

# **Design Report For: NAU Stormwater Runoff Quality and Quantity Mitigation**

CENE 486C: Engineering Design

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## **List of Abbreviations**

ADOT: Arizona Department of Transportation  
ADEQ: Arizona Department of Environmental Quality  
CENE: Civil and Environmental Engineering  
CFS: Cubic Feet per Second  
COD: Chemical Oxygen Demand  
CY: Cubic Yard  
ERU: Equivalent Residential Unit  
HR: Hour  
LID: Low Impact Development  
NAU: Northern Arizona University  
NOAA: National Oceanic and Atmospheric Administration  
NPDES: National Pollutant Discharge Elimination System  
TSS: Total Suspended Solids

## **Acknowledgements**

The team wants to give a special thank you to Mark Lamer for taking on the role of the Technical Advisor and Grading Instructor for this project. He provided much guidance on how to complete this project with meeting both our client's and capstone's needs. With bi-weekly meetings giving the team feedback on content and submittals was greatly appreciated.

Dr. Adam Bringhurst, who was both the team's Technical Advisor and Client, also played a very important role in helping us complete this project. His guidance and ideas allowed us to expand our understanding of project concepts and designs. He also helped us with guidance on what water quality testing to perform on the stormwater and provided access to the lab.

We also want to acknowledge and thank Erin McAnally-Trejo. With her expertise on NAU on-campus sustainability and maintenance, she was able to provide us with useful documents for any guidelines for low impact development infrastructure implementation. Erin also was able to provide important feedback in creating the decision matrix for the location selection for this project.

## **1.0 Project Introduction**

### **1.1 Project Purpose**

The completed project was the Northern Arizona University (NAU) Stormwater Runoff Quality and Quantity Mitigation project. The project improved stormwater management on NAU's Mountain Campus through the implementation of low impact development (LID) practices. It identified potential sites for future LID installations across campus, proposed an LID design for one of these sites, and evaluated the quality of stormwater runoff. The primary goal of the project was to propose low cost, low impact stormwater infrastructure that could reduce NAU's Equivalent Residential Units (ERUs), ultimately saving the university money. To achieve this, the project focused on implementing infrastructure in locations where stormwater could be captured most effectively at the lowest possible cost.

### **1.2 Project Location**

The project is situated across the Northern Arizona University (NAU) Mountain Campus, encompassing the North, Central, and South campus districts. The Mountain Campus spans more than 800 acres in Flagstaff, Arizona, and is characterized by high altitude terrain, ponderosa forests, and seasonal monsoons.

Currently, NAU utilizes Low Impact Development (LID) strategies to mitigate and manage stormwater runoff. Existing infrastructure includes: Bioswales placed to capture and filter surface contaminants, permeable concrete utilized in pedestrian and parking areas to reduce impervious surface area, rain gardens to slow and filter roof runoff, and retention basins designed to attenuate peak flows and promote onsite infiltration.

Figure 1 displays Flagstaff, Arizona with a marker highlighting the project location.

