where we were doing each week, so we sent a summary email every Monday, starting on September 17th, 2018. The emails detailed what we had accomplished over the last week and also what we were planning to do in the upcoming week. WE have also met with our sponsor multiple times in person. The first time was the initial meeting, when Tina and Tom showed us the trail and gave us their ideas/vision for the trail. The second time we briefly talked to Tina while we were taking measurements on the trail. We also met with them when we had visits at other state parks in the area that have fixed similar problems that we're trying to, and when we met with the township supervisors. Tina has been a very helpful and responsive sponsor, providing us with any information that we ask for. She sent us relevant maps and data sheets, as well as sources where we could find additional data.

8.5 Timeline

Now that we have surveyed the trail, we will now be able to start making important steps towards selecting concepts for our design. We first must be able to convert the data from the survey device into a relevant program, like GIS. That will help us to better analyze and interpret the data. Once we return from winter break, we will be able to quantify the surface runoff and erosion from the trail. VTPSUHM will be very useful to help calculate data like time of concentration and maximum flow rate, while also developing hydrographs. The data we gather from that will help in selecting the proper best management practices to implement on the trail. The locations we marked in appendix C could receive a mix of BMPs depending on what we decide will work best. We will also need to figure out how much each BMP will cost to implement. Depending on the type of material and the machinery needed to implement them, the designs could become expensive. We will have to be sure we are being as economical as possible. Each BMP we decide on will also need to be accompanied by a drawing, detailing the dimensions and type of material. All of these things will need to be double checked, which would be our last step in the design process. Throughout all of these steps, out report will need to be constantly updated and edited to reflect our progress.

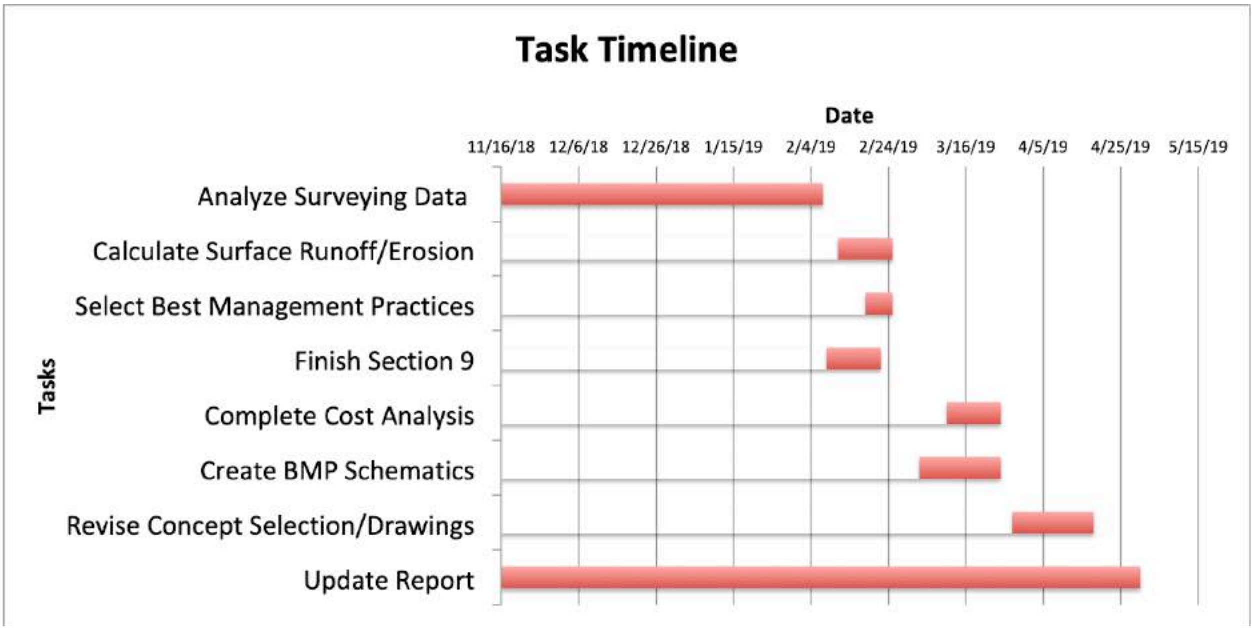


Figure 8.5.1. GANTT Chart of Tasks

9.0 Detailed Design

9.1 Detailed Analysis

Once we knew that we were going to be creating channels to carry the water off the trail, we had to make sure that they would be able to perform efficiently for our target design storm (25 year, 24 hour). In order to make sure our calculations were correct, we decided to double check with hand calculations, specifically with Manning's equation (Figure 9.1). This method is widely used for governing open channel flow. It is a function of channel velocity, flow area, and channel slope, all of which are crucial elements of our design. We used this method for each structure, since the numbers were dependent of the specific size of each channel. Our goal was to calculate the max velocity each channel would experience and compare that to the max allowable velocity of various materials that could possibly be used to line the channel. After deciding on a mannings value of 0.025 based on figure 2, we used formulas based on a trapezoidal shaped channel to calculate the hydraulic radius and area. Once we had calculated the velocity of each point, we compared the values to the numbers listed in Figure 9.3. Based upon our calculations, each structure was under the max permissible velocity compared to the 150 mm Gravel/Cobble mix, which is similar to the material we will be using to line the channel/outslope. The calculations can be found in appendix E. The calculations proved that each structure was able to handle the 25 year, 24 hour storm.

The property boundary of the park was also found to ensure that the water that would be diverted off the trail surface would not be forced onto neighboring landowner properties. This was checked using a map given to the team by the Blair County Planning Commision. The map is given below as figure 9.4. The map shows that there is over 200 feet between the edge of the trail where the structure outlet would be located and the park property boundary. The flows found during analysis, given in table 5.5 in section 5, were very low and it was assumed that these small flow rates would not cause any issues for neighboring properties. It was also assumed no major erosion would result in the vegetated, wooded area off the trial from the diversion of the water.

$$Q = VA = \left(\frac{1.49}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [\text{U.S.}]$$

Q = Flow Rate, (ft^3/s)
v = Velocity, (ft/s)
A = Flow Area, (ft^2)
n = Manning's Roughness Coefficient
R = Hydraulic Radius, (ft)
S = Channel Slope, (ft/ft)

Figure 9.1 Manning's Equation

4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033

Figure 9.2 Various Manning's n Values

Category	Critical Shear (Pa)	Maximum Velocity (m/s)
Soils		
Fine sand (colloidal)	1.2	0.46
Sandy loam	1.7	0.53
Alluvial silt (noncolloidal)	2.3	0.61
Alluvial silt (colloidal)	12.5	1.14
Silty loam (noncolloidal)	2.3	0.61
Firm loam	3.6	0.76
Fine gravels	3.6	0.76
Stiff clay	12.5	1.16
Graded loam to cobbles	18.2	1.14
Graded silts to cobbles	20.6	1.22
Shales and hardpan	32.1	1.83
Gravel/Cobble		
25-mm	15.8	1.14
50-mm	32.1	1.37
150-mm	95.8	1.75
300-mm	191.5	2.67
Vegetation		
Long native grasses	70	1.52
Short native and bunch grasses	40	1.07
Degradable Linings		
Jute net	22	0.53
Straw with net	80	0.61
Coconut fiber with net	110	1.07
Fiberglass roving	96	1.45
Soil Bioengineering		
Live fascine	104	2.1
Willow stakes	125	2.0
Hard Surfacing		
Gabions	480	5.0
Concrete	600	5.5
Source: Fischenich (2001).		

Figure 9.3 Critical Shear and Velocity for Selected Channel Lining Materials

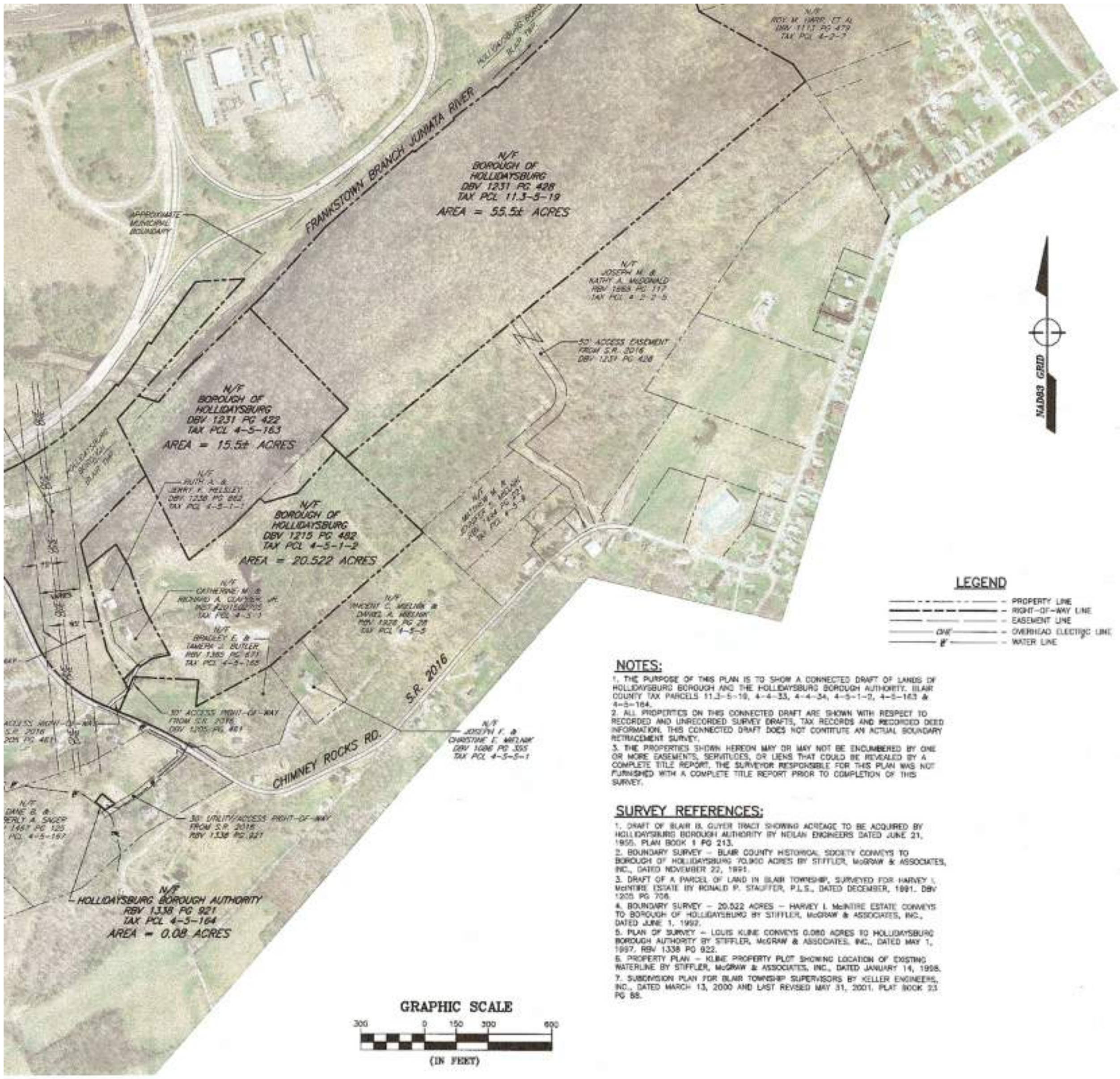


Figure 9.4. Property Boundary of Chimney Rocks Park

After all of our research of different erosion control structures used on roads and trails, the best option for the Chimney Rocks Trail was narrowed down to two of the options, broad-based dips and waterbars. The Pennsylvania Department of Environmental Protection BMP Manual provides design standards for both broad-based dips (figure 3.5 and table 3.2) and waterbars (figure 3.4 and table 3.1). It was decided to use a combination of these structures since the waterbars can be used on trails with slopes over 30% and broad-based dips provide a slightly larger out-slope in its dip section. The combined structure design will be composed of a dip with an out-slope of 3%, spaced no more 100 feet apart, and have a mound after the dip with a higher elevation than the dip. The higher elevation of the mound will help to ensure the volume of water the structure must control does not exceed its capacity. The combined structure design of 3% out-slope and no more than 100 ft spacing on the trail fits within the recommendations for these structures mentioned in the Pennsylvania Department of Environmental Protection BMP Manual.

Once the combined structure design standards were determined the structures were designed in AutoCAD Civil 3D. The structures were designed at the six proposed locations on the main trail defined in section 5. The structures were designed using line work within Civil 3D. The elevations along each line of the structure were determined using Lidar data downloaded from PA DCNR. Civil 3D is able to pull the elevation data at points within a surface created from the lidar data. Once the lines had the specified elevations at each of their vertices, the points within the created structure were altered. The elevation editor function in Civil 3D was used to change the existing elevation values to modify the structure to the proper standards. The alterations were conducted in the locations were the dip and mound would be located. The bottom and top edge of the structures were kept at the existing elevations. This was done to ensure once the structure was in place the ground could be properly graded back to the existing elevation of the trail. After, the alterations of the elevations on the edges of the structure were graded back to the existing elevations using the grading function. The only structure that was not designed based on the combined standards of the waterbar and the broad-based dip was the structure at location 6. This structure was designed to only resemble a broad-based dip since this section of the trail was already slightly out-sloped and there was a 90 degree curve in the trail at this location. The start and end of the structure was sloped inward slightly towards a central point that had a designed outslope to force the water off the trail.

Once the proper standards were met the design was checked with the SWMM program to determine that the volume of water during a 25-year, 24-hour storm could be controlled by each structure. The first few times of checking it was determined that the first designs of each structure would not completely control all the volume. The structures were then altered until it was determined that they would control all the volume of water properly. The slope in the bottom of the dip was kept constant, the height of the mound after the dip was increased slightly. It was only heighted enough to ensure it would control all the water and not cause the slope from the existing trial surface to the top of the mount to be too steep. When all the final structures were designed the elevations alone each line of the structure were exported in to an Excel file so that the designs could be properly implemented. The exported details give the station location were the structure would be implemented, lengths of each segment, and elevations at each important vertices of the structure. The slopes between each vertex is also given. These tables are located in Appendix E.

9.2 Material Selection Process and Design Optimization

The type of material that will be used to create the structures is vital to the design. The chosen aggregate has to look natural in respect to the trail, but also must be able to be able to be compacted and not easily erodible. The material to line the channel and the outfalls must be able to handle the max velocity of runoff from a various rainfall events. The material has to be durable enough to last for years without having to being repaired. We reached out to Eric Chase and Eric Nevel and the PSU Center for Dirt and Gravel Road Studies for recommendations for the type of material we should use for the structures since they have experience buying and implementing dozens of types of material. They suggested investigating 2A and 2RC materials, since they are common fill materials that are compatible. The 2A material ranges from 10-20 $/ton depending on the supplier, and the 2RC material ranges from 10-15 $/ton depending on the supplier. Figure 9.5 shows the descriptions of the two types of material in further detail based on PA suppliers. These two descriptions led us to decide to use the 2RC material, since it does not drain like the 2A material.

This will help to further promote stormwater runoff off of the trail. The compaction will help to reduce erosion from the structure, increasing its lifespan. The material that will line the channel/outslope of the structures will be a gravel like material that will have to be big enough that it will not move based on a 25 year, 24 hour storm. The easiest material to buy would be a gravel mix with a size of 150 mm that is readily available at quarries across central PA. The cost varied from 15-25 $/ton depending on the supplier. Based on our max velocity equations (appendix E), this size of gravel would be most appropriate. This size material had a high enough max allowable velocity to handle the storm. This material is generally referred to as rip rap, and it is commonly used in channel design/erosion control. The material is very easy to replace if it is lost over time due to trail use or runoff, which is why it is recommended that more material is bought than actually needed for the design.

STONE AGGREGATE DESCRIPTIONS
for 2014 ACCOG Jt. Purchasing

NEW NAME	OLD NAME	Description
AASHTO #1	4	• This material has a 4 inch top size, sometimes called ballast. • Too bulky to be used as a surfacing material but it is great for subgrade stabilization. • Used for construction entrances, road base and ditch lining. • Clean material that does not compact
PA 2A		• PennDOT 2A has a 2 inch top size and many fines • Great compaction and used as a road base and under slabs • Primarily a clean material that will compact and will drain • Used where stability and drainability are concerns.
2RC / 2A Modified	2RC	• Material has a 2 inch top size and is a mix of coarse stone and fine material • Fines in material will include dirt, silt, loam, or clay • Great compaction and is used under slabs, road base, and fill • Primarily a dirty material that will compact and does not drain
AASHTO #3	3A	• This material is similar to AASHTO #1, but has a 2.5 inch top size. • It is also a bulky material but is somewhat easier to handle. • Used mostly in drainage situations • Clean material that does not compact
3A Modified		• Blend of #3 and 2RC/2A MOD. 2 ½" topsize • Used as heavy-duty sub-base for roads and parking lots. • Great for areas with deep fill requirements where compaction is desired.

Figure 9.5 Description of Aggregates

9.3 Sustainability in Design

The team is looking to use a combination of broad based dips and modified waterbars in the final design of this project. Before in the research, waterbars using just a piece of wood, as seen in figure 3.3, were another possible structure that could be used in the final design. However, we soon learned that these kind of waterbars are slightly outdated in the trail restoration world and they create a significant amount of maintenance, compared to broad based dips (figure 3.5) and modified waterbars (figure 3.4). We learned this information from Allen Gwinn, who is part of the Army Corps of Engineers at Raystown Lake. Having little to no maintenance was one of the more important customer needs for our sponsor, so if we were to suggest implementing a design that would include a lot of maintenance, we would not be creating something environmentally sustainable for the trail, and it would also be unethical. This was one of the main reasons that we chose to incorporate a combination of broad based dips and modified waterbars using fill material in our final design, because they are more environmentally and economically sustainable for the people of Blair County. Since these trail structures won't require as much maintenance and upkeep, the community will get more use out of the trail. These structures are also more gradual and natural-looking with the trail, whereas the waterbars using just a piece of wood could pose as a tripping hazard on the trail. The sustainability issues were addressed in our engineering design by using a combination of broad based dips and modified waterbars using fill material as our main trail structure instead of waterbars using a piece of wood.

9.4 Drawings

Below is an overview of all the structures along the trail (figure 9.6) and a zoomed in view of the first structure on the trail. The line work designed structure is given as figure 9.7 and the 3D model of the structure is given as figure 9.8. The rest of the designed structures and 3D models are given in Appendix E. Appendix E also contains the construction details of the structures needed for proper implementation and figures that show the change in existing to proposed trail profile at the locations of the structures.

Figure 9.6. Overall Trail Structure Civil 3D Alignment

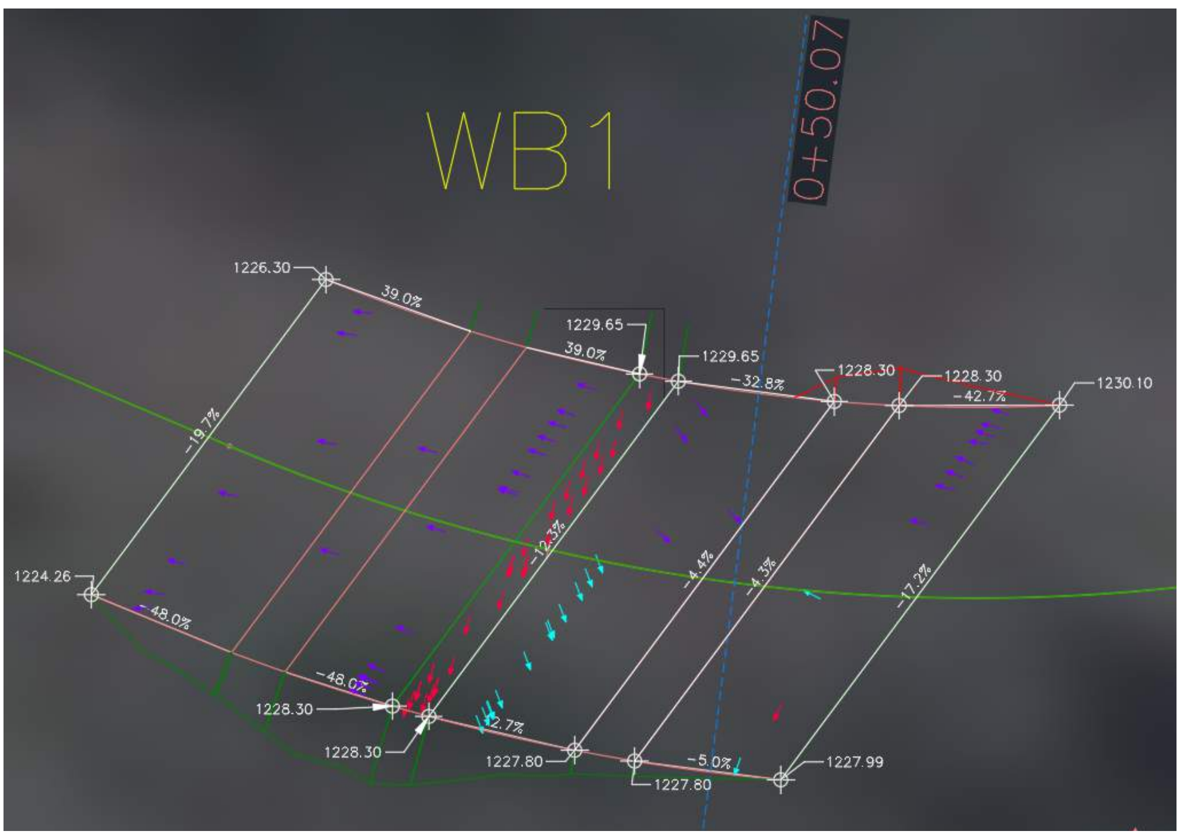


Figure 9.7. Location 1 Structure Civil 3D Drawing

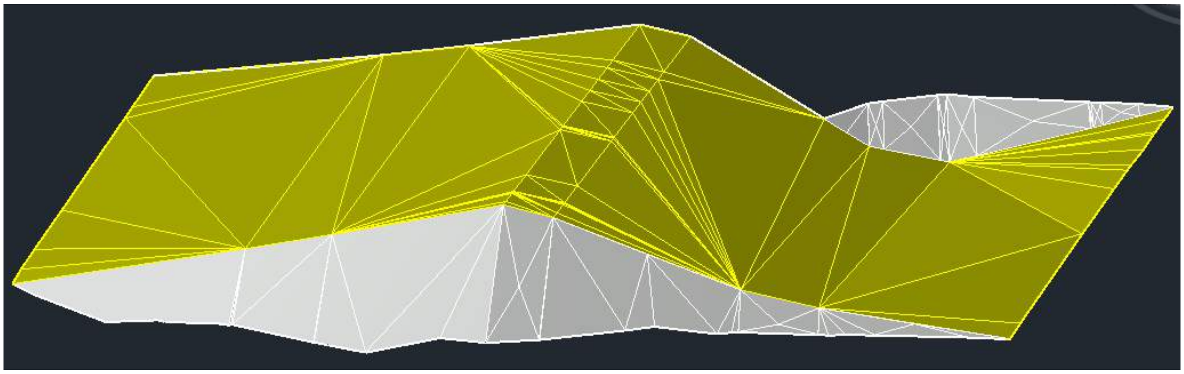


Figure 9.8. Location 1 Structure 3D Model

9.5 Test Procedure

The team will be using the Storm Water Management Model (SWMM) software to test the conceptual designs. This is a modeling software developed by the EPA and it can be used for a single event or long term simulations of water runoff quantity and quality. As the water from the trail is forced off by the structures, small channels will be formed in front of each structure. This channel is the water that is moving off of the trail because the structures are now there, and the team will have to calculate the dimensions of this channel to put it into the software. SWMM will be used to measure if the water in this channel will exceed the threshold that the broad based dip can handle (runoff from a 25-year, 24-hour storm). If the runoff does happen to exceed the threshold, then the structure can be resized accordingly. The team will not be designing our structures for 50- or 100-year storms because they are too rare and it would make the structures too large for this trail. This software can be used to see how much runoff will accumulate from these storms, and how much of it will be diverted, so the team can then see how much of that runoff will not be diverted off the trail from the structures. This will give the sponsors an idea of the possible maintenance they will need to provide if larger storms do occur.

10.0 Final Discussion

10.1 Implementation Process

It is suggested that this project be completed at one time. This would mean that the equipment needed would only have to be rented once, workers and volunteers would only be needed to be organized once and would help to reduce the amount of disturbance to the trial. Implementing the structures at different times would mean they would have to control more water than they were designed for during a precipitation event. Implementing the structures all at once will help the structures to maintain their durability for many years.

Appendix E contains the construction details of the structures needed for proper implementation along with pictures and 3D models for reference during construction. The station location given for each structure is located in the center of the dip along the alignment on the center of the trail. The elevations, slopes and lengths on the four outside edges of the structure are given for each structure. The bottom edge refers the edge at the lower station along the trail. The top edge refers to the edge at the upper station of the trail. The left edge refers to the edge of the trail on the left when looking up the trail. The right edge refers to the edge of the trail on the right when looking up the trail.

Other matters to consider before implementation and during construction:

1. The Civil 3D structures were drawn representing the dip and top of the mound as flat areas. In reality these areas would need to be rounded, if necessary. The dip would be rounded to create a slight channel and the top of the mound would be rounded off. This was not properly shown in Civil 3D since it would have been very difficult to do so.

2. The materials selection section discussed use of different materials in the implementation of the structures. The 2RC material should be used to construct the entire structure. The bottom of the channel should be reinforced using the size 150 mm gravel mix material and the outlet of each dip should be also be reinforced with riprap. The reinforced dip and dip outlet will help to reduce any chance of these areas eroding and help to make these structures perform properly with little maintenance.

3. Although this study only includes material costs for the implementation of the six structures more material could be purchased to fill in the deep gullies that have formed on the trail. The guillies should not be filled in until the structures are complete. Proper material selection should be conducted to ensure the material will not erode/wash out from the filled gullies resulting in filling in the dips of the structures. If the dips of the structures become full with this extra fill material they will not be able to perform properly.

4. The Blair Planning Commission noted that it would be in the best interest of the municipality that cares for the park to have minimum maintenance. It would be best for the trail to be check after any large rain events to ensure the implemented structures were not damaged. If it is found that the structures were damaged then maintenance should be conducted to return the structures back to their original design.

5. It should be noted that the designs drawn in Civil 3D used lidar elevation data. Lidar data can have lots of error associated with them and the elevations along the trail reported from this data could vary greatly from the actual elevations. This is caused by trees and vegetation interrupting the laser that collects the lidar elevation data. To get the proper elevations for the trail and structures a more accurate survey of the trail should be conducted and used in the design process. The survey taken during the fall semester could not be used to design the structures since there was not enough shots taken to get an accurate topographical map of the trail.

6. An additional note about the design in Civil 3D is that the stationing along the alignment differs from the stationing used in ArcGIS and stated in Section 5. This is because the start of the alignment in Civil 3D, the 0+00 location, was not place at the posts that cross the bottom of the trail where the 0+00 was located for the ArcGIS analysis. Although the stationing number differs the exact locations determined in section 5 did not change when the structures were designed in Civil 3D. The only thing that changed was the station numbering from the difference in the start location of stationing.

7. During one of the team's poster sessions of presenting this project an outside source recommended that the product of Geoweb be researched as a potential solution for this trail restoration project. The team did some research into the product and also contacted with the company to ask more detailed questions about how the product could be used in this application. Geoweb is a cellular confinement system that can be used to keep fill materials in place. The company has a lot of information of their webpage in their Slope Protection application page as well as their GeoGallery. The webpage provides photos, videos, and case studies. The link to their page is:
   https://www.prestogeo.com/gallery_presto/products/soil-stabilization/geoweb-slope-protection/?type=casestudy [nam01.safelinks.protection.outlook.com]
   After some discussion, it was recommended by the Presto GeoSystems Civil Design Engineer, Sam Justice, that the Geoweb panels be properly secured on the steep slopes of the trail with #4 (1/2 inch) rebar, at least 24 inches long and also use ATRA Stake Clips to secure them to the panels. The stakes are recommended to be placed in a 3 x 3 cell spacing pattern for proper securing of the panels. She also recommended seeding the infill material if soil was going to be used or if stone, the stone size was recommended to have a size D50 = 2 inches. If more information was needed their webpage provides contact information.
   The team believes that this might be a viable option for the steep sections of the trail where the top soil is already all eroded and the bedrock is exposed. Using a product such as the Geoweb could help to keep the fill material used to construct the structures in place. In large precipitation events the fill material on the steep bedrock surface is going to easily eroded and washed out.

10.2 Test Results and Discussion

Our testing was done in the software program called SWMM, like mentioned in section 9.5. In SWMM, we were able to model each subwatershed as a “subcatchment”, which means that all of the water that is collected in that specific area can be diverted to wherever the user chooses. The dip that will be placed before each structure is modeled as a channel in SWMM. In order to create a channel or “conduit” in SWMM, there must be a junction point at the beginning of the conduit and an outfall point at the end of the conduit. We were able to connect each subcatchment to the proper junction point, which means all the water collected in that specific subcatchment would enter the channel through that point, which is how the water would move naturally. The outfall point refers to where the water would be diverted off the trail. Figure 10.1 shows an entire map of the Chimney Rocks trail in SWMM. Each of the black shaded areas are the subcatchments. The little black circles labeled as J1, J2, etc. are the junction points for each of the six structures. The little black inverted triangles labeled as Outfall1, Outfall2, etc. are the outfall points for each of the six structures. There is a little black line that connects the junction points to the outfall points and these are the conduits or channels.

When initially working in SWMM, the first dimensions that were entered for each structure was a parabolic channel with a depth of 6 inches and a width of 1.5 feet. After running the simulation in regard to a 25 year, 24 hour storm, each structure was able to attenuate the amount of rainfall that it was receiving in its own respective subbasin (subwatershed). The channels we first created were actually too big, and we realized we would be able to make them smaller, which would help with implementation and cost. The next time we ran the simulation, the parabolic channel depth was changed from 6 to 4 inches. This decrease still had no effect on the efficiency of the channels; each proposed channel was still able to attenuate all of the rainfall that it received without flooding it.

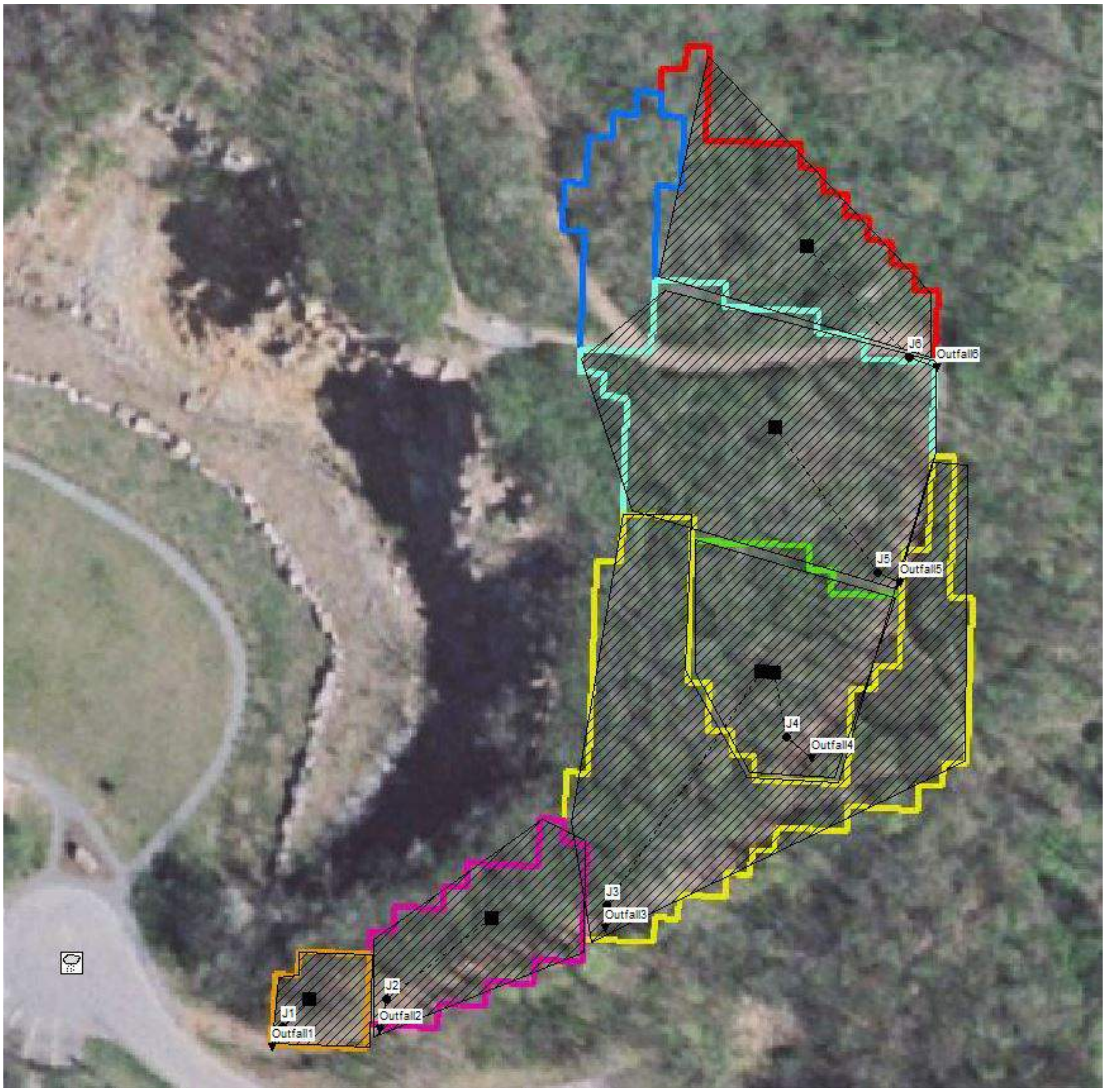


Figure 10.1. Entire map of trail from SWMM.

After completing our final design dimensions for each structure in Civil 3D, we were able to get a better idea of how to run SWMM again so that the structures in SWMM mimicked our final structures in Civil 3D. Before running the simulation again in SWMM, we needed to change some parameters so they matched the parameters in Civil 3D. We changed each channel's roughness to 0.025, like we mentioned in section 9.1. Then, we changed the elevation and shape of each channel to the same dimensions that are in Civil 3D. We made each channel trapezoidal with a base width of 1 feet (except for channel 6 which has a base width of 4 ft), and kept the channel depth at 4 inches (except for channels 3 & 5 which have depths of 6 inches). We input the side slopes that we calculated in Civil 3D into the dimensions of this trapezoidal channel, as well. We were able to correctly update the dimensions for all six structures. We were then able to run the simulation again, still in regard to a 25 year, 24 hour storm, with these updated parameters, and found similar results as before. Each of the proposed channels were still able to attenuate all of the rainfall that is received without flooding. SWMM provides water elevation profiles for each channel at any specific time the user chooses. A water elevation profile can be seen for the third structure below in figure 10.2. The third structure is connected to the largest subcatchment area, which means that it has the most of amount of flow going through it, which is why we wanted to show it in this section. We included a water elevation profile from this final simulation for each channel at the time where the runoff is at its peak (12 PM) in the Appendix F. Water elevation profiles show an outline of the entire length of the channel and how much of the channel is filled with water at a certain point in time during the simulation. The right side of the channel is the junction point, and the left side of the channel is the outfall point on these profiles. As seen in the figure below, the water doesn't reach the top of the proposed channel during this time of peak flow, so there is no flooding. For any of our proposed structures, there is no flooding at any time during the simulation. This means that the structures are able to properly divert all the water that encounters it, so the water doesn't continue down the trail and cause further damage.

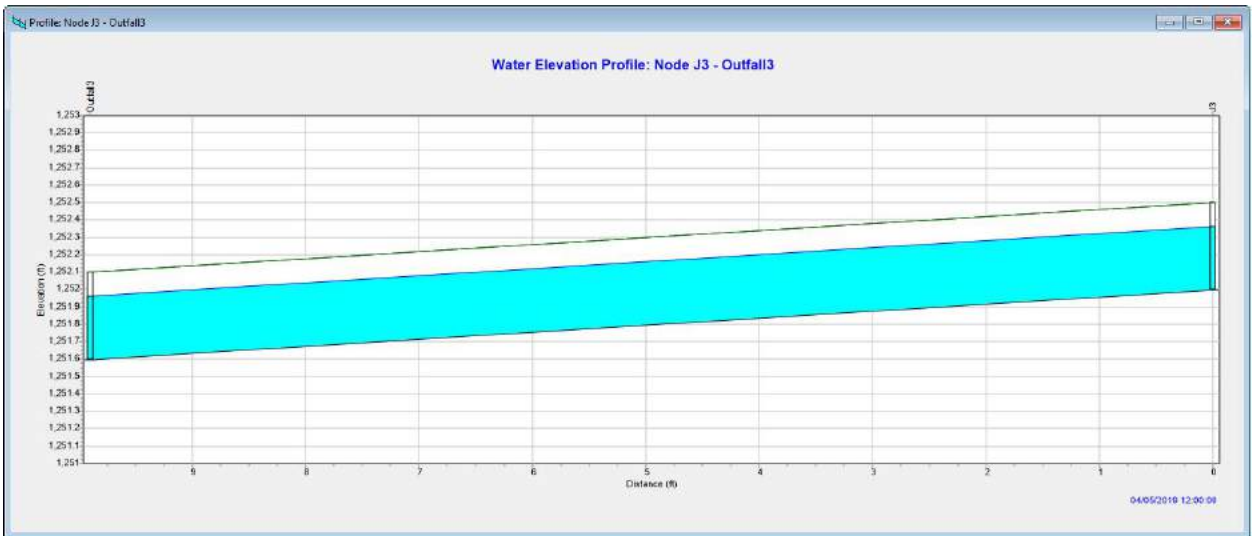


Figure 10.2. Water elevation profile for location 3.

Appendix F includes tables with the dimensions that we input into SWMM for each subcatchment, junction point, outfall point, and conduit channel. In addition to these tables, we also included tables from SWMM directly that show more information about the flow in the channels, the flow into the junction points, the flow out of the outfall points, and the runoff coming from the subcatchments.

These test simulations in SWMM passed our expectations as well as met the customer's needs and specifications. These simulations showed that these channels were able to completely attenuate all the rainfall received using data for a 25 year, 24 storm, with extra room, without flooding. This means that these channels will also be able to attenuate larger storms that potentially occur in the area, without flooding. Because of this, not much maintenance or upkeep will be required since all of the water will be diverted from the trail, and no further gullies will be formed. These structures are durable enough to handle larger storms, as well as regular, smaller ones. This durability also ensures the sustainability of the trail and means that the trail will last for a long time.

11.0 Economic Analysis

One of the major goals of this feasibility study was to find ways to make sure this design was as inexpensive as possible without compromising the quality of the design. We figured that the design is more likely to get implemented if it is relatively low cost, however, this does not mean that we were willing to overlook the importance of analyzing all aspects of the job and not cutting corners. We knew the bulk of the cost would be the material needed to complete our proposed structures and the rental cost of the necessary machinery. Once we had accurately sized them and selected the proper materials we had to decide what machinery would be necessary to complete the job. We had considered recommending that volunteers with wheelbarrows could be suitable to move the material up the trail to the structure locations, but we deemed this not feasible due to the amount of material we are basing our design on. We decided the best course of action was to rent a skid steer loader, if the borough does not have access to one. It is small enough to get up the trail but it is powerful enough to carry all of the necessary material. We also estimated the price of renting a motorized compactor if the borough of Hollidaysburg does not own one. Table 11.1 is the cost analysis that we created to estimate the price of completing our design. There are some costs that were left off, like cost of labor and operating prices for the truck that will pick up the material. We assumed that the borough already knows those prices and it was better that we did not guess what they are.

Overall, we think this is a practical estimation of what the cost will be for the project. The cost of the material and equipment came out to be relatively similar. Labor costs can be decreased if a volunteer group is contacted about possibly helping with the implementation of the design. There are also grants that can be applied for that would help to further reduce our cost estimation. Implementing this design is a cheaper alternative than simply filling the gullies that form from storm water runoff at the beginning of each year. This design is meant to last long term and will not require maintenance at the same frequency as other designs like waterbars (figure 3.3). Our maintenance cost will simply be adding more 2RC material or rip rap over time as they degrade or get washed away. Another additional cost that should be considered would be the cost of an engineering firm taking a survey of the trail. Since our design ended up using lidar data to acquire the elevation points for the trail, the elevations of each point on the structures are not completely accurate to the existing elevations. A comprehensive survey would give more precise elevation data that could help make the implementation of the design easier.

Table 11.1 Cost Analysis

Material		
2A Stone	10 to 20	$/ton
2RC stone	10 to 15	$/ton
volume of material (compacted)	30	cubic yards
weight of material	1.6	ton/cubic yard
volume of material (loose)	40	cubic yards
total weight of material	64	tons
cost of 2 Rc material	960	$
Rip Rap cost	15 to 25	$/ton
Rip Rap weight	2	ton/cubic yard
Rip Rap needed	1.6	cubic yards
Cost of Rip Rap	80	$
Total Cost of material	1040	$

Labor / Equipment		
loader, skid steer	40-90	$/hr
Length of job	16	hr
compactor rental	93	$/day
cost of material (with compactor)	1306	$
cost of material (w/o compactor)	1120	$
*Loader, skid steer price assumed to be 70 $/hr		
*Assume already have a truck to transport matieral		
Total cost of Job	2160	$

12.0 Conclusions and Recommendations

12.1 Conclusion of Customer Needs and Specifications

The final proposed design was able to capture and satisfy most of the original customer needs and target specifications of this project. The proposed design and structures will be constructed of fill material as specified in section 9. Implementing the structures every so often on the trial rather than completely changing the entire existing trail helps to maintain the natural look of the trial and does not impose any major environmental impacts. The material chosen for the structures has a diameter size of 150 mm and the target specification for the fill material was to be less than 1.5 inches in diameter. The environmental impacts of this project was also met with the proposed implemental of the structures since they will help to reduce the amount of erosion and storm water discharge than occurs on the trial. The structures will help to divide and disperse the total volume of water than currently accumulates on the trail. Reducing the amount of accumulated flow will help the diverted water to infiltrate rather than becoming overland runoff. Diverting the water off the trail will help to achieve the specification of reducing the gully formation to less than 3 inches in depth.

Another customer need was safety of the trail for its users. The associated specifications to achieve safety on the trail was to keep any obstructing structures implemented on the trail to less than 6 inches tall and the maximum slope of the structures to be 10%. The designed mounds and dips of the structures did not all meet these specifications. But when designing the structures in Civil 3D the slope of the structures was kept in mind and kept to the minimum as possible with the elevations that there was to work with. Although the slopes could not be kept to under 10%, the structures were designed into the trail surface so that someone could naturally walk on them with the grade change rather than having to step over any obstructions. The existing elevations of the trail also posed issues for the structures meeting the specifications set for the customer need of meeting regulations. The combined broad-based dip and waterbar structure used for the design was supposed to have a 3% out-slope in the dip. In some of the locations on the trail this was not met since then existing elevations did not permit it. This forced the design of these structures to have an outslope that ranged from 3% to 5%. The structures did meet the specification of the structures being able to control the volume of water of a 25-year, 24-hour storm though, shown though the analysis with SWMM. The pre-development runoff on the trail was also reduced with the proposed structures.

Labor implementation of the proposed solution was an important customer need expressed by the sponsors. It was mentioned that volunteer work and labor rather than the use of equipment was a high priority of the proposed design. After some thought and research it was decided that the use of some equipment would be needed to help transport the materials up the trail to the locations of the trail. A specification was set that no less than half of the trail work could be completed by volunteer work and that at most three pieces of equipment would be needed to aid in the implementation process. It is believed that these specifications can be satisfied when the proposed design is implemented. The use of equipment to haul the heavy material up the trail will also help the safety of the implementation process of the design to be met. The use of volunteers in the implementation process of the trial helps to get the community involved and can be used as a learning experience for all that are involved.

In the analysis portion of the design process, that involved the use of SWMM, it was found that most of the structures were slightly over designed. They had a larger capacity than what was needed for the 25-year, 24-hour storm. This allows for the structures to be able to control slightly larger volumes of flow and also means that the structures will be able to have an extended period of durability without required maintenance. This helps the design to satisfy the customer need of sustainability and durability by meeting the target specification of requiring less than 2 hours of work each month of the year and having a lifespan of eight to ten years without major repairs.

Lastly the customer need of keeping the project at a minimum cost was met. The target specification was set by reviewing the cost of other trail projects. The goal of the project was to keep the cost under $15,000. The proposed design was determined to cost $1,040 in material which may vary depending on the vendor that the material is purchased. The cost of the labor and equipment was also estimated in Section 11 but the true cost of these factors is really going to vary. It will be depended upon if the equipment is already available to the township or if it will be rented and if the project will be implemented by paid works or if volunteer work will be utilized. Although a true cost estimate cannot be determined at this point for the entire project the project will definitely cost less than $15,000. Table 12.1 shows the satisfaction rating on how the proposed design met the original customer needs determined at the beginning of the design process.

Table 12.1. Customer need satisfaction chart.

Customer Need	Satisfaction Rating (1-10)
Keep it Natural	10
Safety	9
Environmental Impact	9
Labor Implementation	8
Sustainability / Durability	9
Cultural Impact	10
Alignment with Ethics/Values	10
Meet Regulations	9
Cost	9

12.2 Recommendations

The following list includes recommendations and concluding comments for improvement of the design and implementation of the proposed design solution. Also refer to Section 10.1 since other important recommendations and implementation comments were also given there.

1. Quantifying the amount of erosion that occurs on the trail ended up being out of the scope of the project although it was a specification that was set at the beginning of the design process. This might be an important analysis to conduct when applying for a grant since one could show the impact of the proposed implementation of the structures on the amount of erosion that occurs on the trail.

2. Due to time constraints and push backs with technical issue with AutoCAD Civil 3D the design of a structure for the side trail was not complete. The sponsors did express at the beginning of the project that they would like to see this trial to have some improvements as well as the main trail. When this project is implemented, if time and funds allow there should be a structure or some kind of restoration efforts designed for the side trial, as well.