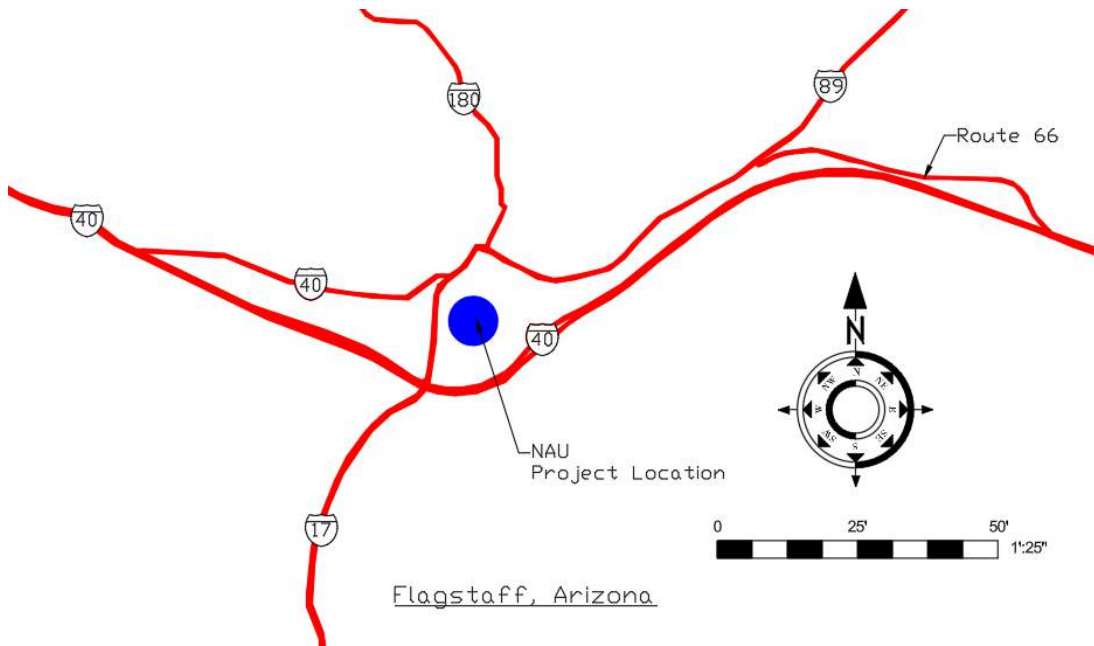


Figure 1: Project Location

Figure 2 displays an aerial photo of the project location found on Google Earth [1].



Figure 2: Aerial Vicinity Map

Appendix A-C shows what the team labeled as NAU's North, Central and South campus respectively. Campus was divided in this way to help with data management. The area south of

Pine Knoll drive was not inventoried at the request of the client because it is a predominately native ecosystem with little infrastructure.

### **1.3 Project Constraints/Limitations**

This project is constrained and limited by budget, existing infrastructure and vegetation, and size of location. For the budget, the client has requested that any proposed LID must require little construction and materials to keep the project as cheap as possible. The main goal for the budget of this project is to collect as much stormwater as possible with as little construction as possible. The locations for proposed LID are limited to areas that do not have any existing utilities, infrastructure such as concrete, or any trees and native vegetation. To stay in budget, the locations for any proposed LID must be geographically small. The goal is to eventually implement many LIDs on NAU campus on smaller sites.

The client for this project has offered some criteria that make a location less desirable for proposed LID, although they still want the information the team has gathered. Criteria that make a location less desirable are areas in the historic area on NAU Mountain campus such as Old Main. Areas in highly trafficked areas are less desirable because of pedestrians or bikers traveling through them. Any sites that would require an underdrain to transport stormwater are also considered less desirable options.

## **2.0 Location Inventory**

The location inventory started with the team creating a site investigation plan. This allowed a complete and organized approach. A field assessment form was created that had space to record potentially important information for each location. An example of this form can be found in Appendix D. While in the field, the team utilized MapItFast to geolocate areas of interest, this provided coordinates, area, and a photo that corresponded to each location. Using these two resources, the team inventoried the NAU Mountain Campus. The boundaries of the inventory were north of Pine Knoll Drive and south of Dupont Avenue. This consisted of walking those boundaries, identifying possible locations, using MapItFast, and filling out the field assessment form. The team found a total of 70 possible locations.

The following figure shows the 70 possible locations. The points are color coded based on location on NAU Mountain Campus. Green represents north campus, red represents central campus, and yellow represents south campus.



Figure 3: Identified Locations

## 3.0 Watershed Analysis

### 3.1 Delineate Watersheds

The coordinates of the potential locations identified during the location inventory were overlaid with a topographical map of NAU campus [2] in ArcGIS Online. Using the contours, the team hand traced each water shed to determine the watershed area (A), length of longest flow path (L), and the slope of longest flow path (S).

Figure 4 below shows an example of watershed delineation for location C-7.



Figure 4: Location C-7 Watershed Delineation

### 3.2 Find Storm Event Flow

Using the coordinates of the potential locations identified during the location inventory and satellite imagery from Google Earth, the watershed coefficients and watershed resistance coefficients were determined for each potential location. These values, along with the area, length, and slope determined during watershed delineation, were then plugged into the ADOTRational, which used equations 1 and 2 below to determine the flow rates. Rainfall intensity was determined using precipitation frequency provided by NOAA and is provided in Appendix E.

Equation 1: Time of Concentration [3]

$$T_c = 11.4L^{0.5}K_b^{0.52}S^{-0.31}i^{-0.38}$$

Where:

$T_c$  = Time of concentration (hours)

$L$  = Length of the longest flow path (miles)

$K_b$  = Watershed resistance coefficient

$S$  = Slope of the longest flow path (ft/mile)

$i$  = Rainfall intensity (in/hr), for a duration equal to time of concentration

Equation 2: Peak Flow Rate of Runoff [4]

$$Q = C_f C i A$$

Where:

$Q$  = Peak flow rate of runoff (cubic feet per second)

$C_f$  = Antecedent precipitation factor

$C$  = Runoff coefficient

$i$  = Rainfall intensity (in/hr), for a duration equal to time of concentration

$A$  = watershed area (acres) that drains to the design location

Table 1 below shows the watershed resistance coefficients provided by the ADOT Highway Drainage Design Manual [3] and used for time of concentration calculations.