3. An Erosion and Sediment Control Plan was originally a proposed deliverable of the project. The trail in total was found to be over 5000 square feet which would make the construction on the entire trail to require an E&S Plan. The plan was not written since the construction will only be taking place in the location of the structures. The total area to be disturbed while constructing the structures will be less than 2000 square feet. An E&S plan is only required over 5000 square feet of disturbed area.

4. During research the team visited Canoe Creek State Park. The park ranger there mentioned that their park has a group of volunteers that help maintain the trails and groups of students from local high schools help with implementation of structures on the trails. Reaching out to local schools and organizations to get volunteer help with the project would be a great idea. Most high schools require the students to complete volunteer hours as a graduation requirement. Helping with the implementation of the project would also be a great learning experience for the students. Other groups that could be contacted for potential volunteer help would be local boy scouts, local girl scouts or students from the Penn State Altoona outdoors club.

References:

Akbarimehr, Naghdi. "Reducing erosion from forest roads and skid trails by management practices." *Journal of Forest Science*, vol. 58, no. 4, 2012, pp. 165-69. *Czech Academy of Agricultural Sciences*, doi:10.17221/136/2010-JFS. Accessed 12 Oct. 2018.

"Chapter 102. Erosion and Sediment Control." *The Pennsylvania Code*, 30 Oct. 1972, www.pacode.com/secure/data/025/chapter102/chap102toc.html. Accessed 10 Dec. 2018.

Chapter 338: Stormwater Management. Board of Supervisors of the Township of Blair, 11 Dec. 2011. *ECode360*, ecode360.com/30763344. Accessed 9 Dec. 2018.

"Climate in Altoona, Pennsylvania." *BestPlaces*, Sperling's Best Places, 2018.

Environmentally Sensitive Maintenance for Dirt & Gravel Roads. PSU Center for Dirt & Gravel Studies, 2017.

FEMA Flood Map Service Center. Department of Homeland Security, 26 Sept. 2017, msc.fema.gov/portal/home. Accessed 12 Oct. 2018.

Hesselbarth, Woody, et al. "Trail Construction and Maintenance Notebook." *United States Department of Agriculture*, 2007, www.fs.fed.us/t-d/pubs/htmlpubs/htm07232806/page06.htm. Accessed 12 Oct. 2018.

Marion, Jeffery, and Jeremy Wimpey. "Assessing the influence of sustainable trail design and maintenance on soil loss." *Journal of Environmental Management*, vol. 189, 15 Mar. 2017, pp. 46-57. *ScienceDirect*, doi:10.1016/j.jenvman.2016.11.074. Accessed 12 Oct. 2018.

NOAA's National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server. (2014, August 27). NOAA ATLAS 14 POINT

PRECIPITATION FREQUENCY ESTIMATES: PA. Retrieved from: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa

Olive, Nathanial, and Jeffery Marion. "The influence of use-related, environmental, and managerial factors on soil loss from recreational trails." *Journal of Environmental Management*, vol. 90, no. 3, Mar. 2009, pp. 1483-93. *ScienceDirect*, doi:10.1016/j.jenvman.2008.10.004. Accessed 12 Oct. 2018.

Pennsylvania Department of Environmental Protection. (2006). Pennsylvania Stormwater Best Management Practices Manual (DEP Publication Number 363-0300-002). Harrisburg, PA.

Pennsylvania Spatial Data Access (PASDA). (2017). Retrieved from: http://www.pasda.psu.edu/

Pennsylvania State, General Assembly, Assembly, Pennsylvania Department of Environmental Protection. *Erosion and Sediment Pollution Control Program Manual*. 31 Mar. 2012. 2012 General Assembly, Assembly Document 363-2134-008.

Sawyers, Clay; Aust, W. Michael; Bolding, M. Chad; Lakel III, William A. 2012. *Effectiveness and costs of overland skid trail BMPs.* In: Butnor, John R., ed. 2012. Proceedings of the 16th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-156. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 283-289. Accessed 8, Nov. 2018

Technical Bulletin: Trail Surface Aggregate (TSA). University Park, Pennsylvania State University, Center for Dirt & Gravel Studies, 2013.

Tomczyk, Aleksandra, and Marek Ewertowski. "Quantifying short-term surface changes on recreational trails: The use of topographic surveys and 'digital elevation models of differences' (DODs)." *Geomorphology*, vol. 183, 1 Feb. 2013, pp. 58-72. *ScienceDirect*, doi:10.1016/j.geomorph.2012.08.005. Accessed 12 Oct. 2018.

Web Soil Survey. United States Department of Agriculture: Natural Resource Conservation Service, 21 Aug. 2017, websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. Accessed 12 Oct. 2018.

Appendix A: Web Soil Survey Soils Report

Custom Soil Resource Report
Soil Map

9

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Blair County, Pennsylvania
Survey Area Data: Version 14, Sep 18, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 23, 2010—Feb 22, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
HeD	Hagerstown-Rock outcrop complex, 8 to 25 percent slopes	1.8	35.7%
MnC	Mertz channery silt loam, 8 to 15 percent slopes	0.0	0.0%
MnD	Mertz channery silt loam, 15 to 25 percent slopes	0.4	8.6%
OuD	Opequon silty clay loam, 15 to 25 percent slopes	0.2	5.0%
OxF	Opequon-Hagerstown-Rock outcrop complex, 25 to 50 percent slopes	0.4	8.2%
Qu	Quarries-Dumps complex	2.1	42.5%
Totals for Area of Interest		**5.0**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not

Blair County, Pennsylvania

HeD—Hagerstown-Rock outcrop complex, 8 to 25 percent slopes

Map Unit Setting

National map unit symbol: l6c9
Elevation: 400 to 3,000 feet
Mean annual precipitation: 30 to 46 inches
Mean annual air temperature: 44 to 57 degrees F
Frost-free period: 130 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Hagerstown and similar soils: 50 percent
Rock outcrop: 30 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hagerstown

Setting

Landform: Hills
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Residuum weathered from limestone

Typical profile

H1 - 0 to 14 inches: silty clay loam
H2 - 14 to 40 inches: clay
H3 - 40 to 60 inches: silty clay loam

Properties and qualities

Slope: 8 to 25 percent
Depth to restrictive feature: 40 to 84 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: High (about 10.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: B
Hydric soil rating: No

Description of Rock Outcrop

Setting

Landform: Valley sides
Landform position (two-dimensional): Shoulder, backslope

Landform position (three-dimensional): Mountainflank
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Bedrock exposures

Properties and qualities
Depth to restrictive feature: 0 to 4 inches to lithic bedrock

Minor Components

Opequon
Percent of map unit: 5 percent
Hydric soil rating: No

MnC—Mertz channery silt loam, 8 to 15 percent slopes

Map Unit Setting
National map unit symbol: l6db
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 46 to 59 degrees F
Frost-free period: 120 to 214 days
Farmland classification: Farmland of statewide importance

Map Unit Composition
Mertz and similar soils: 90 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mertz

Setting
Landform: Ridges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Cherty residuum weathered from cherty limestone

Typical profile
H1 - 0 to 21 inches: channery silt loam
H2 - 21 to 60 inches: gravelly clay loam
H3 - 60 to 80 inches: very gravelly silty clay loam

Properties and qualities
Slope: 8 to 15 percent
Depth to restrictive feature: 72 to 99 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)

Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Hublersburg

Percent of map unit: 5 percent
Landform: Ridges on valleys
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

MnD—Mertz channery silt loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: l6dc
Mean annual precipitation: 34 to 48 inches
Mean annual air temperature: 46 to 59 degrees F
Frost-free period: 130 to 199 days
Farmland classification: Not prime farmland

Map Unit Composition

Mertz and similar soils: 90 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mertz

Setting

Landform: Ridges
Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Parent material: Loamy colluvium derived from cherty limestone

Typical profile

H1 - 0 to 21 inches: channery silt loam
H2 - 21 to 60 inches: gravelly clay loam
H3 - 60 to 80 inches: very gravelly silty clay loam

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: 72 to 99 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Hublersburg

Percent of map unit: 5 percent
Landform: Ridges on valleys
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

OuD—Opequon silty clay loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 2sg9t
Elevation: 300 to 3,000 feet
Mean annual precipitation: 39 to 50 inches
Mean annual air temperature: 47 to 56 degrees F
Frost-free period: 155 to 192 days
Farmland classification: Not prime farmland

Map Unit Composition

Opequon and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Opequon

Setting

Landform: Hills
Landform position (two-dimensional): Shoulder, summit, backslope
Landform position (three-dimensional): Nose slope, side slope

Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Clayey residuum weathered from limestone and dolomite

Typical profile

Ap - 0 to 5 inches: silty clay loam
Bt1 - 5 to 13 inches: silty clay
Bt2 - 13 to 16 inches: silty clay
R - 16 to 26 inches: bedrock

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: 12 to 20 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline (0.0 to 0.2 mmhos/cm)
Available water storage in profile: Very low (about 1.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: D
Hydric soil rating: No

Minor Components

Hagerstown

Percent of map unit: 5 percent
Landform: Ridges
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Side slope, base slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Rock outcrop

Percent of map unit: 5 percent
Landform: Hills
Landform position (two-dimensional): Shoulder, summit, backslope
Landform position (three-dimensional): Nose slope, side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

OxF—Opequon-Hagerstown-Rock outcrop complex, 25 to 50 percent slopes

Map Unit Setting

National map unit symbol: l6dv
Elevation: 300 to 3,000 feet
Mean annual precipitation: 30 to 46 inches
Mean annual air temperature: 44 to 59 degrees F
Frost-free period: 130 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Opequon and similar soils: 40 percent
Hagerstown and similar soils: 30 percent
Rock outcrop: 20 percent
Minor components: 8 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Opequon

Setting

Landform: Hills
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from limestone

Typical profile

H1 - 0 to 8 inches: silty clay loam
H2 - 8 to 16 inches: silty clay
H3 - 16 to 20 inches: bedrock

Properties and qualities

Slope: 35 to 50 percent
Depth to restrictive feature: 12 to 20 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: D
Hydric soil rating: No

Description of Hagerstown

Setting

Landform: Valley floors, ridges
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Residuum weathered from limestone

Typical profile

H1 - 0 to 8 inches: silty clay loam
H2 - 8 to 41 inches: clay
H3 - 41 to 60 inches: clay

Properties and qualities

Slope: 35 to 45 percent
Depth to restrictive feature: 40 to 84 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: High (about 10.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Hydric soil rating: No

Description of Rock Outcrop

Setting

Landform: Valley sides
Landform position (two-dimensional): Backslope, shoulder
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Parent material: Bedrock exposures

Minor Components

Hublersburg

Percent of map unit: 5 percent
Landform: Ridges on valleys
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Clarksburg

Percent of map unit: 2 percent
Hydric soil rating: No

Holly

Percent of map unit: 1 percent
Landform: Flood plains
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Qu—Quarries-Dumps complex

Map Unit Setting

National map unit symbol: l6dy
Elevation: 300 to 1,300 feet
Mean annual precipitation: 35 to 50 inches
Mean annual air temperature: 44 to 57 degrees F
Frost-free period: 120 to 214 days
Farmland classification: Not prime farmland

Map Unit Composition

Quarries: 50 percent
Dumps: 30 percent
Minor components: 2 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quarries

Setting

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Variable

Description of Dumps

Setting

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mine spoil or earthy fill

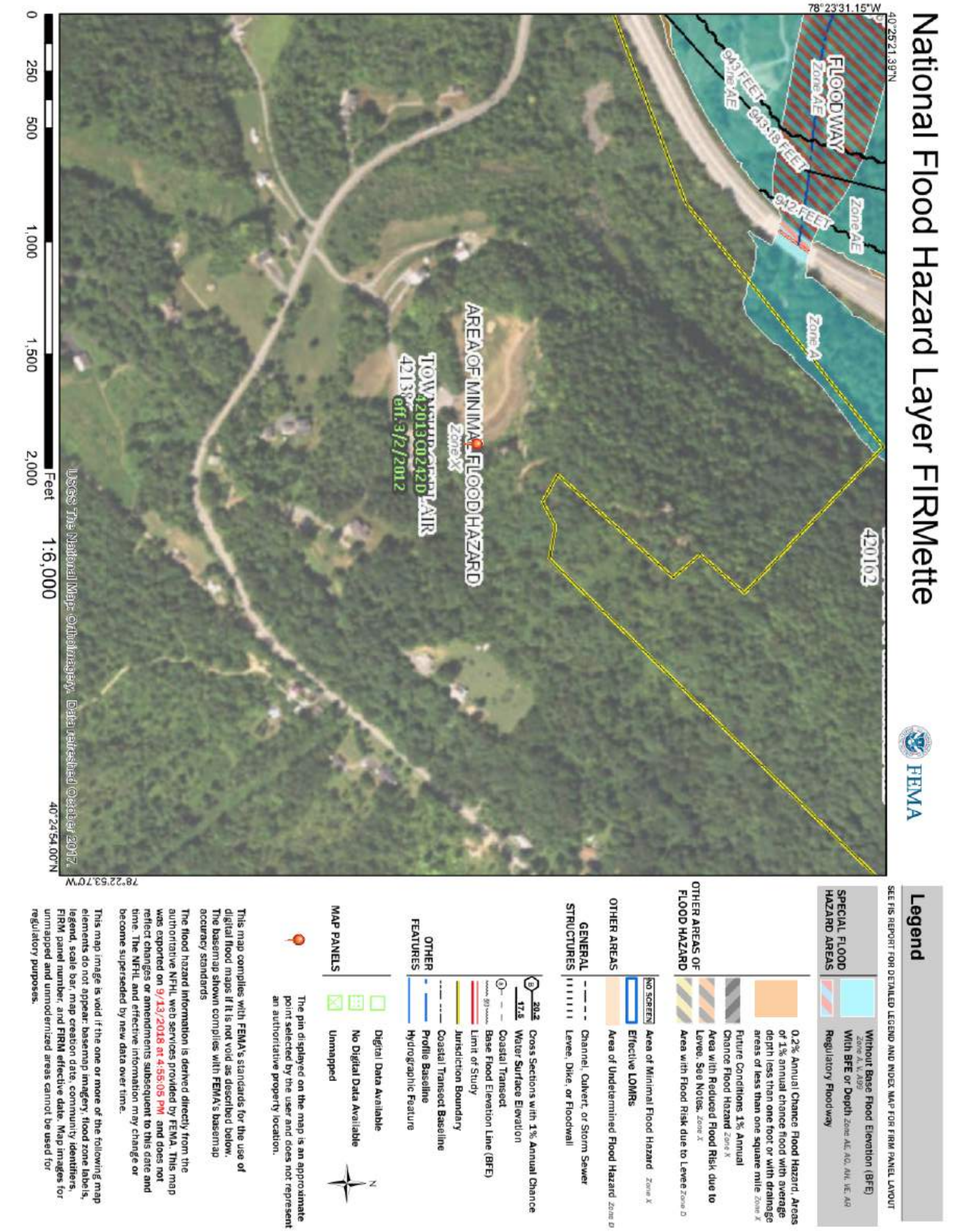
Minor Components

Aquents

Percent of map unit: 2 percent
Landform: Hills
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave

Across-slope shape: Concave
Hydric soil rating: Yes

Appendix B: FEMA Flood Map



Appendix C: Surveying Notes

10/14/18 - Main Trail Notes

**Started the measuring on the right pole (as looking up the trail) that is located at the trailhead.

Distance (ft)	Side of trail the diverted water will be forced	Other Trail conditions	Substrate on trail at this location	Possible Methods
57.3	Right - before natural berm (Location #1)		Rocky - no digging	Addition of fill to form a water bar or rolling dip
		Gully averaging 5” deep & 2’ wide parabolic shape		Filled
126.2	Right (Location #2)		Rocky - no digging	Addition of fill to form a water bar or rolling dip
250.5	Right- large berm would need to be excavated - could potentially be used as part of diversion method (Location #3)		Rocky - no digging	Addition of fill to form a water bar or rolling dip
326.5		Steepest portion of the trail Gully Average 8” deep & 2.5’ wide	Slippery on left side of mostly clay material - gully on the right of rocky material	Add stone steps on the clay section so it is less slippery in wet conditions Potentially fill in the gully but not needed
363.7	Right - divert water onto the side trail (Location #4)			
483.7	Right - above 23.4’ long (Location #5)			Switch back/waterbar or step Fill material needed for the construction
496.6 (to bench leg)				
		Gully to the bedrock		
629.55	Left (Location #6)	First stretch of trail to contribute to diversion by bench		Possibly a diversion to catch water from upslope from this point
681.55		By root at top of incline of rocky portion		None needed

		Not much canopy cover		
		Grassy trail		
781.55		Turn in trail -- bare soil		None needed
858.55		Bare soil with leaf cover		None needed
959.55		On the left the side trail leading to the chimney rocks		None needed
1081.55		On right - mowed area off the trail		None needed
Overlook		Trail is all grass and relatively flat		None needed

Trail Notes for the side trail at 959.55 ft on main train (Location #7)

106' long
Add a diversion at the turn in the trail around 47' off the main trail - should help reduce the muddyness of the rest of this trail
Mostly roots from 82 to 106' - no changes needed

November 11, 2018: Trail Survey with Total Station

Survey of the Main Trail Starting at the Trailhead:

Station Name	Northing (y)	Easting (x)	Elevation	Description
1	395935.78	1791116.68	1220.58	SS
2	395936.15	1791126.31	1221.98	SS
3	395936.64	1791135.75	1224.01	SS
4	395929.52	1791135.77	1223.7	SS
5	395925.9	1791136.47	1224.44	SS
6	395924.3	1791143.53	1225.8	SS
7	395925.65	1791153.32	1227.24	SS
8	395932.63	1791156.39	1227.47	SS

9	395938.41	1791157.89	1228.55	SS
10	395936.97	1791165.8	1229.46	SS
11	395931.2	1791171.32	1230.38	SS
12	395944.93	1791184.43	1232.31	SS
13	395935.28	1791180.97	1231.59	SS
14	395938.66	1791188.2	1233.12	SS
15	395949.73	1791200.28	1235.66	SS
16	395959.01	1791208.55	1237.6	SS
17	395961.68	1791227.72	1240.48	SS
18	395966.19	1791242.69	1243.62	SS
19	395969.87	1791241.93	1243.93	SS
20	395972.18	1791243.63	1246.95	SS
21	395975.35	1791243.51	1246.95	BS
22	395976	1791245.38	1247.2	SS
23	395969.18	1791249.63	1247.77	SS
24	395972.27	1791257.36	1249.12	SS
25	395978.06	1791257.93	1249.24	SS
26	395983.61	1791264.88	1250.85	SS
27	395978.48	1791272.87	1251.16	SS
28	395978.81	1791278.59	1252.27	SS
29	395986.35	1791285.56	1253.39	SS
30	395992.65	1791292.03	1254.79	SS
31	395991.15	1791297.49	1254.88	SS
32	395991.05	1791305.81	1256.8	SS
33	395998.67	1791312	1258.42	SS
34	396006.45	1791317.8	1260.05	SS
35	396007.31	1791326.15	1261.38	SS
36	396002.66	1791330.72	1262.28	SS

37	396016.46	1791328.46	1262.7	SS
38	396015.46	1791333.53	1262.81	SS
39	396014.09	1791336.7	1262.71	SS
40	396013.44	1791338.79	1263.75	SS
41	396017.47	1791342.79	1264.37	SS
42	396021.58	1791340	1263.77	SS
43	396026.89	1791337.63	1264.89	SS
44	396031.45	1791338.97	1266.15	SS
45	396030.5	1791344.77	1265.37	SS
46	396032.59	1791351.23	1267.43	SS
47	396039.32	1791350.16	1267.9	SS
48	396044.59	1791348.53	1270.07	SS
49	396049.38	1791351.78	1271.89	SS
50	396047.74	1791355.56	1271.3	SS
51	396047.89	1791360.13	1271.59	SS
52	396053.89	1791359.89	1273.35	SS
53	396058.81	1791359.58	1275.14	SS
54	396058.27	1791363.9	1274.89	SS
55	396057.3	1791364.95	1274.48	SS
56	396056.53	1791365.97	1273.97	SS
57	396055.57	1791368.22	1275.39	SS
58	396062.47	1791372.64	1276.89	SS
59	396064.88	1791372.17	1276.63	SS
60	396067.47	1791376.16	1277.97	SS
61	396069.05	1791374.13	1277.97	SS
62	396074.3	1791370.85	1279.91	SS
63	396069.54	1791367.21	1278.85	SS
64	396071.81	1791380.06	1279.61	SS

65	396076.71	1791377.53	1280	SS
66	396081.8	1791376.71	1281.55	SS
67	396083.41	1791381.64	1281.95	SS
68	396082.35	1791387.66	1282.32	SS
69	396085.6	1791386.97	1282.16	SS
70	396090.95	1791382.43	1283.91	SS
71	396091.33	1791387.58	1283.73	SS
72	396092.82	1791394.24	1284.49	SS
73	396099.38	1791393.13	1285.66	SS
74	396106.66	1791391.49	1287.42	SS
75	396109.15	1791396.83	1287.58	SS
76	396111.16	1791403.31	1288.55	SS
77	396114.77	1791399.5	1288.84	SS
78	396120.96	1791396.77	1290.77	SS
79	396121.03	1791401.02	1290.48	SS
80	396122.55	1791407.58	1291.75	SS
81	396128.59	1791403.69	1292.89	SS
82	396129.62	1791410.56	1294.05	SS
83	396133.01	1791411.01	1294.05	BS
84	396137.91	1791407.55	1294.48	SS
85	396142.43	1791401.44	1296.21	SS
86	396144.69	1791408.5	1296.18	SS
87	396149.19	1791413.06	1328.97	SS
88	396156.26	1791403.21	1299.47	SS
89	396156.62	1791409.35	1299.13	SS
90	396159.24	1791414.1	1300.33	SS
91	396164.03	1791410.75	1300.56	SS
92	396167.99	1791404.35	1302.03	SS

93	396171.05	1791411.98	1302.28	SS
94	396176.11	1791416.51	1304	SS
95	396182	1791414.22	1304.83	SS
96	396184.36	1791408.86	1305.66	SS
97	396186.17	1791405.52	1306.69	SS
98	396190.98	1791417.2	1306.95	SS
99	396198.59	1791417.43	1308.34	SS
100	396202.06	1791407.93	1309.58	SS
101	396209.23	1791416.17	1310.25	SS
102	396214.91	1791416.24	1311.29	SS
103	396215.38	1791413.37	1311.54	SS
104	396215.87	1791410.49	1311.86	SS
105	396215.85	1791407.56	1312.2	SS
106	396216.21	1791404.31	1312.82	SS
107	396217.32	1791400.48	1314.32	SS
108	396220.63	1791399.84	1314.54	SS
109	396224.58	1791403.26	1314.9	SS
110	396231.03	1791406.02	1315.04	SS
111	396228.16	1791397.66	1316.06	SS
112	396227	1791399.43	1316.06	BS
113	396221.33	1791397.04	1316	SS
114	396215.47	1791389.79	1317.95	SS
115	396224.39	1791386.5	1318.46	SS
116	396216.82	1791380.59	1318.87	SS
117	396212.32	1791373.7	1321.04	SS
118	396217.34	1791370.1	1321.32	SS
119	396219.36	1791362.78	1322.88	SS
120	396214.5	1791357.69	1323.61	SS

121	396208.68	1791352.28	1325.32	SS
122	396212.62	1791347.11	1325.64	SS
123	396215.68	1791340.18	1327.12	SS
124	396206.71	1791335.61	1328.08	SS
125	396210.11	1791326.15	1329.24	SS
126	396213.23	1791317.7	1330.35	SS
127	396204.23	1791307.44	1331.43	SS
128	396210.86	1791300.77	1331.9	SS
129	396211.32	1791286.04	1332.83	SS
130	396211.91	1791291.81	1332.82	BS
131	396222.49	1791288.15	1333.44	SS
132	396223.41	1791282.1	1334.25	SS
133	396226.55	1791273.97	1335.8	SS
134	396233.79	1791277.33	1336.9	SS
135	396237.21	1791270.22	1338.37	SS
136	396240.72	1791262.4	1340.02	SS
137	396248.2	1791267.33	1341.05	SS
138	396251.59	1791258.65	1341.8	SS
139	396260.03	1791260.53	1343.25	SS
140	396263.1	1791252.05	1343.63	SS
141	396272.46	1791256.54	1344.59	SS
bm	395932.48	1791163.93	1231.35	

Survey of the Side Trail to the Chimney Rocks (start at chimney rocks):

Name	Northing	Easting	Elevation	Description
1	54.158461	1.124341	12.317856	BS
2	39.352055	0.816863	-6.629714	BS
3	29.664097	-5.134795	-6.405076	SS
4	31.577551	-0.791291	-6.194796	SS

5	33.998854	6.255086	-5.59461	SS
6	28.729325	6.633082	-4.641025	SS
7	26.503544	0.891721	-5.13971	SS
8	23.534303	-3.638339	-5.076724	SS
9	22.775106	1.356088	-4.255394	SS
10	22.004877	6.556763	-3.504459	SS
11	18.380129	1.868861	-3.505371	SS
12	15.044138	-2.389344	-2.914491	SS
13	13.276972	2.190717	-2.333986	SS
14	11.935796	7.01862	-1.454738	SS
15	8.341275	1.948628	-1.476443	SS
16	5.506866	-1.983195	-1.139078	SS
17	2.985502	8.203357	0.274046	SS
18	-1.597409	9.18972	0.908736	SS
19	-6.392137	5.254833	1.537078	SS
20	-5.204588	8.707688	1.428916	SS
21	-5.995301	12.355843	1.974414	SS
22	-7.951576	10.714541	2.060404	SS
23	-9.307143	8.009475	2.19615	SS
24	-11.108357	14.693036	2.84142	SS
25	-12.559586	12.417533	2.886884	SS
26	-15.612328	10.145604	3.496487	SS
27	-17.932383	12.006985	4.040448	SS
28	-21.853812	12.784633	4.868658	SS
29	-23.470175	5.75086	5.124105	SS
30	-25.833467	7.109619	5.55472	SS
31	-27.106309	10.039849	6.364153	SS
32	-30.40229	3.331253	7.011049	SS
33	-32.294246	4.737954	7.340389	SS
34	-34.007496	7.829937	8.165586	SS
35	-37.440651	1.411898	8.914713	SS
36	-38.592611	3.75531	9.119699	SS
37	-40.443001	6.213402	9.942153	SS
38	-43.007226	1.077375	10.231308	SS
39	-45.099128	2.950384	10.583083	SS
40	-45.40771	5.309567	11.170977	SS

41	-49.004596	0.645862	11.840463	SS
42	-49.006485	1.803869	11.626181	SS
43	-48.685702	4.068577	11.719484	SS
44	-48.462829	6.1168	12.016257	SS
45	-55.054858	0.676792	12.801886	SS
46	-55.344519	3.197991	12.600684	SS
47	-55.184219	5.737578	12.442548	SS
48	-54.034098	8.86532	12.568015	SS
bm	0	0	0	sream c

Appendix D: Watershed Analysis

Table D.1. Subwatershed for the Chimney Rocks Park Trail

Sub-basin	Area (acres)	Average CN	Longest Flowpath (ft)	Slope (%)	Travel Time (min)*	Time of Concentration (min)**
Location 1	0.353	83	44.72	26	4.43	4.71
Location 2	0.108	82.29	80.54	17	8.42	9.46
Location 3	0.342	80.52	287.27	17	10.01, 0.47	27.64
Location 4	0.158	80.84	116.37	24	8.72, 0.03	11.21
Location 5	0.389	77.95	301.25	29	8.08, 0.39	24.01
Location 6	0.169	68.43	199.54	22	9.03, 0.22	26.00
Location 7	0.166	83	146.59	13	11.27	17.22

* Sheet flow, Shallow Concentrated flow

** Used SCS Watershed Lag Method for time of concentration

Table D.2. Subwatershed Soil Hydraulic Group and Dominant Land Use

Sub-basin	Soil Hyd Grp	Land Use
Location 1	4	Forest
Location 2	3&4	Forest
Location 3	2,3&4	Forest
Location 4	3&4	Forest
Location 5	2&4	Forest
Location 6	2&4	Forest
Location 7	4	Forest

Table D.3. Estimated Average Runoff Determined Using SCS CN Method Within ArcGIS

Average recurrence interval (years)	24-hr Precipitation Depth (inches)	Location 1 (in)	Location 2 (in)	Location 3 (in	Location 4 (in)	Location 5 (in)	Location 6 (in)	Location 7 (in)
2	2.66	1.19	1.20	1.17	1.20	0.97	0.5259	1.20
5	3.31	1.72	1.72	1.68	1.72	1.43	0.8721	1.72
10	3.84	2.18	2.18	2.13	2.18	1.83	1.1925	2.18
25	4.61	2.85	2.85	2.80	2.85	2.46	1.7051	2.85
50	5.24	3.42	3.42	4.01	3.42	3.47	2.4431	3.42
100	5.98	4.11	4.11	3.94	4.11	3.63	2.7168	4.11

Table D.4. Estimated Average Runoff Determined With Weighted Curve Number Method

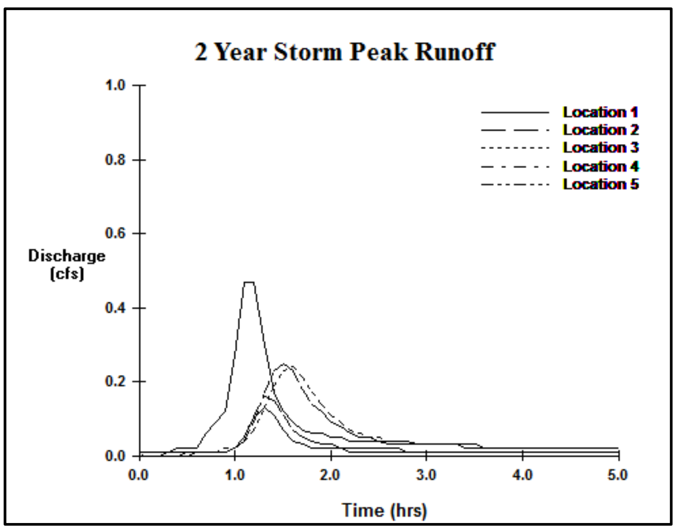
Average recurrence interval (years)	24-hr Precipitation Depth (inches)	Location 1 (in)	Location 2 (in)	Location 3 (in	Location 4 (in)	Location 5 (in)	Location 6 (in)	Location 7 (in)
2	2.66	1.18	1.13	1.03	1.05	0.89	0.48	1.18
5	3.31	1.70	1.65	1.52	1.54	1.35	0.81	1.69
10	3.84	2.15	2.09	1.95	1.98	1.76	1.13	2.15
25	4.61	2.82	2.76	2.60	2.63	2.38	1.64	2.82
50	5.24	3.39	3.32	3.15	3.18	2.91	2.09	3.39
100	5.98	4.07	4.00	3.82	3.85	3.56	2.64	4.07

Table D.5. Volume of Runoff for each Sub-Watershed from SCS CN Runoff values from GIS

Average recurrence interval (years)	24-hr Precipitation Depth (inches)	Location 1 (ft3)	Location 2 (ft3)	Location 3 (ft3)	Location 4 (ft3)	Location 5 (ft3)	Location 6 (ft3)	Location 7 (ft3)
2	2.66	1525	470	1453	688	1370	323	723
5	3.31	2204	674	2086	986	2019	535	1036
10	3.84	2793	855	2644	1250	2584	732	1314
25	4.61	3652	1117	3476	1635	3474	1046	1717
50	5.24	4382	1341	4978	1962	4900	1499	2061
100	5.98	5267	1611	4891	2357	5126	1667	2477

Table D.6. Peak Flow Rates Found using VTPSUHM

Average recurrence interval (years)	24-hr Precipitation Depth (inches)	Location 1 (cfs)	Location 2 (cfs)	Location 3 (cfs)	Location 4 (cfs)	Location 5 (cfs)	Location 6 (cfs)	Location 7 (cfs)
2	2.66	0.47	0.13	0.24	0.16	0.25	0.05	0.17
5	3.31	0.70	0.20	0.36	0.24	0.39	0.09	0.25
10	3.84	0.89	0.25	0.48	0.31	0.51	0.13	0.32
25	4.61	1.18	0.34	0.66	0.42	0.72	0.20	0.42
50	5.24	1.41	0.41	0.80	0.51	0.90	0.26	0.50
100	5.98	1.70	0.49	0.97	0.62	1.11	0.34	0.60



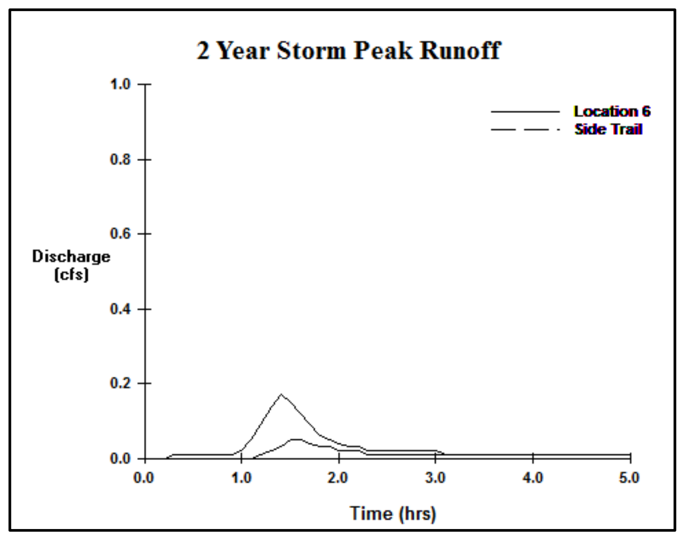
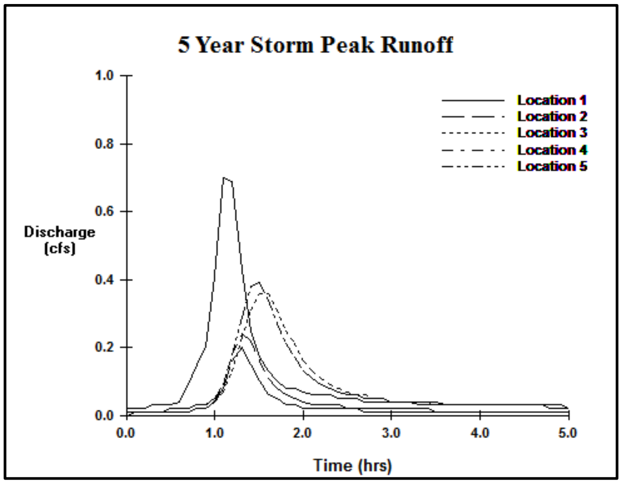


Figure D.1. 2 Year Storm Peak Runoff Hydrographs



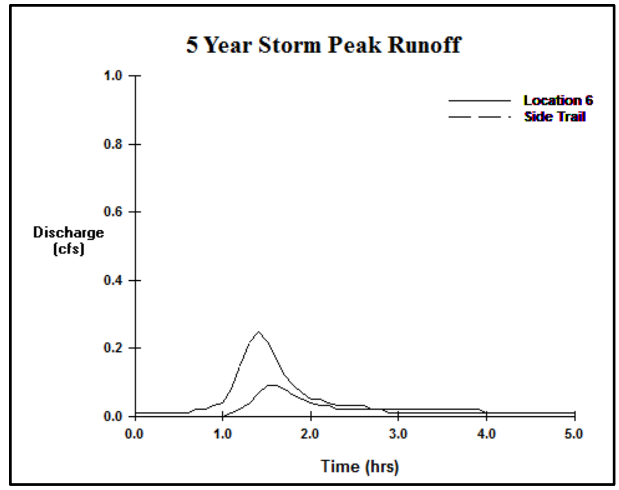
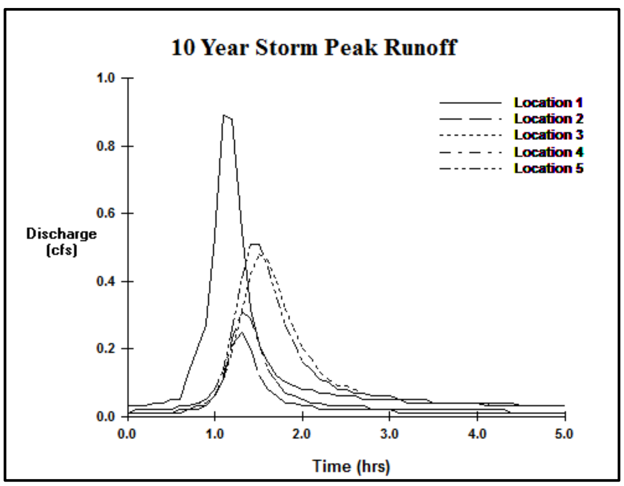


Figure D.2. 5 Year Storm Peak Runoff Hydrographs



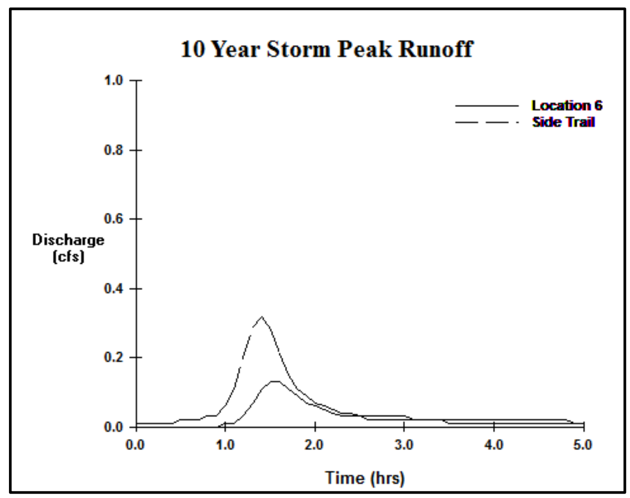
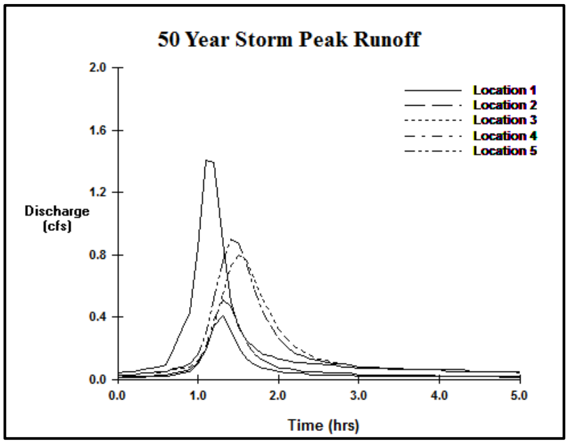


Figure D.3. 10 Year Storm Peak Runoff Hydrographs



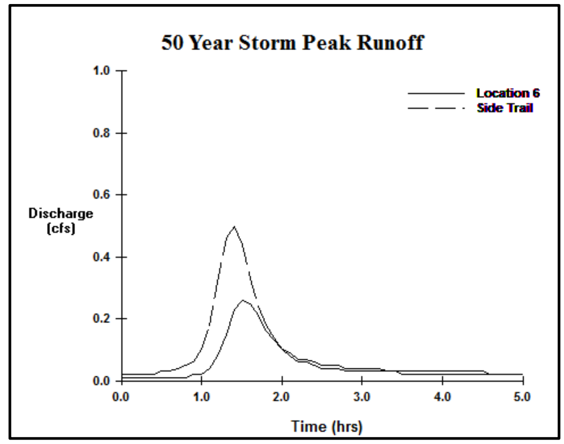
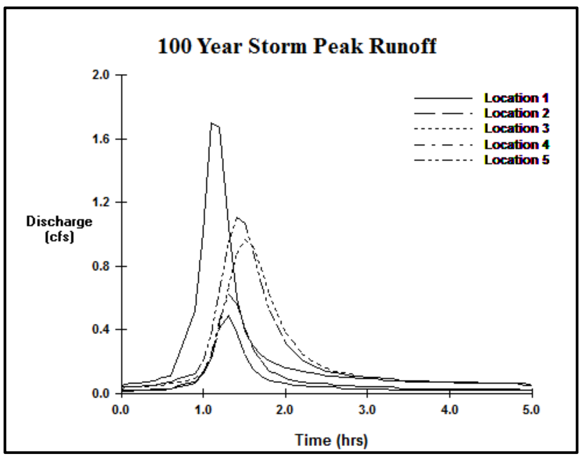


Figure D.4. 50 Year Storm Peak Runoff Hydrographs



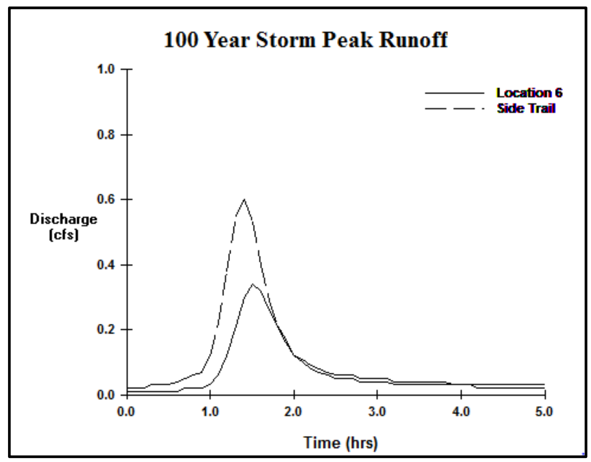


Figure D.5. 100 Year Storm Peak Runoff Hydrographs

Appendix E: Detailed Analysis, Design, and Civil 3D Results

Table E.1 Maximum Allowable Velocity at Each Structure using Manning's n Equation

	n	WP (ft)	Area (ft^2)	R (ft)	S	Q (cfs)	V (ft/s)		Structure #	diameter (ft)	depth (ft.)
Location 1	0.025	1.784444444	0.4	0.224159	0.04	1.759439	4.398598		1	1.5	0.4
Location 2	0.025	1.812820513	0.433333	0.239038	0.05	2.224325	5.133057		2	1.3	0.5
Location 3	0.025	2.038461538	0.52	0.255094	0.03	2.159123	4.15216		3	1.3	0.6
Location 4	0.025	1.812820513	0.433333	0.239038	0.03	1.722955	3.976049		4	1.3	0.5
Location 5	0.025	1.876190476	0.466667	0.248731	0.04	2.200069	4.714433		5	1.4	0.5
Location 6	0.025	2.016666667	0.533333	0.264463	0.03	2.268378	4.253208		6	1.6	0.5
	A	2td/3									
	P	t+8(d^2)/3t									
			m/s	ft/s							
	Max allowable velocity		1.75	5.74175							