Table 1: Watershed Resistance Coefficients [3]

Description of Landform	$K_b$	
	Defined Drainage Network	Overland Flow Only
Mountain with forest and dense ground cover (average slopes- 50% or greater)	0.15	0.30
Mountain with rough rock and boulder cover (average slopes- 50% or greater)	0.12	0.25
Foothills (average slopes- 10% to 50%)	0.10	0.20
Alluvial fans, pediments and rangelands (average slopes- 10% or less)	0.05	0.10
Irrigation Pastures <sup>a</sup>	-	0.20
Tilled Agricultural Fields <sup>a</sup>	-	0.08
Urban		
Residential, L is less than 1,000 ft <sup>b</sup>	0.04	-
Residential, L is greater than 1000 ft <sup>b</sup>	0.025	-
Grass; parks, cemeteries, etc <sup>a</sup>	-	0.20
Bare ground; playgrounds, etc <sup>a</sup>	-	0.08
Notes: a- No defined drainage network b- L is length in $T_c$ equation. Streets serve as drainage network		

Table 2 and 3 below show the antecedent precipitation factors and runoff coefficients provided by the COF Stormwater Design Manual [4] and used for peak runoff flow rate calculations. See

Table 2: Antecedent Precipitation Factors [4]

Storm Frequency	Factor
25-Year	1.10
50-Year	1.20
100-Year	1.25

Table 3: Runoff Coefficients [4]

Surface Description	Runoff Coefficient
Streets	.95
Asphaltic Concrete	.95
Concrete	.95
Brick Pavers	.90
Compacted ABC roadways/ shoulders	.70
Driveways and sidewalks	.95
Gravel (loose, non-compacted)	.50
Roofs	.95

Appendix F for the full table of ADOT Rational inputs and results.

## **4.0 Stormwater Quality Analysis**

### **4.1 Laboratory Preparation**

Prior to completing any laboratory work, the team created an Engineering Laboratory Project Plan Documentation to gain access to the NAU environmental engineering lab. Please refer to Appendix G to see the full binder. The project plan documents all lab work to be completed, the methods to be performed, any equipment needed, who will be responsible, and safety precautions/emergency procedures. To compile this document, the Safety Data Sheets (SDSs) from the Hach Company were used to determine all safety precautions and emergency procedures. The SDSs used for the laboratory binder include safety information for the Chemical Oxygen Demand (COD) procedure [5], the nitrate procedure [6], but not for the Total Suspended Solids (TSS) procedure.

Additionally, the team created a sampling plan to define how and where samples will be collected to complete lab work. The team decided that instead of relying on an actual storm event, they will be simulating a storm event to capture stormwater runoff. Refer to Appendix H for the team's detailed sampling plan. In practice, the simulated storm event was completed by using a battery-powered rain hose that siphoned water from five-gallon buckets, this equipment was provided by Dr. Adam Bringham. For each location, 10 gallons of water was showered on a specific square footage that would produce the first half inch of a storm event. The samples were captured using plastic sheeting and a small catch pool. Three samples were collected from each location yielding nine total samples.

The parking lot runoff sample was collected from a curb cut in the South Commuter parking lot on campus at NAU. The field runoff sample was collected in the South Bowl field located north of the Steve Sanghi College of Engineering. The roof runoff sample was taken from the building at the address of 321 E Pine Knoll Dr used for Civil and Environmental Engineering (CENE) capstone projects.

### **4.2 Laboratory Methods**

The laboratory methods that were completed included Oxygen Demand, Chemical (HACH Method 8000 [7]), Suspended Solids (Standard Method 2540 [8]), and Nitrate (HACH Method 8039 [9]). The goal of these laboratory tests was to understand the water quality of parking lot, field, and roof runoff. This affected our decision matrix to ensure the spots being treated had lower quality water. As stated previously, the methods used for all of these procedures are located in Appendix G.

## **4.3 Results of Analysis**

### **4.3.1 Nitrate Testing Results**

Parking lot runoff yielded the highest concentrations of nitrate while the field and roof runoff yielded similar results. Refer to Appendix I.1 for the raw data from this testing. Road or parking lot runoff is typically a high contributor to nitrate in stormwater because it's an impervious surface. The team recommends that locations from the inventory that receive high amounts of road runoff should be prioritized because adding vegetation to these areas will help mitigate the transportation of nitrate. High concentrations of nitrate in drinking water can cause cyanosis, also known as blue baby syndrome [9]. Additionally, high nitrate concentrations can cause eutrophication in aquatic ecosystems leading to serious environmental disruption [9]. It is important to note that other fields on NAU campus may be fertilized and therefore test higher for nitrate.