Figure E.1. Overall Trail Structure Civil 3D Alignment

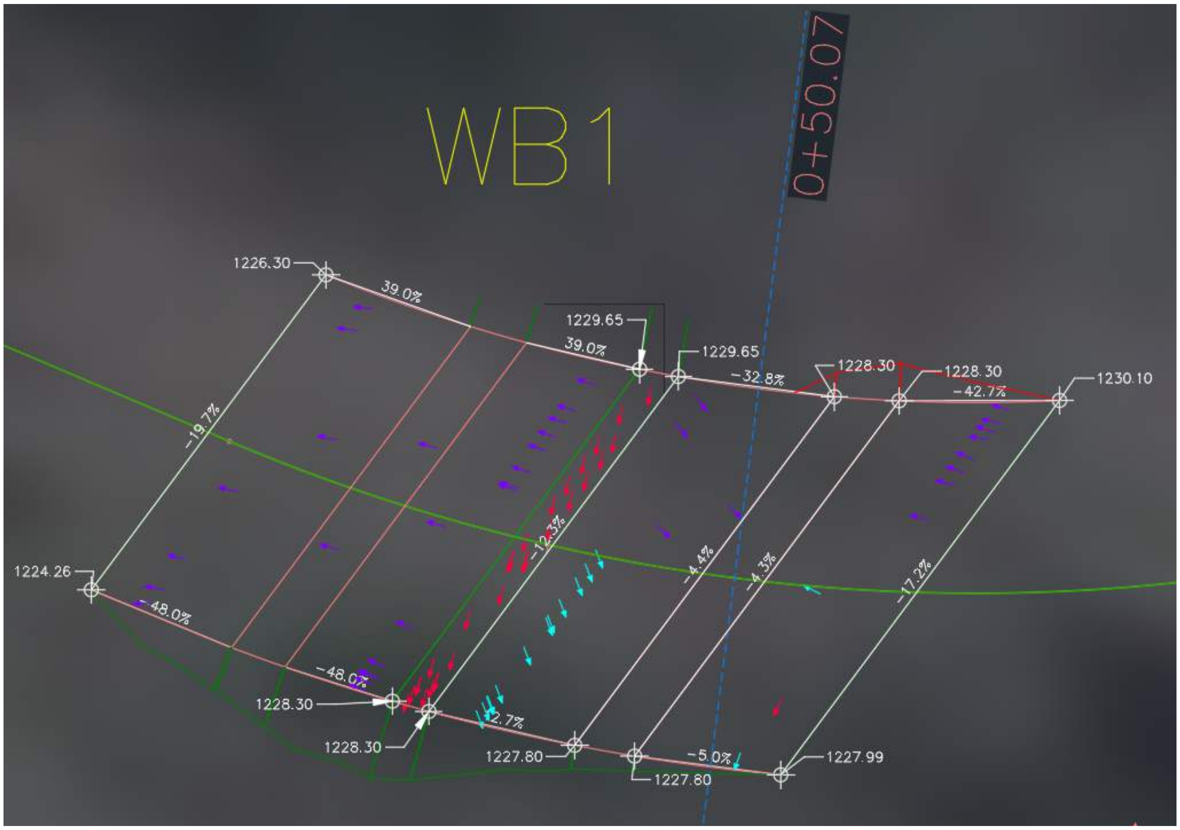


Figure E.2. Location 1 Structure Civil 3D Drawing

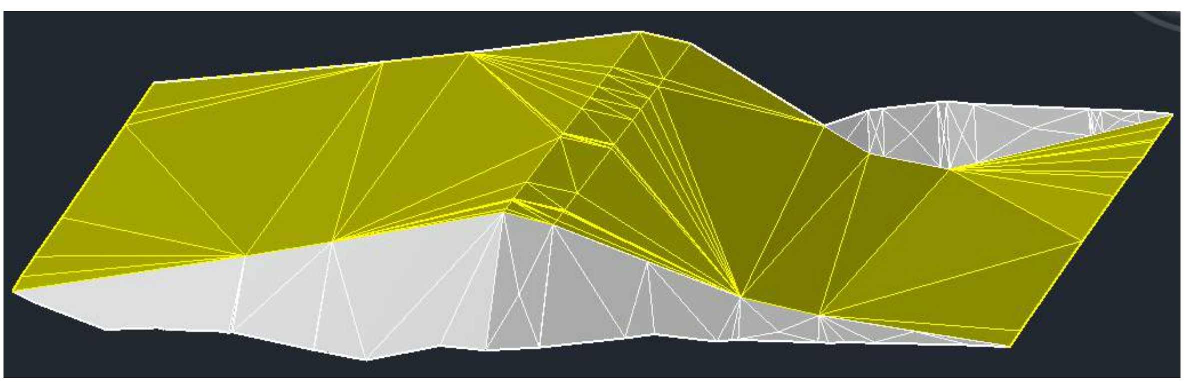


Figure E.3. Location 1 Structure 3D Model

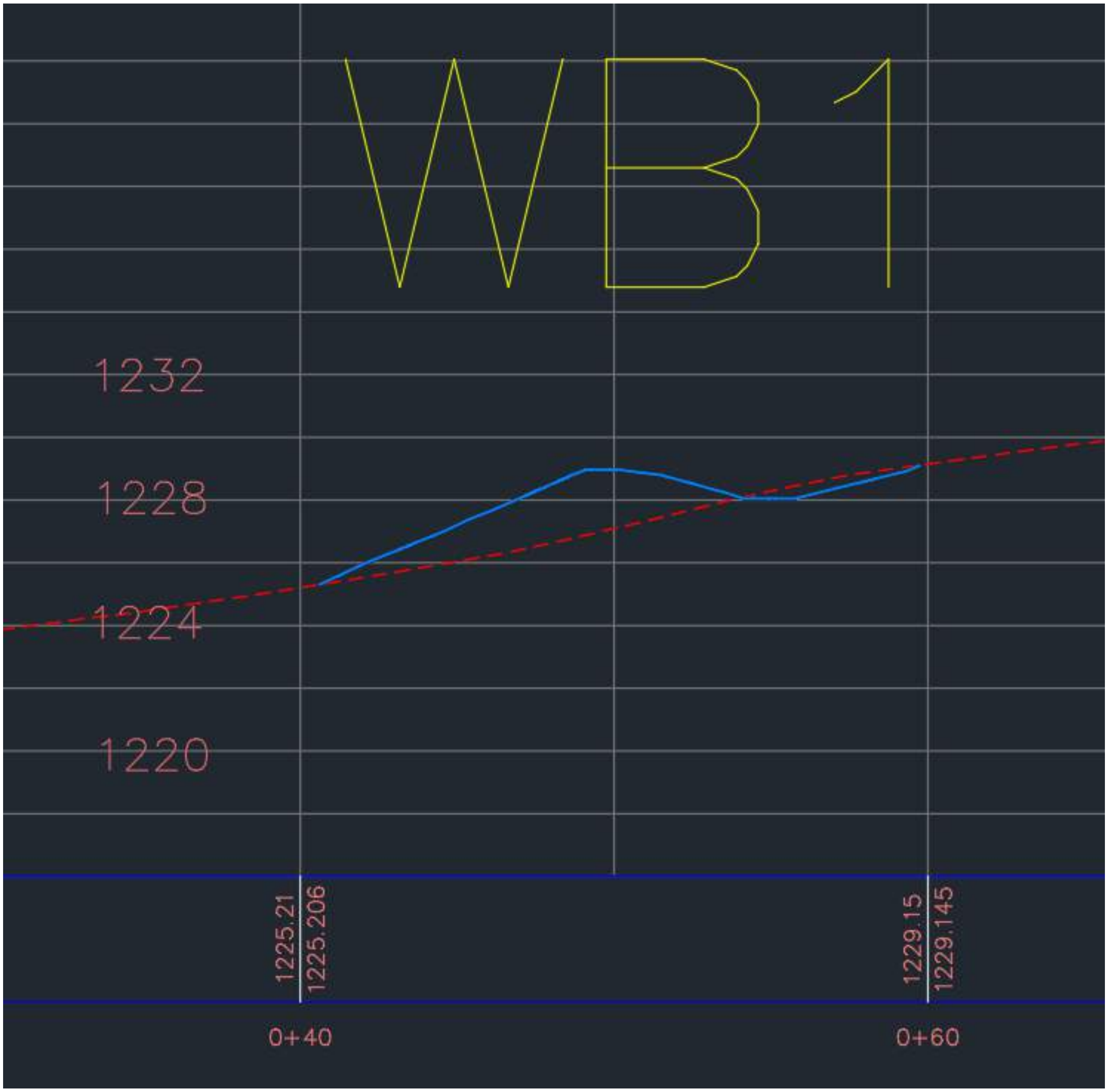


Figure E.4. Location 1 Profile View of Existing and Proposed Ground Elevation

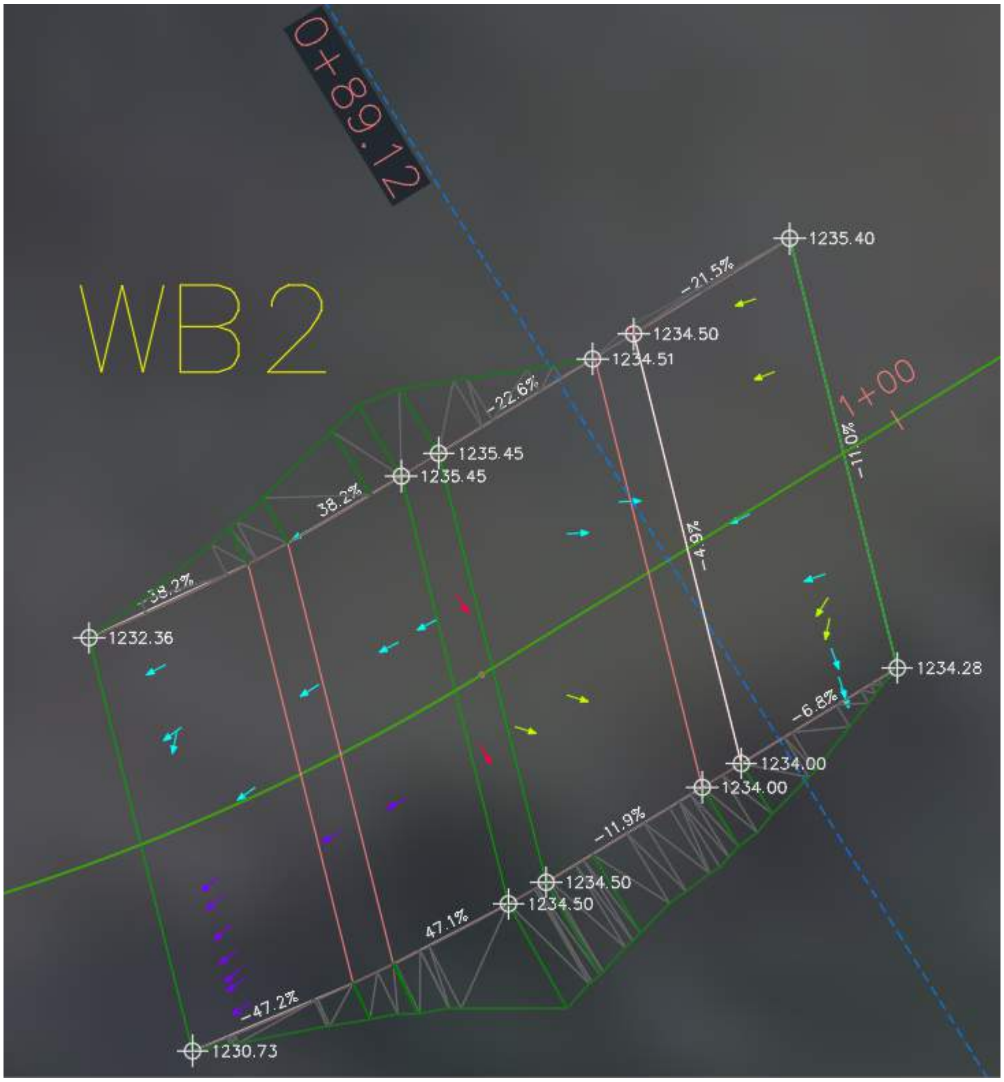


Figure E.5. Location 2 Structure Civil 3D Drawing

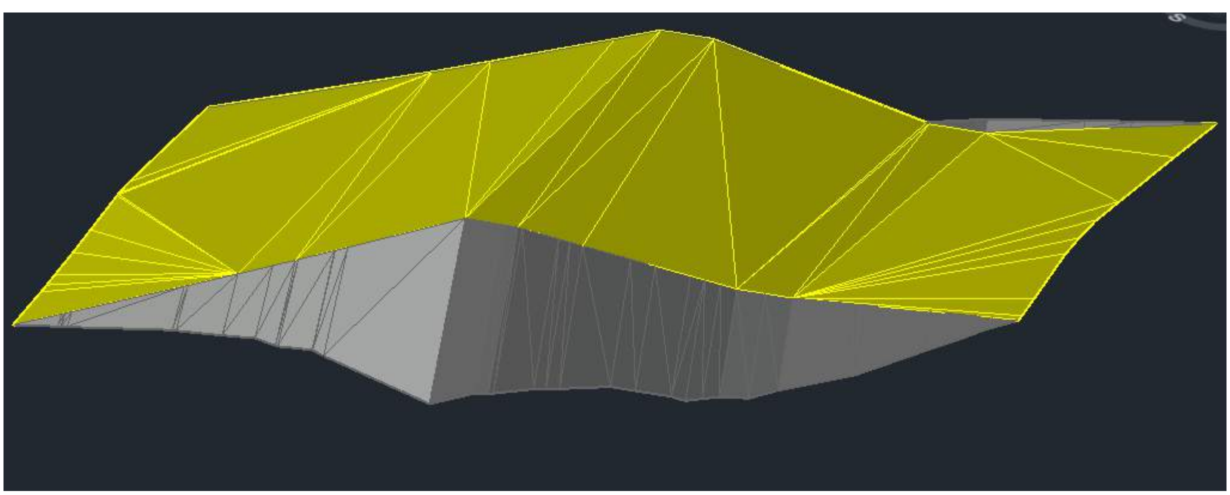


Figure E.6. Location 2 Structure 3D Model

Figure E.7. Location 2 Profile View of Existing and Proposed Ground Elevation

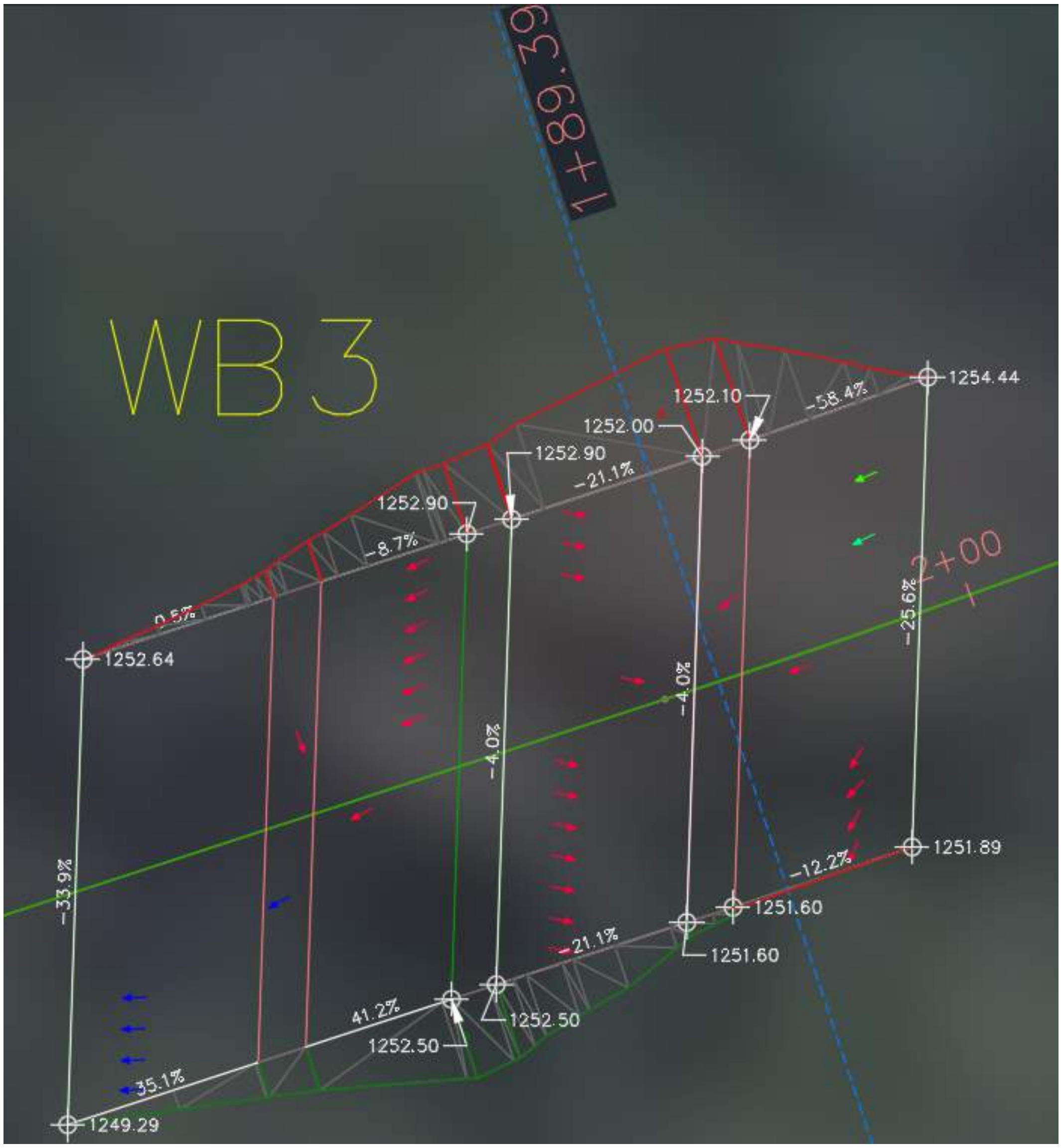


Figure E.8. Location 3 Structure Civil 3D Drawing

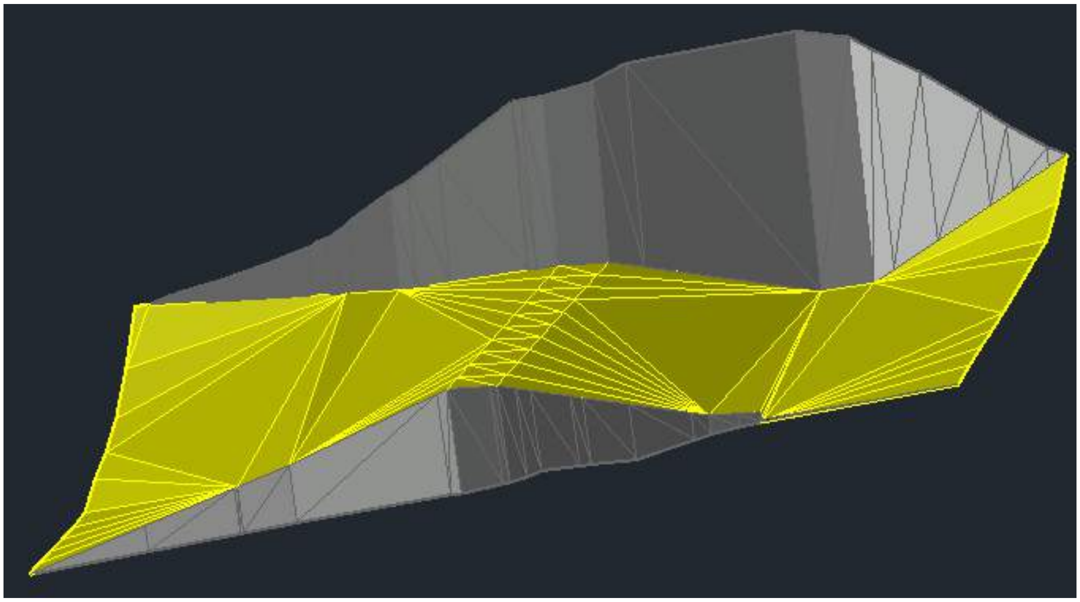


Figure E.9. Location 3 Structure 3D Model

Figure E.10. Location 3 Profile View of Existing and Proposed Ground Elevation

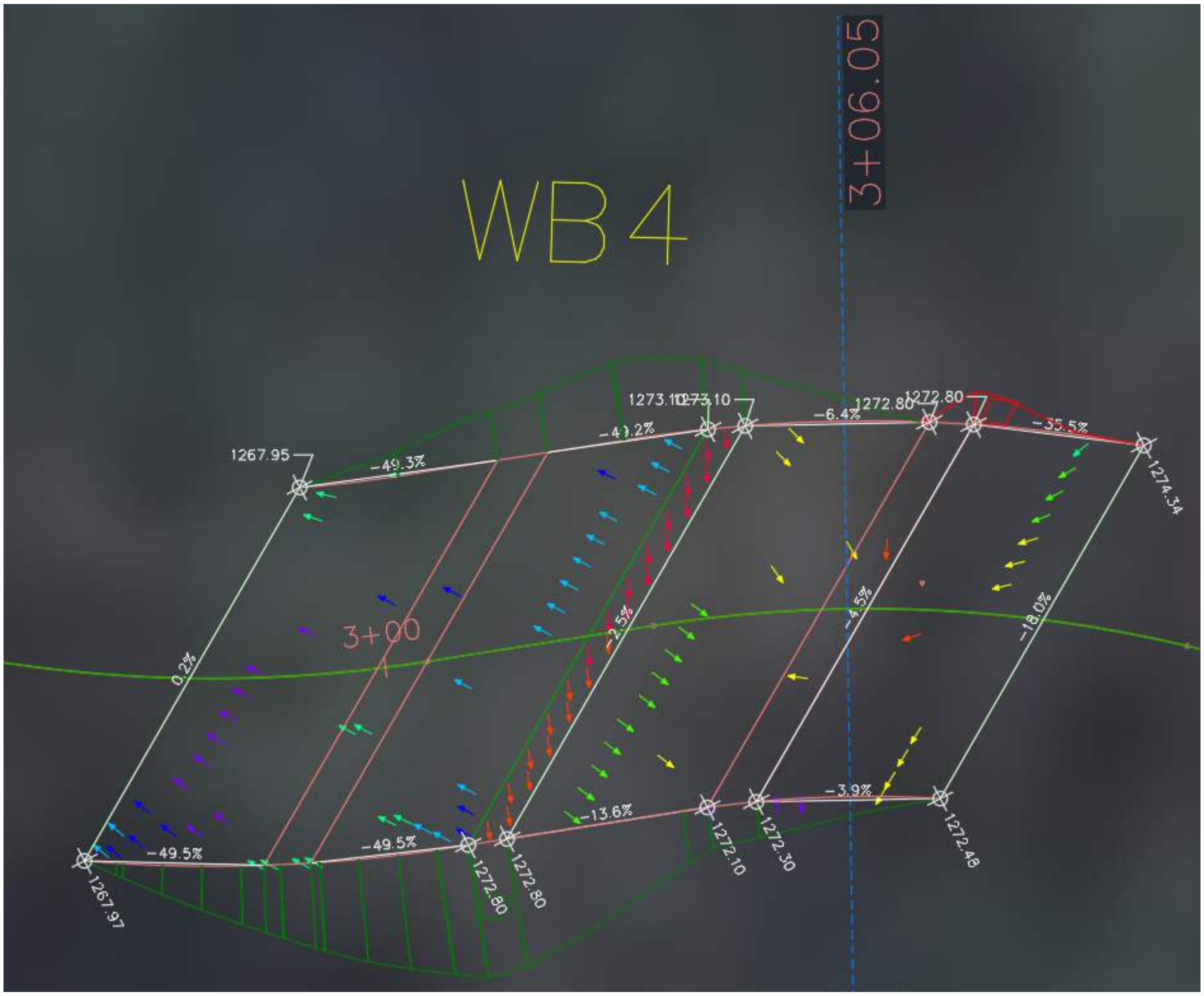


Figure E.11. Location 4 Structure Civil 3D Drawing

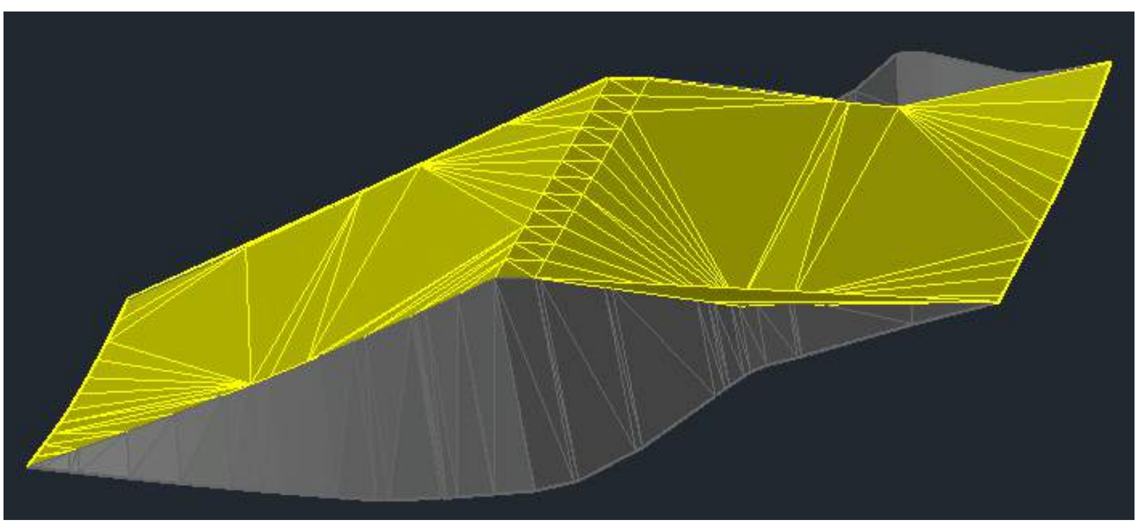


Figure E.12. Location 4 Structure 3D Model

Figure E.13. Location 4 Profile View of Existing and Proposed Ground Elevation

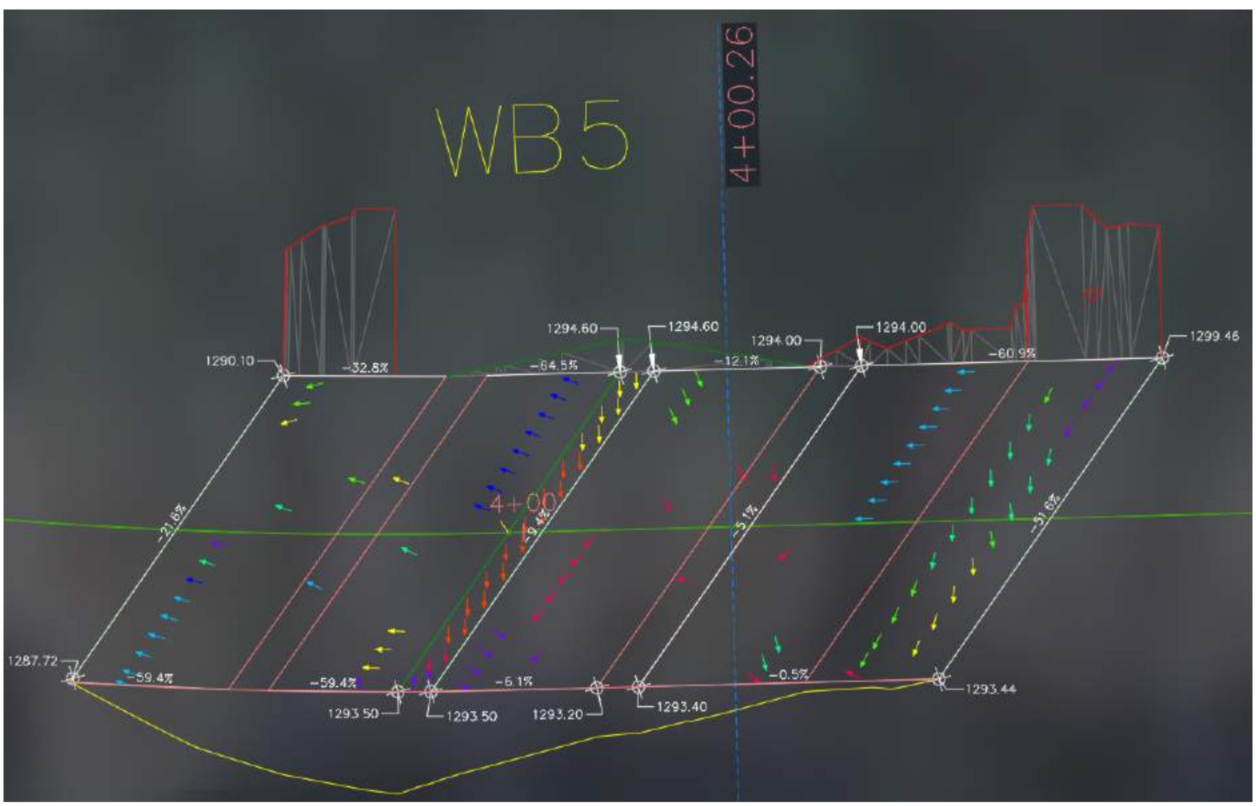


Figure E.14. Location 5 Structure Civil 3D Drawing

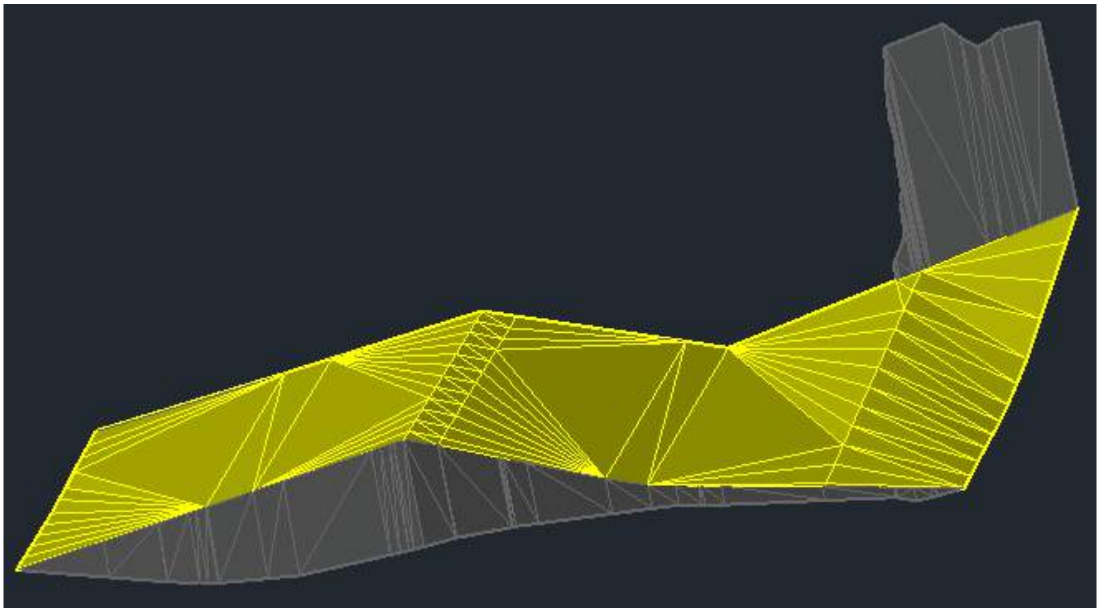


Figure E.15. Location 5 Structure 3D Model

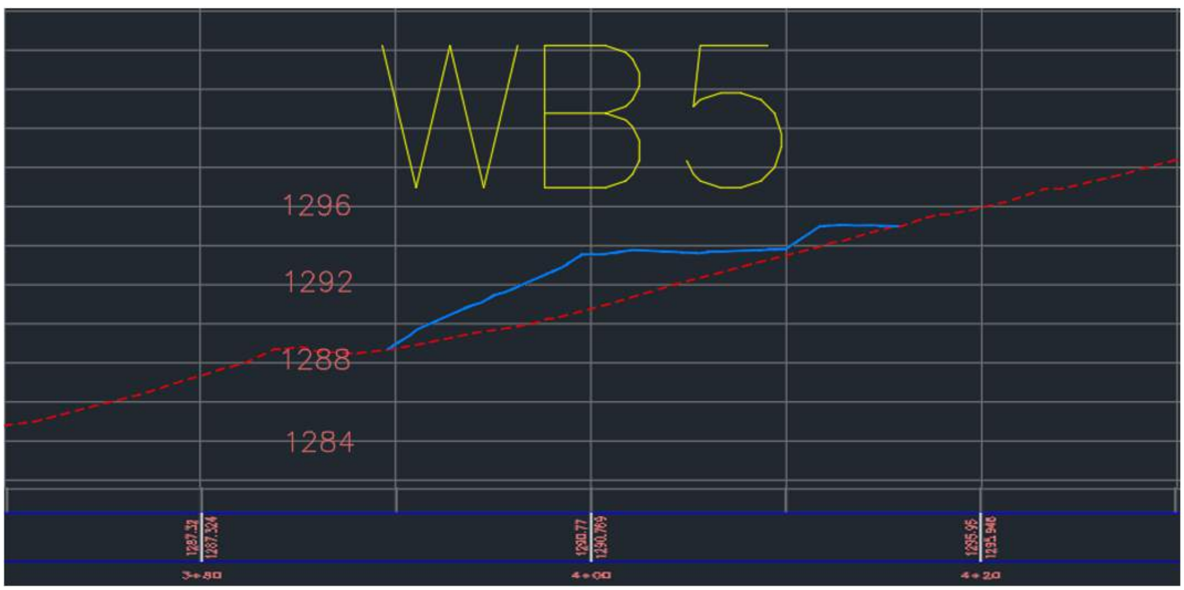


Figure E.16. Location 5 Profile View of Existing and Proposed Ground Elevation

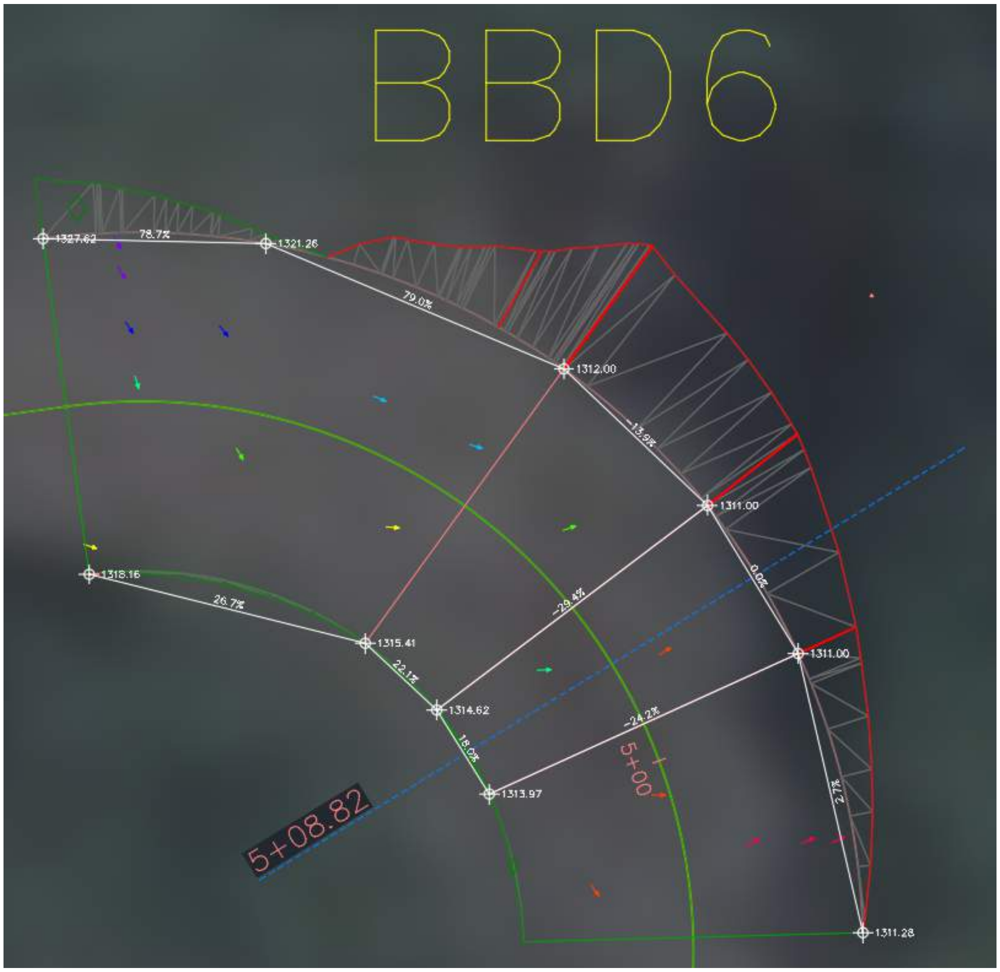


Figure E.17. Location 6 Structure Civil 3D Drawing

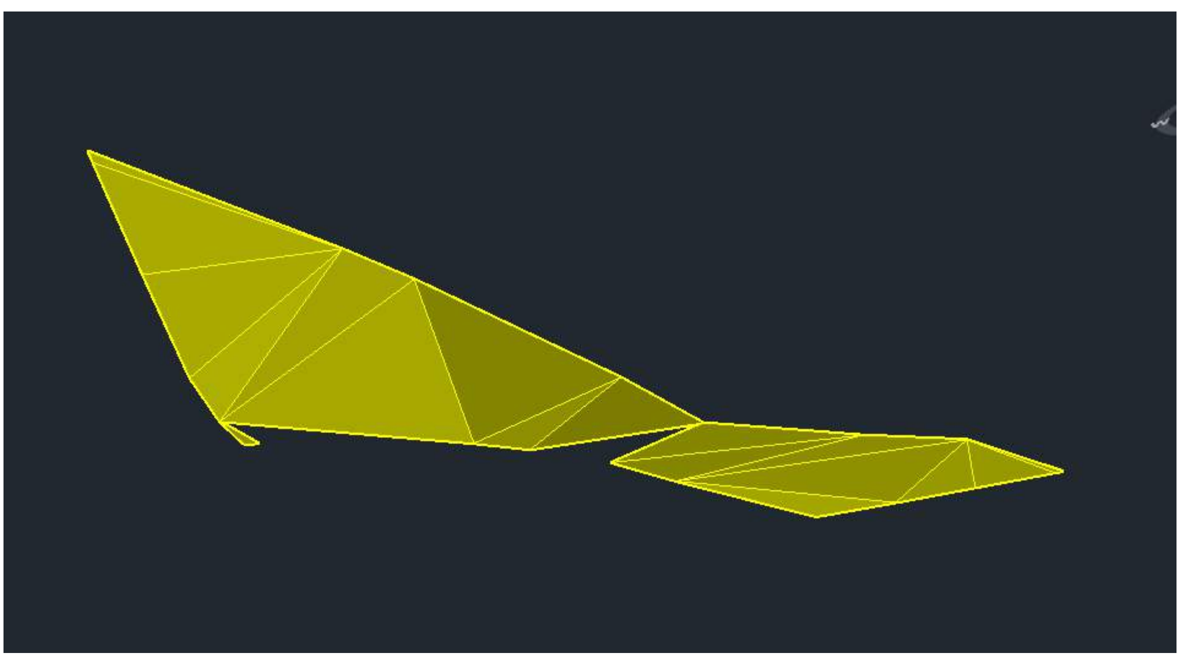


Figure E.18. Location 6 Structure 3D Model

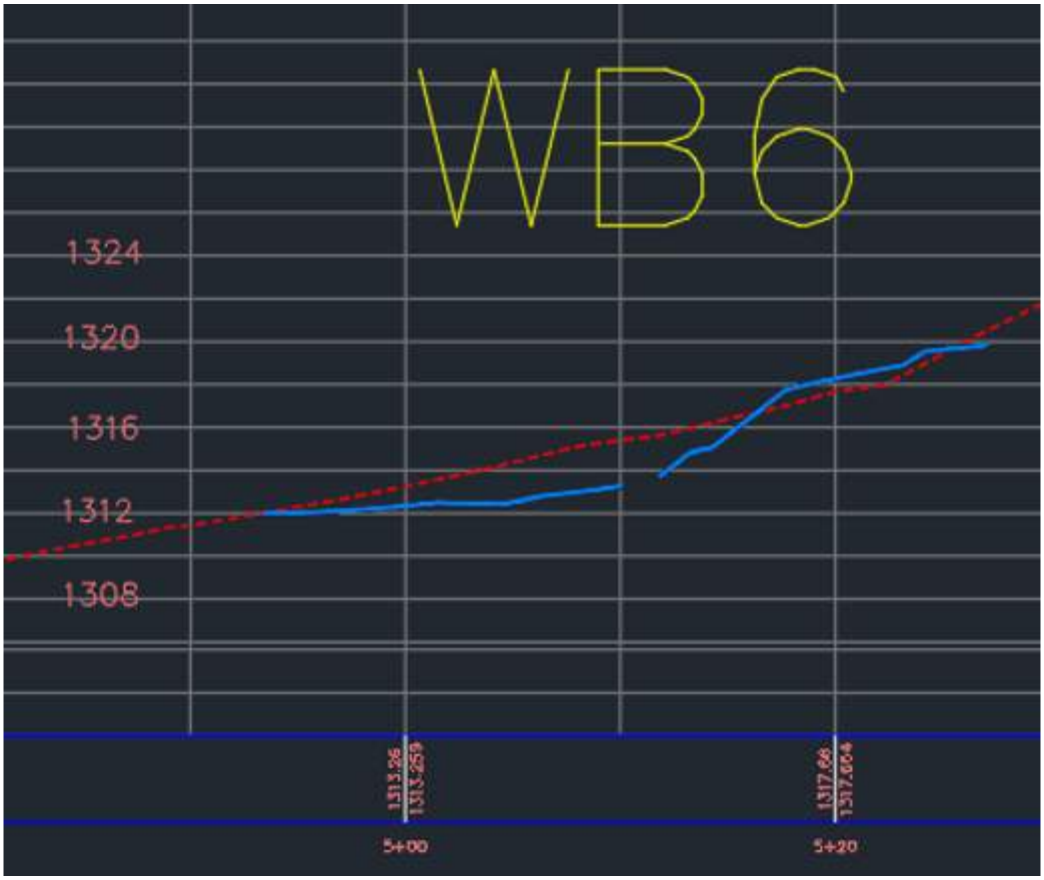


Figure E.19. Location 6 Profile View of Existing and Proposed Ground Elevation

Design Construction Details for each Structure

Table E.2. Location 1 Structure Stationing and Elevation Data

Left Side of Stucture and Trail					
Top	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
	0+00.00	1230.10'	4.21'		-42.73%
	0+04.21	1228.30'	1.70'	42.73%	0.00%
	0+05.91	1228.30'	1.04'	0.00%	32.77%
	0+06.95	1228.64'	3.08'	-32.77%	32.77%
	0+10.03	1229.65'	1.03'	-32.77%	0.00%
	0+11.06	1229.65'	3.04'	0.00%	-39.02%
	0+14.11	1228.46'	1.52'	39.02%	-39.02%
	0+15.63	1227.87'	4.03'	39.02%	-39.02%
Bottom	0+19.66	1226.30'		39.02%	
Right Side of Structure and Trail					
	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1224.26'	3.98'		47.95%
	0+03.98	1226.17'	1.49'	-47.95%	47.95%
	0+05.47	1226.88'	2.95'	-47.95%	47.95%
	0+08.42	1228.30'	0.99'	-47.95%	0.00%
	0+09.41	1228.30'	3.92'	0.00%	-12.74%
	0+13.34	1227.80'	1.59'	12.74%	0.00%
	0+14.93	1227.80'	3.86'	0.00%	5.02%
Bottom	0+18.79	1227.99'		-5.02%	
Bottom Edge of Structure					
	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1226.30'	1.53'		-19.29%
	0+01.53	1226.00'	0.57'	19.29%	-19.31%
	0+02.11	1225.89'	4.62'	19.31%	-19.23%
	0+06.73	1225.00'	2.03'	19.23%	-17.59%
	0+08.76	1224.64'	0.99'	17.59%	-20.24%
	0+09.75	1224.44'	0.54'	20.24%	-33.08%
Right	0+10.29	1224.26'		33.08%	
Top Edge of Structure					
	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1230.10'	0.69'		-14.14%
	0+00.69	1230.00'	0.65'	14.14%	-18.23%
	0+01.34	1229.88'	0.12'	18.23%	-14.43%
	0+01.46	1229.86'	0.74'	14.43%	-21.07%
	0+02.20	1229.71'	1.02'	21.07%	-9.39%
	0+03.22	1229.61'	0.31'	9.39%	-12.93%