### **4.3.2 Total Suspended Solids Results**

The field runoff samples yielded the highest number of suspended solids. Refer to Appendix I.2 for the raw data from this testing. Locations with high runoff from fields are likely to have more erosion due to sediment deposition. Higher amounts of total suspended solids can also affect downstream aquatic ecosystems because it can impact how much sunlight they are able to get [8].

### **4.3.3 Chemical Oxygen Demand Results**

The field runoff yielded significantly higher concentrations of COD compared to roof and parking lot runoff. Refer to Appendix I.3 for raw data from this test. Locations with high runoff from fields are likely to have higher organic pollution. High COD concentrations depletes dissolved oxygen levels in the runoff and can lead to ecosystem disruption in downstream environments [7].

## **4.4 Discussion of Results**

The laboratory testing for this project meets regulations for total suspended solids and nitrate, while chemical oxygen demand is used as a metric to understand the amount of organics present. Total suspended solids entering the wastewater system must be less than 30 mg/L according to the Flagstaff Stormwater Design Manual that is in accordance with Arizona Department of Environmental Quality (ADEQ) [4]. According to the National Pollutant Discharge Elimination System (NPDES), nitrate levels must be under 10 mg/L to prevent environment and health hazards [10]. Therefore, the results from laboratory testing for this project indicate that stormwater runoff from the sites used meet regulatory requirements; however, this testing does not account for every location where LID can be implemented at NAU.

Based on the laboratory testing, the team recommends that locations receiving high flows of parking lot and field runoff is the top priority for implementing LID. Implementing LID in these locations would absorb more sediments, organic pollutants, and nitrates. This would result in less

impact to downstream ecosystems from stormwater runoff. LID solutions should still be implemented for locations receiving roof runoff to reduce flooding but should not be a high priority compared to locations receiving parking lot and field runoff.

## **5.0 Design Location Selection**

A decision matrix was constructed to assist in the selection of the most desirable locations to implement LID. This helped narrow the team's options. The decision matrix is comprised of several constraints and specific criteria that were provided to the team by the client. The client's main request was to find locations that had the highest impact on stormwater mitigation and the lowest impact on the existing environment/infrastructure.

### **5.1 Stormwater Mitigation Potential**

Stormwater mitigation potential was determined based on the calculated stormwater runoff flow rate for a 5-year flood. These values ranged from 0cfs - 4.8cfs with an average of 0.45cfs. Locations with a flow rate greater than or equal to 0.9cfs were given a score of 3. Locations with a flow rate between 0.45cfs and 0.9cfs were given a score of 2. Locations with a flow rate of less than 0.45cfs were given a score of 1. Locations with a flow rate of 0cfs were not considered viable for this project. This category was given a weight of 5 for the decision matrix because our client wants enough stormwater to be collected to qualify for ERU credits.

### **5.2 Impact on Existing Environment**

The potential impact on the existing environment/infrastructure was determined by the following categories: presence of existing infrastructure, presence of existing landscaping, ease of access for construction and maintenance, and visibility.

Presence of existing infrastructure means what was found around the location including utilities, signs, concrete, and irrigation systems. It was scored based on the presence and prevalence of existing infrastructure due to this being important to the clients. A score of 1 means that there was existing infrastructure that cannot be moved or removed. A score of 2 means that there was existing infrastructure that could be moved or removed. A score of 3 means that there was no existing infrastructure. This category was given a weight of 2 because it is important for keeping the cost of implementation to a minimum.

Presence of existing landscaping means the vegetation and any new native landscaping that is in each location. It was considered for the decision matrix because disrupting this was something the client wanted to avoid. A score of 1 means that there were medium to large trees or brand-new native landscaping that would have to be removed. A score of 2 means that there were small trees or shrubs that would have to be removed. A score of 3 means that there was no landscaping or vegetation besides grass or lawn that would need to be removed. This category was given a weight of 2 because it is important for keeping the cost of implementation to a minimum.

Ease of access for construction and maintenance is where the location is relative to roads or paths. It was scored based on how close the location was to an access road to ensure it could be reached for construction and maintenance. A score of 1 means that the location was not easily accessible for small construction or maintenance equipment and larger. A score of 2 means that the location was easily accessible to small construction and maintenance equipment. A score of 3 means that the location was easily accessible to large construction and maintenance equipment. This category was given a weight of 1 because it helps keep construction and maintenance costs low.