	0+03.53	1229.57'	1.00'	12.93%	-16.58%
	0+04.53	1229.41'	2.39'	16.58%	-17.00%
	0+06.92	1229.00'	4.60'	17.00%	-18.33%
	0+11.52	1228.16'	0.72'	18.33%	-22.67%
Right	0+12.24	1227.99'		22.67%	

Table E.3. Location 2 Structure Stationing and Elevation Data

Left Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Bottom	0+00.00	1232.36'	4.02'		38.23%
	0+04.02	1233.90'	1.03'	-38.23%	38.23%
	0+05.05	1234.29'	2.21'	-38.23%	38.23%
	0+07.25	1235.14'	0.82'	-38.23%	38.23%
	0+08.07	1235.45'	1.00'	-38.23%	0.00%
	0+09.07	1235.45'	4.14'	0.00%	-22.65%
	0+13.21	1234.51'	0.06'	22.65%	-22.65%
	0+13.27	1234.50'	1.05'	22.65%	0.00%
	0+14.32	1234.50'	4.19'	0.00%	21.51%
Top	0+18.51	1235.40'		-21.51%	

Right Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1234.28'	4.19'		-6.77%
	0+04.19	1234.00'	1.05'	6.77%	0.00%
	0+05.24	1234.00'	2.95'	0.00%	11.93%
	0+08.19	1234.35'	1.24'	-11.93%	11.93%
	0+09.43	1234.50'	0.99'	-11.93%	0.00%
	0+10.43	1234.50'	2.98'	0.00%	-47.14%
	0+13.41	1233.09'	1.02'	47.14%	-47.14%
	0+14.43	1232.61'	3.99'	47.14%	-47.14%
Bottom	0+18.42	1230.73'		47.14%	

Bottom Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Right	0+00.00	1230.73'	1.40'		19.30%
	0+01.40	1231.00'	0.29'	-19.30%	19.91%
	0+01.69	1231.06'	0.41'	-19.91%	23.86%
	0+02.10	1231.16'	0.87'	-23.86%	22.53%
	0+02.97	1231.35'	0.85'	-22.53%	25.19%
	0+03.82	1231.57'	1.28'	-25.19%	25.73%
	0+05.10	1231.89'	0.05'	-25.73%	23.84%
	0+05.15	1231.91'	0.06'	-23.84%	27.54%
	0+05.21	1231.92'	0.56'	-27.54%	13.46%
	0+05.77	1232.00'	4.01'	-13.46%	9.08%
Left	0+09.78	1232.36'		-9.08%	

Top Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Right	0+00.00	1234.28'	0.13'		37.50%
	0+00.13	1234.33'	0.60'	-37.50%	30.63%
	0+00.73	1234.52'	1.46'	-30.63%	33.10%
	0+02.19	1235.00'	0.67'	-33.10%	18.73%
	0+02.86	1235.12'	0.87'	-18.73%	13.67%
	0+03.73	1235.24'	1.22'	-13.67%	2.73%
	0+04.95	1235.28'	2.95'	-2.73%	2.73%
	0+07.89	1235.36'	2.28'	-2.73%	1.96%
Left	0+10.17	1235.40'		-1.96%	

Table E.4. Location 3 Structure Stationing and Elevation Data

Left Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1254.44'	4.01'		-58.36%
	0+04.01	1252.10'	1.07'	58.36%	-9.35%
	0+05.08	1252.00'	4.26'	9.35%	21.12%
	0+09.34	1252.90'	1.00'	-21.12%	0.00%
	0+10.34	1252.90'	3.26'	0.00%	-8.70%
	0+13.59	1252.62'	1.06'	8.70%	0.52%
	0+14.66	1252.62'	4.00'	-0.52%	0.52%
	0+18.66	1252.64'	0.26'	-0.52%	0.52%
Bottom	0+18.92	1252.64'		-0.52%	

Right Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Bottom	0+00.00	1249.29'	4.26'		35.08%
	0+04.26	1250.78'	1.06'	-35.08%	35.08%
	0+05.32	1251.16'	3.26'	-35.08%	41.22%
	0+08.58	1252.50'	1.00'	-41.22%	0.00%
	0+09.58	1252.50'	4.26'	0.00%	-21.14%
	0+13.83	1251.60'	1.04'	21.14%	0.00%
	0+14.87	1251.60'	0.02'	0.00%	-694.28%
	0+14.89	1251.47'	0.01'	694.28%	-694.28%
	0+14.90	1251.40'	3.98'	694.28%	12.20%
Top	0+18.88	1251.89'		-12.20%	

Bottom Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1252.64'	1.00'		-106.07%
	0+01.00	1251.58'	1.00'	106.07%	-80.26%
	0+02.00	1250.78'	1.00'	80.26%	-48.76%
	0+03.00	1250.29'	1.00'	48.76%	-32.32%
	0+04.00	1249.97'	1.00'	32.32%	-48.06%
	0+05.00	1249.49'	1.00'	48.06%	-8.42%
	0+06.00	1249.41'	1.00'	8.42%	-2.86%
	0+07.00	1249.38'	1.00'	2.86%	-2.91%
	0+08.00	1249.35'	1.00'	2.91%	-2.95%
	0+09.00	1249.32'	0.90'	2.95%	-2.95%
Right	0+09.90	1249.29'		2.95%	

Top Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1254.44'	1.00'		-78.51%
	0+01.00	1253.65'	1.00'	78.51%	-54.03%
	0+02.00	1253.11'	1.00'	54.03%	-14.14%
	0+03.00	1252.97'	3.00'	14.14%	-16.23%
	0+06.00	1252.49'	1.00'	16.23%	-14.76%
	0+07.00	1252.34'	1.00'	14.76%	-12.43%
	0+08.00	1252.21'	1.00'	12.43%	-15.11%
	0+09.00	1252.06'	0.99'	15.11%	-17.84%
Right	0+09.99	1251.89'		17.84%	

Table E.5. Location 4 Structure Stationing and Elevation Data

Left Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1274.34'	4.35'		-35.45%
	0+04.35	1272.80'	1.12'	35.45%	0.00%
	0+05.47	1272.80'	0.28'	0.00%	6.41%
	0+05.75	1272.82'	4.40'	-6.41%	6.41%
	0+10.15	1273.10'	0.95'	-6.41%	0.00%
	0+11.10	1273.10'	2.15'	0.00%	-49.24%
	0+13.24	1272.04'	1.96'	49.24%	-49.24%
	0+15.20	1271.08'	1.29'	49.24%	-49.24%
	0+16.49	1270.44'	2.54'	49.24%	-49.24%
	0+19.03	1269.19'	2.52'	49.24%	-49.24%
Bottom	0+21.55	1267.95'		49.24%	

Right Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1272.48'	4.67'		-3.85%
	0+04.67	1272.30'	1.25'	3.85%	-16.05%
	0+05.92	1272.10'	0.64'	16.05%	13.61%
	0+06.56	1272.19'	4.50'	-13.61%	13.61%
	0+11.06	1272.80'	0.99'	-13.61%	0.00%
	0+12.05	1272.80'	0.81'	0.00%	-49.49%
	0+12.87	1272.40'	0.99'	49.49%	-49.49%
	0+13.86	1271.91'	0.99'	49.49%	-49.49%
	0+14.86	1271.41'	0.99'	49.49%	-49.49%
	0+15.85	1270.92'	0.22'	49.49%	-49.49%
	0+16.07	1270.81'	0.78'	49.49%	-49.49%
	0+16.84	1270.43'	0.41'	49.49%	-49.49%
	0+17.26	1270.22'	0.58'	49.49%	-49.49%
	0+17.84	1269.94'	0.99'	49.49%	-49.49%
	0+18.83	1269.44'	0.99'	49.49%	-49.49%
	0+19.83	1268.95'	0.99'	49.49%	-49.49%
	0+20.82	1268.46'	0.18'	49.49%	-49.49%
	0+21.00	1268.37'	0.82'	49.49%	-49.49%
Bottom	0+21.82	1267.97'		49.49%	

Bottom Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1267.95'	1.00'		-15.68%
	0+01.00	1267.79'	1.00'	15.68%	-10.97%
	0+02.00	1267.68'	1.00'	10.97%	-7.42%
	0+03.00	1267.61'	1.00'	7.42%	-5.93%
	0+04.00	1267.55'	1.00'	5.93%	-1.90%
	0+05.00	1267.53'	1.00'	1.90%	-0.66%
	0+06.00	1267.53'	1.00'	0.66%	5.52%
	0+07.00	1267.58'	1.00'	-5.52%	9.89%
	0+08.00	1267.68'	1.00'	-9.89%	9.89%
	0+09.00	1267.78'	1.00'	-9.89%	9.89%
	0+10.00	1267.88'	0.91'	-9.89%	9.89%
Right	0+10.91	1267.97'		-9.89%	

Top Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1274.34'	1.00'		-49.64%
	0+01.00	1273.85'	1.00'	49.64%	-34.50%
	0+02.00	1273.50'	1.00'	34.50%	-31.76%
	0+03.00	1273.18'	1.00'	31.76%	-20.46%
	0+04.00	1272.98'	1.00'	20.46%	-11.54%
	0+05.00	1272.86'	1.00'	11.54%	-7.18%
	0+06.00	1272.79'	1.00'	7.18%	-7.18%
	0+07.00	1272.72'	1.00'	7.18%	-7.18%
	0+08.00	1272.65'	1.00'	7.18%	-7.18%
	0+09.00	1272.58'	1.00'	7.18%	-7.21%
	0+10.00	1272.50'	0.32'	7.21%	-7.27%
Right	0+10.32	1272.48'		7.27%	

Table E.6. Location 5 Structure Stationing and Elevation Data

Left Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1299.46'	4.00'		-53.99%
	0+04.00	1297.30'	0.64'	53.99%	-53.99%
	0+04.64	1296.96'	4.32'	53.99%	-53.99%
	0+08.97	1294.62'	1.24'	53.99%	0.00%
	0+10.21	1294.62'	4.97'	0.00%	-0.41%
	0+15.17	1294.60'	1.01'	0.41%	0.00%
	0+16.18	1294.60'	5.19'	0.00%	-44.76%
	0+21.37	1292.28'	4.86'	44.76%	-44.76%
Bottom	0+26.23	1290.10'		44.76%	

Right Side of Structure and Trail

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Top	0+00.00	1293.44'	4.00'		-12.73%
	0+04.00	1292.93'	4.97'	12.73%	-12.73%
	0+08.97	1292.30'	1.24'	12.73%	0.00%
	0+10.21	1292.30'	4.95'	0.00%	4.04%
	0+15.16	1292.50'	0.99'	-4.04%	0.00%
	0+16.15	1292.50'	3.86'	0.00%	-49.15%
	0+20.01	1290.60'	1.20'	49.15%	-49.15%
	0+21.21	1290.02'	4.73'	49.15%	-49.15%
Bottom	0+25.93	1287.69'		49.15%	

Bottom Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1290.10'	1.00'		-26.21%
	0+01.00	1289.84'	1.00'	26.21%	-21.69%
	0+02.00	1289.62'	1.00'	21.69%	-25.91%
	0+03.00	1289.36'	1.00'	25.91%	-31.57%
	0+04.00	1289.05'	1.00'	31.57%	-19.11%
	0+05.00	1288.86'	1.00'	19.11%	-25.95%
	0+06.00	1288.60'	1.00'	25.95%	-17.63%
	0+07.00	1288.42'	1.00'	17.63%	-17.60%
	0+08.00	1288.24'	1.00'	17.60%	-17.58%
	0+09.00	1288.07'	1.00'	17.58%	-17.57%
	0+10.00	1287.89'	1.00'	17.57%	-17.57%
	0+11.00	1287.72'	0.14'	17.57%	-17.57%
Right	0+11.14	1287.69'		17.57%	

Top Edge of Structure

	Station	Elevation(Actual)	Length	Grade Back	Grade Ahead
Left	0+00.00	1299.46'	0.83'		-94.78%
	0+00.83	1298.67'	1.00'	94.78%	-90.44%
	0+01.83	1297.77'	1.00'	90.44%	-85.23%
	0+02.83	1296.91'	1.00'	85.23%	-93.45%
	0+03.83	1295.98'	1.00'	93.45%	-53.73%
	0+04.83	1295.44'	1.00'	53.73%	-45.31%
	0+05.83	1294.99'	1.00'	45.31%	-31.69%
	0+06.83	1294.67'	1.00'	31.69%	-24.20%
	0+07.83	1294.43'	1.00'	24.20%	-23.69%
	0+08.83	1294.19'	1.00'	23.69%	-24.43%
	0+09.83	1293.95'	1.00'	24.43%	-27.66%
	0+10.83	1293.67'	0.83'	27.66%	-27.66%
Right	0+11.67	1293.44'		27.66%	

Table E.7. Location 6 Structure Stationing and Elevation Data

Left Side of Structure and Trail

Station	Elevation(Actual)	Length	Grade Bacl	Grade Ahead
0+00.00	1327.62'	8.11'		-78.37%
0+08.11	1321.26'	2.29'	78.37%	-78.37%
0+10.39	1319.47'	6.71'	78.37%	-78.37%
0+17.11	1314.21'	2.82'	78.37%	-78.37%
0+19.93	1312.00'	7.21'	78.37%	-13.87%
0+27.14	1311.00'	6.31'	13.87%	0.00%
0+33.45	1311.00'	10.47'	0.00%	2.66%
0+43.92	1311.28'		-2.66%	

Right Side of Structure and Trail

Station	Elevation(Actual)	Length	Grade Bacl	Grade Ahead
0+00.00	1318.18'	0.54'		-29.71%
0+00.54	1318.02'	0.33'	29.71%	-31.28%
0+00.87	1317.92'	0.68'	31.28%	-31.87%
0+01.55	1317.70'	0.12'	31.87%	-32.05%
0+01.68	1317.66'	0.05'	32.05%	-29.34%
0+01.72	1317.64'	1.84'	29.34%	-29.84%
0+03.57	1317.09'	0.31'	29.84%	-30.23%
0+03.88	1317.00'	0.25'	30.23%	-30.11%
0+04.13	1316.92'	0.18'	30.11%	-24.33%
0+04.31	1316.88'	0.26'	24.33%	-26.62%
0+04.57	1316.81'	0.23'	26.62%	-26.48%
0+04.80	1316.75'	1.95'	26.48%	-25.12%
0+06.75	1316.26'	1.12'	25.12%	-23.42%
0+07.86	1316.00'	0.44'	23.42%	-22.40%
0+08.31	1315.90'	0.63'	22.40%	-22.75%
0+08.94	1315.76'	1.55'	22.75%	-23.44%
0+10.49	1315.39'	0.18'	23.44%	-23.94%
0+10.67	1315.35'	1.50'	23.94%	-23.35%
0+12.17	1315.00'	1.11'	23.35%	-20.45%
0+13.28	1314.77'	0.77'	20.45%	-19.86%
0+14.05	1314.62'	1.64'	19.86%	-19.25%
0+15.69	1314.31'	0.69'	19.25%	-19.66%
0+16.38	1314.17'	0.31'	19.66%	-17.91%
0+16.68	1314.11'	0.13'	17.91%	-15.65%
0+16.81	1314.09'	0.69'	15.65%	-13.83%
0+17.50	1314.00'	0.15'	13.83%	-17.86%
0+17.64	1313.97'	1.44'	17.86%	-16.54%
0+19.09	1313.73'	0.49'	16.54%	-16.94%
0+19.57	1313.65'	1.02'	16.94%	-19.03%
0+20.60	1313.46'	1.21'	19.03%	-13.31%
0+21.81	1313.30'	0.54'	13.31%	-13.38%
0+22.35	1313.22'	0.42'	13.38%	-14.00%
0+22.77	1313.17'	0.10'	14.00%	-8.85%
0+22.86	1313.16'	0.31'	8.85%	-11.54%
0+23.18	1313.12'		11.54%	

Bottom Edge of Structure

Station	Elevation(Actual)	Length	Grade Bacl	Grade Ahead
0+00.00	1313.12'	3.00'		-23.23%
0+03.00	1312.42'	3.00'	23.23%	-12.97%
0+06.00	1312.03'	3.00'	12.97%	-11.93%
0+09.00	1311.68'	3.00'	11.93%	-12.04%
0+12.00	1311.32'	0.30'	12.04%	-12.09%
0+12.30	1311.28'		12.09%	

Top Edge of Structure

Station	Elevation(Actual)	Length	Grade Bacl	Grade Ahead
0+00.00	1318.16'	3.00'		12.46%
0+03.00	1318.53'	3.00'	-12.46%	40.05%
0+06.00	1319.74'	3.00'	-40.05%	118.88%
0+09.00	1323.30'	3.00'	-118.88%	130.35%
0+12.00	1327.21'	0.30'	-130.35%	134.46%
0+12.30	1327.62'		-134.46%	

Appendix F: SWMM Results

Water Elevation Profiles:

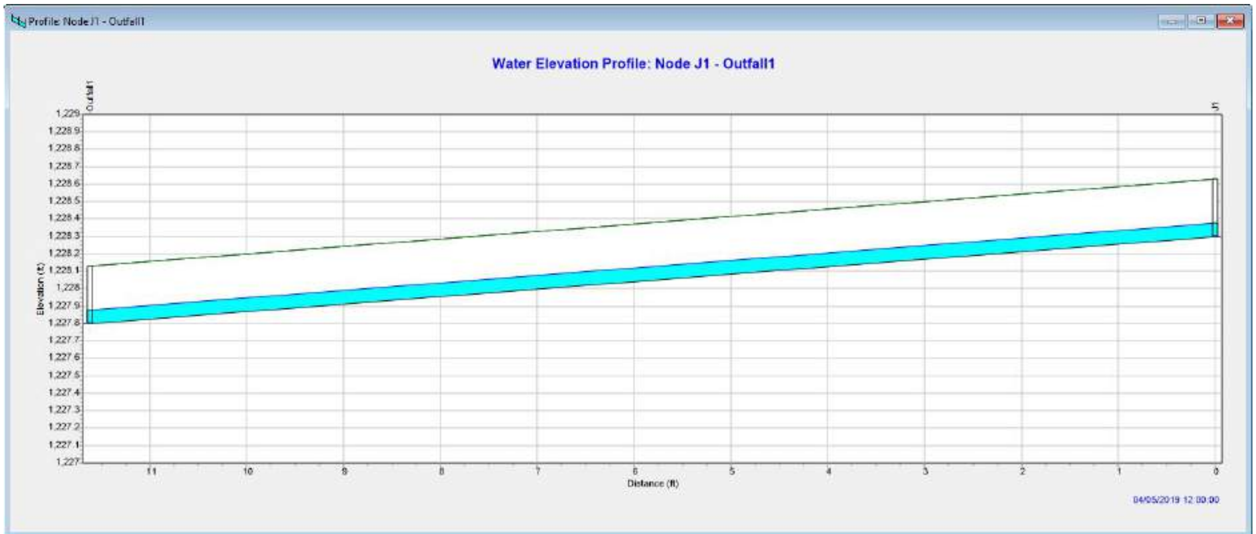


Figure F.1. Water elevation profile at location 1.

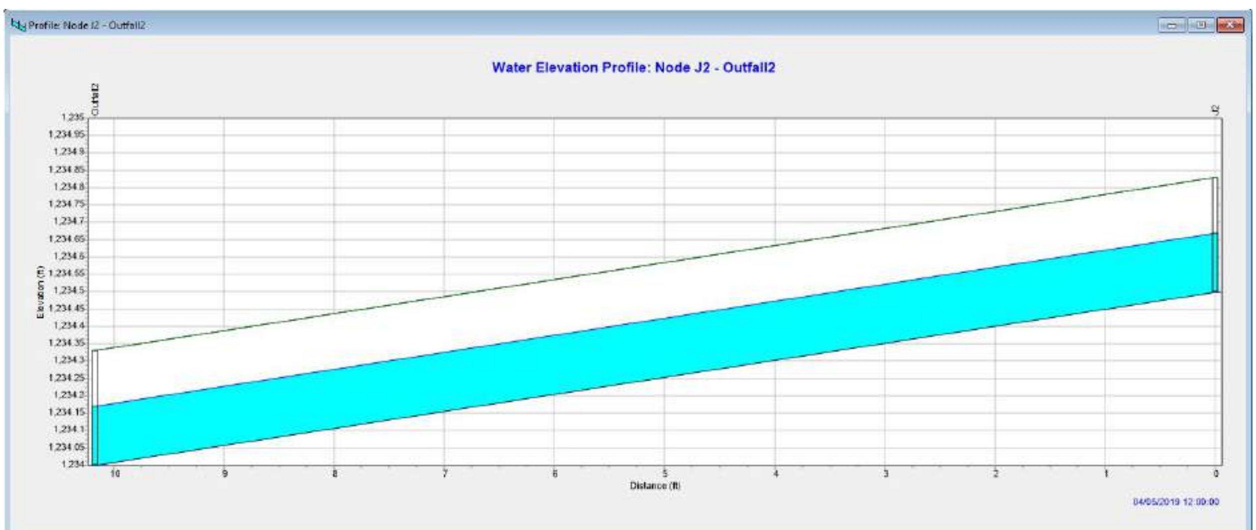


Figure F.2. Water elevation profile at location 2.

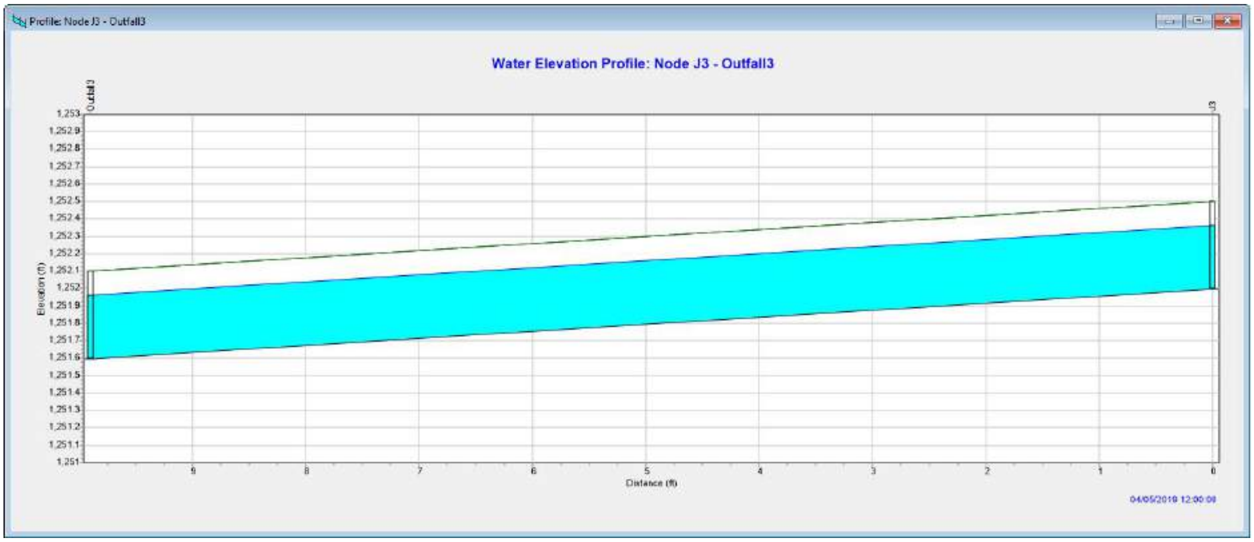


Figure F.3. Water elevation profile at location 3.

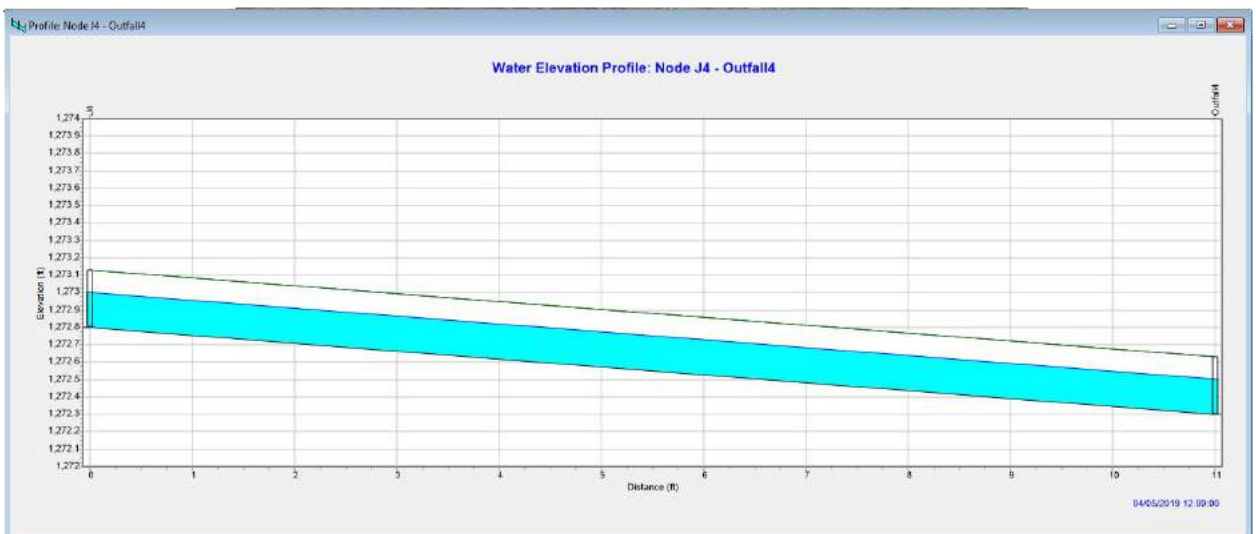


Figure F.4. Water elevation profile at location 4.

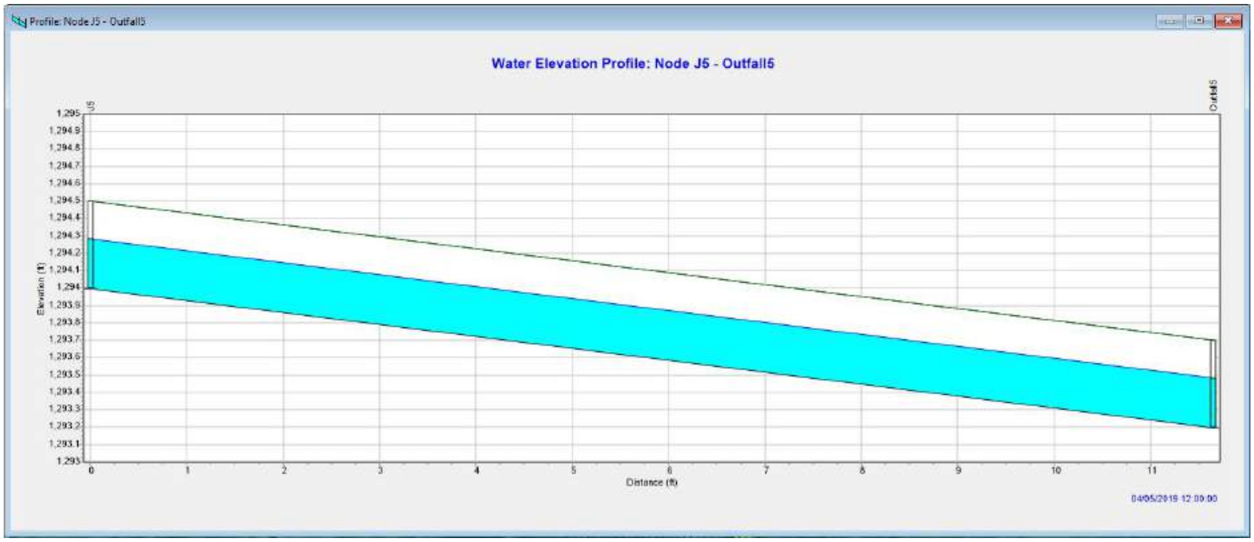


Figure F.5. Water elevation profile at location 5.

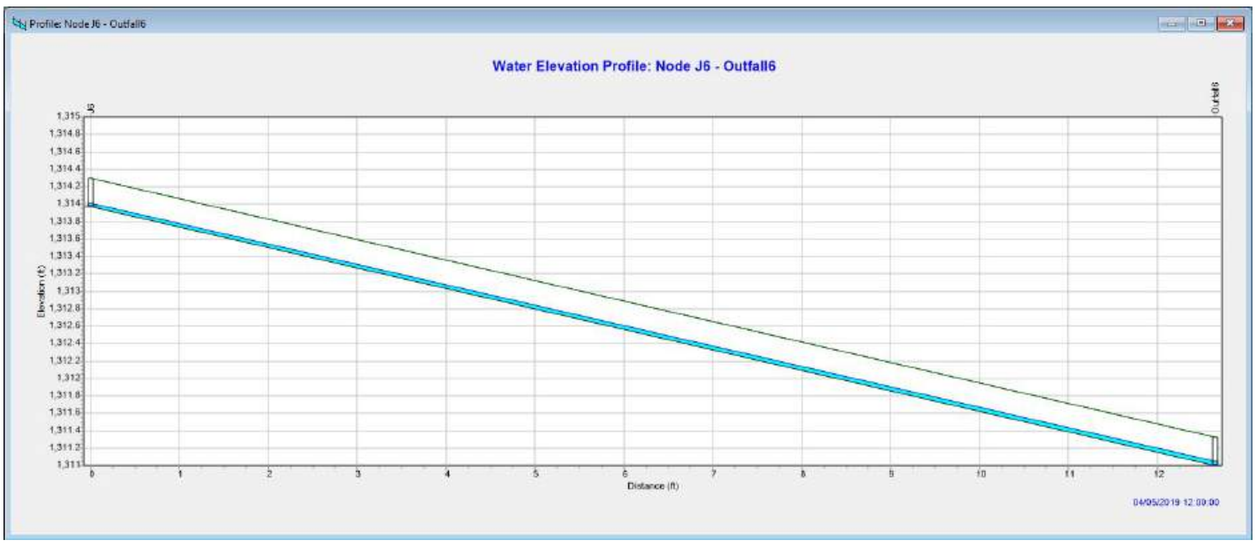


Figure F.6. Water elevation profile at location 6.

SWMM Element Dimensions:

Table F.1. Dimensions for each of the subcatchments.

Subcatchments			
	Area (ac)	Slope (%)	Curve Number
Location1	0.03	26	83
Location2	0.11	17	82.29
Location3	0.33	17	80.52
Location4	0.14	24	80.84
Location5	0.3	28	76.54
Location6	0.16	22	68.43

Table F.2. Dimensions for each of the junction points.

Junctions	
	Elevation (ft)
J1	1228.9
J2	1234.5
J3	1252
J4	1272.8
J5	1294
J6	1313.97

Table F.3. Dimensions for each of the outfall points.

Outfalls	
	Elevation (ft)
Outfall1	1227.8
Outfall2	1234
Outfall3	1251.6
Outfall4	1272.3
Outfall5	1293.2
Outfall6	1311

Table F.4. Dimensions for each of the conduits.

Channels/Conduits						
	Length (ft)	Manning's n	Depth (ft)	Bottom Width (ft)	Left Slope (ft/ft)	Right Slope (ft/ft)
C1	11.62	0.025	0.33	1	0.127	0.05
C2	10.17	0.025	0.33	1	0.119	0.068
C3	9.9	0.025	0.5	1	0.211	0.122
C4	11	0.025	0.33	1	0.136	0.039
C5	11.65	0.025	0.5	1	0.12	0.005
C6	12.65	0.025	0.33	4	0.027	0.139

SWMM Flow Results:

Summary Results

Topic: Link Flow — Click a column header to sort the column.

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| ft/sec	Max / Full Flow	Max / Full Depth
C1	CONDUIT	0.16	0	12:00	2.06	0.11	0.24
C2	CONDUIT	0.59	0	12:00	3.38	0.38	0.52
C3	CONDUIT	1.71	0	12:00	4.40	0.64	0.73
C4	CONDUIT	0.73	0	12:00	3.53	0.49	0.62
C5	CONDUIT	1.47	0	12:00	5.06	0.45	0.57
C6	CONDUIT	0.70	0	12:00	3.73	0.04	0.14

Figure F.7. Link flow for each location's conduits.

Summary Results

Topic: Node Depth — Click a column header to sort the column.

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Day of Maximum Depth	Hour of Maximum Depth	Maximum Reported Depth Feet
J1	JUNCTION	0.01	0.08	1228.38	0	12:00	0.08
J2	JUNCTION	0.01	0.17	1234.67	0	12:00	0.17
J3	JUNCTION	0.03	0.37	1252.37	0	12:00	0.36
J4	JUNCTION	0.02	0.20	1273.00	0	12:00	0.20
J5	JUNCTION	0.02	0.29	1294.29	0	12:00	0.28
J6	JUNCTION	0.00	0.05	1314.02	0	12:00	0.05
Outfall1	OUTFALL	0.01	0.08	1227.88	0	12:00	0.08
Outfall2	OUTFALL	0.01	0.17	1234.17	0	12:00	0.17
Outfall3	OUTFALL	0.03	0.37	1251.97	0	12:00	0.36
Outfall4	OUTFALL	0.02	0.20	1272.50	0	12:00	0.20
Outfall5	OUTFALL	0.02	0.29	1293.49	0	12:00	0.28
Outfall6	OUTFALL	0.00	0.05	1311.05	0	12:00	0.05

Figure F.8. Node depth for each location's junction point and outfall point.

Summary Results

Topic: Node Inflow   Click a column header to sort the column.

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Day of Maximum Inflow	Hour of Maximum Inflow	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
J1	JUNCTION	0.16	0.16	0	12:00	0.00286	0.00286	0.000
J2	JUNCTION	0.59	0.59	0	12:00	0.0103	0.0103	0.000
J3	JUNCTION	1.71	1.71	0	12:00	0.0302	0.0302	0.000
J4	JUNCTION	0.74	0.74	0	12:00	0.0129	0.0129	0.000
J5	JUNCTION	1.47	1.47	0	12:00	0.0259	0.0259	0.000
J6	JUNCTION	0.70	0.70	0	12:00	0.0123	0.0123	0.000
Outfall1	OUTFALL	0.00	0.16	0	12:00	0	0.00286	0.000
Outfall2	OUTFALL	0.00	0.59	0	12:00	0	0.0103	0.000
Outfall3	OUTFALL	0.00	1.71	0	12:00	0	0.0302	0.000
Outfall4	OUTFALL	0.00	0.73	0	12:00	0	0.0129	0.000
Outfall5	OUTFALL	0.00	1.47	0	12:00	0	0.0259	0.000
Outfall6	OUTFALL	0.00	0.70	0	12:00	0	0.0123	0.000

Figure F.9. Node inflow for each location’s junction point and outfall point.

Summary Results

Topic: Outfall Loading   Click a column header to sort the column.

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
Outfall1	75.49	0.01	0.16	0.003
Outfall2	95.17	0.02	0.59	0.010
Outfall3	97.64	0.05	1.71	0.030
Outfall4	95.24	0.02	0.73	0.013
Outfall5	95.38	0.04	1.47	0.026
Outfall6	95.24	0.02	0.70	0.012

Figure F.10. Outfall loading for each location’s outfall point.

Summary Results

Topic: Subcatchment Runoff   Click a column header to sort the column.

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
Location1	4.60	0.00	0.00	1.06	3.50	0.00	0.16	0.759
Location2	4.60	0.00	0.00	1.10	3.46	0.01	0.59	0.751
Location3	4.60	0.00	0.00	1.19	3.37	0.03	1.71	0.731
Location4	4.60	0.00	0.00	1.17	3.38	0.01	0.74	0.735
Location5	4.60	0.00	0.00	1.38	3.18	0.03	1.47	0.690
Location6	4.60	0.00	0.00	1.73	2.83	0.01	0.70	0.614

Figure F.11. Subcatchment runoff for each location’s subcatchment.

Appendix G: Team Member Resumes

Annaliese M. Long

axl5451@psu.edu | lieselong@gmail.com
610-757-5505

Local Address
301 S. Pugh St., Apt. 712
State College, PA 16801

Permanent Address
252 Flagstone Rd.
Chester Springs, PA 19425

PROFILE

Highly motivated Biological Engineering candidate seeking a full-time position beginning the summer of 2019 in biological, environmental, or related engineering field

EDUCATION

The Pennsylvania State University — **University Park, PA**
B.S. Biological Engineering; Natural Resources Option — **Graduation: May 2019**
Minors: Environmental Engineering, Watershed & Water Resources
Certificate: Humanitarian Engineering & Social Entrepreneurship (HESE Program)

- HESE is an integrated learning, research, and entrepreneurship program that brings together students in rigorous research, design, field testing, and launch of technology-based enterprises in low and middle-income countries

Study Abroad (Winter 2018): New Zealand Sustainability & Natural Resources

RESEARCH

HESE Fieldwork — **Kisumu, Kenya, Africa**
Research with GreenBriq, HESE program — *May 2018*

- 3 weeks of fieldwork research on transforming an invasive species into a sustainable fuel source in Kenya, which is being used to further develop an entrepreneurship venture

SOFTWARE

ArcGIS, MATLAB, VTPSUHM, Microsoft Excel, SolidWorks

PROFESSIONAL EXPERIENCE

PSU School of Engineering Design, Technology, and Professional Programs — **University Park, PA**
HESE Program Assistant Intern — *August 2018 – present*

- Assist the HESE program with coordinating recruiting and networking events throughout entire university for potential students for the program
- Connect the alumni of the HESE program with the current members through networking events

PA Department of Environmental Protection — **Pottsville, PA**
Engineering, Scientific and Technical Intern — *June 2018 – August 2018*

- Assisted in the creation of an ArcGIS program to show and detail over 185 mining inspection sites in the Northeast region of Pennsylvania
- Maintained and consolidated a database of over 14,000 PA mining maps via Microsoft Access
- Observed Pre-Application meetings between the Department and consultant engineers for specific projects in the region

Pennsylvania State University Campus Dining Hall — **University Park, PA**
Warnock Dining Hall Staff — *October 2016 – Present*

- Complete various tasks throughout the kitchen, serving line and dining area to ensure cleanliness and organization; occasionally train new employees on daily tasks

Bellewood Country Club — **Pottstown, PA**
Country Club Waitress — *May 2017 – August 2017*

- Communicated with 25-member kitchen and floor staff to ensure efficient, quality customer service
- Executed financial transactions with customers and quickly resolved any customer disputes

LEADERSHIP & INVOLVEMENT

Atlas Benefitting THON — **University Park, PA**

- Special Interest Organization benefitting THON, raising funds for the Four Diamonds Fund, awarded First Overall Special Interest Organization for raising $171,000 for THON 2018

THON Pass List Captain — *December 2016 – April 2017*

- Coordinated time slots on a pass list queue for 8 families and over 50 students for entire 46-hour THON weekend

Fundraising Outreach Admin Captain — *March 2017 – March 2018*

- Assisted in planning and implementation of restaurant fundraisers, canning and canvassing weekends, and various other fundraisers; acquired necessary permits and materials for fundraisers

American Society of Agricultural & Biological Engineers (National & PSU) — ***September 2017 – Present***
Society of Women Engineers (PSU) — ***August 2015 – Present***

Molly K. Laurie

Permanent Address:
9009 Old Route 20
Ripley NY, 14775

mkl5301@psu.edu
mlaurie.laurie@gmail.com
(716) 753-0464

Campus Address:
801 Toftrees Ave. Apt. 281
State College, PA 16803

OBJECTIVE

To be considered for the Outstanding Senior Award for the Biological Engineering graduation class of 2019.

EDUCATION

The Penn State University — Expected May 2019
Biological Engineering, Bachelor of Science — Overall GPA 3.73
Natural Resource Engineering Option
Environmental Engineering, Minor
Watersheds & Water Resources, Minor
Penn State Behrend Honors Program — Fall 2015 to Spring 2017

Jamestown Community College
General Education Courses
Overall GPA 4.0

TECHNICAL EXPERIENCE

Natural Resource Conservation Service — Summer 2018
Intern
Observed normal everyday office and field work operations
Helped survey and stake out projects for contractors
Managed the Wetlands Reserve Program (WRP) for three counties and conducted on site monitoring
Helped in preliminary surveying and design of a small drainage project on a grape farm
Gained further experience with ArcGIS

Barbercheck Lab — September 2017 to May 2018
Lab Assistant
Assist Grad students with laboratory, greenhouse, and fieldwork
Preform soil testing to determine different soil characteristics
Make media for the insect colonies and media plates for fungal work under aseptic conditions

Chautauqua County Soil and Water Conservation District — Summer 2017
Job Shadow
Observed streambed restoration projects in the county
Helped to resurvey/review farm projects to insure construction met the engineering specs
Conducted hydro-seeding along roads were recent construction had occurred

ACADEMIC EXPERIENCE

Senior Capstone Project: Chimney Rocks Trail Restoration — Fall 2018 to Spring 2019
Student
Identified the problem, customer needs, and developed design specifications
Analyzed the existing trail conditions by surveying, and with ArcGIS and AutoCAD Civil 3D
Learned and gained experience with Civil 3D
Designed erosion control structures using Civil 3D, based on PA specifications and regulations

Biology: A Molecular Approach, Jamestown Community College — Fall 2014
Student
Engaged in a year-long lab based research; developed troubleshooting and lab math skills
Conducted research through experiments, analyzed data and wrote a formal lab report
Gained experience with lab equipment

COMPUTER SKILLS

Microsoft Office Suite, AutoCAD, Photoshop, MATLAB, ArcGIS

WORK EXPERIENCE

Midway State Park May 2014 to August 2017

Ride Operator
Assistant Trainer (Summer 2016)
Trainer (Summer 2017)
Developed customer service skills; resolved customer concerns
Trained new employees on safety and operation of the amusement rides

CLUBS

Alpha Epsilon The Honor Society of Agricultural, Food, and Biological Engineers
Member Inducted Fall 2017

American Society of Agricultural and Biological Engineers
Member Fall 2017 to Present

Penn State Spur Collectors
Member Fall 2017 to Present

AWARDS

Dean's List	Fall 15, Spring 16, Fall 16, Spring 17, Fall 17, Spring 18, Fall 18
Frank S. Palkovic Trustee Scholarship Recipient	Fall 2016 to Spring 2017
Martenas Family Trustee Scholarship	Fall 2017 to Spring 2018
Peikert Scholarship in Agricultural Engineering	Fall 2017 to Spring 2018
Kim L. Masser Memorial Trustee Matching Scholarship	Fall 2018 to Spring 2019
Harry & Kathleen Ulrich Agricultural Science	Fall 2018 to Spring 2019

Nelson Zhukas

npz5014@psu.edu
412-667-0898

School Address:
478 E. Calder Way Apt. 303
State College, PA 16801

Home Address:
272 Cascade Road
Pittsburgh PA, 15221

Objective

To obtain a job in the Environmental or Natural Resource engineering field where I can contribute to a company as well as grow as a professional.

Education

- Pursuing a B.S. from Pennsylvania State University
  - **Major**: Biological Engineering (*Natural Resources Engineering*)
  - **Minors**: Environmental Engineering / Watersheds & Water Resources
    - Intended Graduation Year: 2019

- **Relevant Collegiate Courses**
  - Measurement & Monitoring of Hydrologic Systems
  - Principles of Soil and Water Engineering
  - Design of Stormwater and Erosion Control Facilities
  - Mathematical Modeling of Biological and Physical Systems

Job Experience

- **Laborer at Zhukas Construction Inc**. (Pittsburgh, PA) 2013-2018
  - Collaborated with subcontractors to remodel kitchens, bathrooms
  - Created timelines to finish jobs in a timely manner
  - Helped in material calculations and cost analysis

Project Experience

- **Erosion and Sediment Control Plan** 2018
  - Calculated stormwater runoff using relevant computer program
  - Proposed best management practices to control erosion during construction
  - Developed BMP installation sequence narrative to ensure proper installation

Involvements

- **THON Operations Committee Member (Sustainability Liaison)** 2018
  - Measured specific types of waste to calculate amount of recycling
  - Constructed aesthetically pleasing waste containers to encourage children to recycle

Skills

Microsoft Office, Solidworks, Mattlab, GIS

Appendix H: Deliverables Agreement

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Partnerships and Possibilities

Chimney Rocks Park Trail Restoration

Sustainable Communities Collaborative, Fall 2018/Spring 2019

Community Project Partner:
Collaborator #1: Tina Enderlein, 814-693-2080, tenderlein@blaircounty.org
Collaborator #2: Tom Shaffer, 814-949-5789, tls24@psu.edu

University Project Contact:
Course Instructor: Jeffrey Catchmark, BE 460/466, 814-863-0414, jmc102@psu.edu
Megan Marshall, BE 460/466, 814-865-3392, mnm11@psu.edu

Sustainability Institute:
Ilona Ballreich: 814-865-2291 or 814-599-6000 (c) ixb20@psu.edu

Student Team: Chimney Rock 'n' Roll

Molly Laurie, mkl5301@psu.edu
Annaliese Long, axl5451@psu.edu
Nelson Zhukas, npz5014@psu.edu

The Project

Problem Statement:

The trail at Chimney Rocks Park in Hollidaysburg, PA has been affected by stormwater runoff and is in need of some restoration. There are some very steep sections that have caused some issues with erosion. Also, there are some parts of the half mile trail that have become very uneven from channels caused by runoff. This trail is sometimes difficult to use in the winter and spring seasons due to mud. Blair County also has two existing initiatives that are threatened by this unusable park trail - improving "active living" infrastructure and managing stormwater.

Community Partner Objectives:

The objective of this project is to design a detailed site plan with recommended best management practices to minimize the erosion problems and to stabilize the trail. With this new site plan, the Chimney Rocks trail will hopefully have three-season access. The sponsors of this project want the trail to remain natural looking, so improving the trail with dirt, gravel and other related materials can be used, but the plan should not include paving the trail. After this plan has been implemented, the hope is that the trail will require little to no maintenance, possibly only after large runoff events. With the implementation of this site plan, hopefully, the initiatives, improving "active living" and managing stormwater, will be fulfilled.

1

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Partnerships and Possibilities

Chimney Rocks Park Trail Restoration

Sustainable Communities Collaborative, Fall 2018/Spring 2019

Community Partner's preferred mode of communication (please check):

Tina Enderlein:

___ Phone (# ________________________________)

_x_ e-mail __tenderlein@blaircounty.org_________________

___ text ____

Tom Shaffer:

___ Phone (# ________________________________)

_x_ e-mail __tls24@psu.edu_________________

___ text ____

Partner Responsibilities:

- Meet with student team to discuss project (one member of student team will be identified as contact to communicate with sponsor)
- Provide all relevant information regarding the project: data, background information, contact information of applicable resources/personnel if available, etc.
- Be available to answer questions and provide feedback to students and faculty
- Complete sponsor evaluation for student team at end of fall and end of spring semester

Intellectual Property Rights:

Student Participant Project Results provided shall be used solely for Sponsor's internal review and analysis. Any and all rights to the Student Participant Project Results, including all Intellectual Property Rights, if any, shall remain the rights of the individual Student Participants as appropriate under the law regarding rights to and ownership of intellectual property unless there is a separate written agreement addressing the ownership of intellectual property. Prior to any commercial use or subsequent transfer of any Student Participant Project Results, Sponsor must obtain the appropriate rights from the respective owners.

Description of Course:

BE 460 – Semester: Fall, Day: T/Th 3:35-5:30 PM. BE 466 – Semester: Spring, Days: T/Th 3:35-5:30 PM. Department: Agricultural and Biological Engineering. College: Engineering. Enrollment: 50

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Partnerships and Possibilities

Chimney Rocks Park Trail Restoration

Sustainable Communities Collaborative, Fall 2018/Spring 2019

Students will develop skills and techniques for managing and executing engineering design projects in the following fields: agricultural engineering, food and biological processing engineering, and/or natural resource engineering. Projects are sponsored by faculty, industry, or community initiatives and are structured to span two semesters. In the Fall semester, the emphasis is on classroom lectures and project proposal development. In the Spring semester, the emphasis is on hands-on laboratory activities, project execution, and report preparation. Project teams perform all facets of the design process. This includes problem identification, planning of the project, formulation of design specifications, development and evaluation of alternative conceptual designs, development of detailed designs, consideration of safety and design optimization, design implementation, design testing, and analysis and documentation of results. Students improve their writing skills through preparation and refinement of various documents including a design notebook, proposal, statement of work, design specification, status reports, and a final report. Students also present their results in other formats, including poster and oral presentations for both technical and non-technical audiences.

Course Information & Learning Objectives:

- Course Learning Objectives (list below)

The BE 460/466 course sequence is entirely project-based. In BE 460, student teams develop their project proposals and learn some tools that will help them execute their projects. In BE 466, student teams complete and report on their design projects. Upon completing the courses, students should be able to:

01. Interact with a sponsor (supervisor, co-worker, client) to formulate equitable design criteria (time, cost, specifications) for a meaningful engineering project
02. Develop an action plan to complete the project on time and within budget
03. Conceptualize systems to satisfy design criteria
04. Analyze technical and economic merits of design alternatives
05. Work effectively in a team that includes co-workers, customers and vendors
06. Communicate well using verbal, written and electronic methods
07. Develop and improve writing skills
08. Demonstrate professionalism in interactions with colleagues, faculty, and staff
09. Demonstrate an appreciation of economic, global, societal, and ethical issues
10. Demonstrate knowledge of contemporary issues

- Estimated number of students involved in the project: 3
    - Roles of Student Team Members: Who is doing what?
      Annaliese Long: Communicator
      Molly Laurie: Planner

3

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Partnerships and Possibilities

Chimney Rocks Park Trail Restoration

Sustainable Communities Collaborative, Fall 2018/Spring 2019

Nelson Zhukas: Scribe

- Estimated number of hours for completion of the project: senior capstone design project that team will complete over two semesters (in spring, 4 hours per week of scheduled class time are for project work, plus additional time outside class)

University Responsibilities:

- Provide clear instruction to students about the project.
- Provide this project agreement form to students to help define the project, share information and helpful hints about project components;
- Share the date and time of the end of semester event with students and link to evaluation survey
- SCC will visit classes in the first weeks of the semester and conduct a mid-semester check-in with partners and faculty
- As appropriate, facilitate site visit and identify additional stakeholders

Expected Deliverables & Timeline: Use the space below to list major milestones for the project and the expected deliverables during the course of the fall and spring semesters.

- Project Proposal by December 4th
- Update Memos provided weekly
- Design Specifications Report by March 1st
- Final Report, GIS Analysis with Total Station Survey Data, and CAD drawings of final design for professors and sponsors by April 29th
- Erosion & Sediment Control Plan (E&S Plan) for the trail by April 29th

Timeline of Tasks

- **September**
  - Develop a team agreement by September 4th
  - Establish date and time for students and community partner to meet
- **November**
  - Complete project agreement/deliverables form by November 16th
- **December**
  - Attend the Campus & Community Sustainability Expo, November 29, 2018 from 4:30 pm to 6:30 pm in the State College Borough Building (246 S. Allen Street)
  - Complete project proposal report and presentation by December 10th

4

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Partnerships and Possibilities

Chimney Rocks Park Trail Restoration

Sustainable Communities Collaborative, Fall 2018/Spring 2019

- **January – March**
  - Complete design specifications report
  - Present poster to Industrial and Professional Advisory Council (IPAC)
- **April – May**
  - Present poster at Campus & Community Sustainability Expo, TBD
  - Complete final design report and presentation
  - Provide final deliverables to community project partner