Visibility is dependent on the location of the implemented LID infrastructure. It was important due to NAU having certain aesthetics at different parts of campus; the design had to fit this aesthetic. It was scored based on how adding new infrastructure would disturb existing aesthetics. Locations that were visible from the road or pedway received a score of 1. Locations that were visible from paved sidewalks or fields received a score of 2. Locations that weren't visible from paved paths or fields were given a score of 3. This category was given a weight of 1 because it is important for following campus aesthetics but can be mitigated during the design phase.

## 5.2 Selected Location

The decision matrix resulted in locations with scores between 11 and 32. Table 4 shows the decision matrix results for the top five locations, which were forwarded to the client for her input. See Appendix J for the full decision matrix results.

Plot Number	Stormwater Mitigation Potential	Presence of Existing Infrastructure	Presence of Existing Landscaping	Ease of Access for Construction and Maintenance	Visibility	Score
N-17	3	3	3	3	2	32
C-10	3	3	3	2	3	32
C-12	3	3	3	3	2	32
S-22	3	3	3	2	2	31
N-1	3	2	3	3	2	30

Table 4: Decision Matrix Results

The client decided not to pursue N-17 due to future development in that area and selected C-12 and S-22 as her preference for design. The team selected plot S-22 for our design as it would have a greater positive impact due to a history of flooding and erosion.

## 6.0 Design

### 6.1 Existing Conditions

The team conducted a survey of the selected location to provide an accurate topographic map of the area and precise elevations of important features that need to be modified or left untouched in the design. This was added to the project scope due to a recommendation by the team's grading instructor.

Plot S-22 is located at the southwest corner of the Rolle Activity Center. Figure 5 below shows the location of the plot in relation to the NAU campus.



Figure 5: Plot S-22 Location

Figure 6 shows a satellite image of the location with 7 numbered points of interest.



Figure 6: Points of Interest

Point of Interest 1 is a curb cut that feeds into a short concrete channel which feeds stormwater into the center of the plot. Figure 7 below shows the concrete. Figure 8 shows the channel that the stormwater has created.



Figure 7: Inlet 1



Figure 8: Inlet 1 Channel

Point of Interest 2 is a culvert outlet that transports parking lot runoff into the plot. Figure 9 below shows the culvert outlet. Figure 10 shows the channel that the stormwater has created.



Figure 9: Parking Lot Culvert Outlet



Figure 10: Parking Lot Culvert Outlet Channel

Point of Interest 3 is two curb cuts that allow parking lot and road runoff into the plot. Figure 11 below shows the curb cuts. Figure 12 shows the channels that the stormwater has created.



Figure 11: Curb Cuts



Figure 12: Curb Cut Channels

Point of Interest 4 is a culvert inlet that moves stormwater from the plot and into a storm drain. Figure 13 below shows the culvert inlet.



Figure 13: Culvert Inlet

Point of Interest 5 is a 6-inch culvert that facilitates stormwater runoff from the culvert at point 2, underneath the pedestrian trail that cuts across the plot. Figure 14 below shows the upstream opening of the pipe and Figure 15 shows the downstream opening of the pipe.



Figure 14: Trail Culvert Inlet



Figure 15: Trail Culvert Outlet

Point of Interest 6 is a location with flooding concern. Figures 16 and 17 below show pooling water due to snow melting. This is one of the reasons that this location was chosen for LID implementation.



Figure 16: Pooling Water



Figure 17: Existing Flooding

Point of Interest 7 is where the stormwater from each source meets and moves towards the exit culvert where it goes into the sewer system. Figure 18 below shows this area of convergence.



Figure 18: Area of Convergence

## **6.2 Existing Hydrology**

Rolle Activity Center has several points of contact for inflow. There is a curb cut at Point of Interest 1 which has a 2-year storm event flow of 0.2 CFS and feeds into a shallow channel that becomes an incised channel after roughly 100 feet. The stormwater entering this channel is largely road runoff. Due to the flooding and erosion occurring in this area, the majority of the proposed design focuses on this channel. Using FlowMaster, the team modeled the existing hydrologic conditions using the survey results. All cross sections show subcritical flow except cross sections 3 and 7 show supercritical flow making them more likely to cause erosion. Refer to Appendix K for all existing FlowMaster results using the 2-year flow rate.

There are 2 curb cuts at Point of Interest 3 which have a combined 2-year storm event flow of 0.3 CFS. The two inlets feed rock lined channels and combine into one channel after roughly 20 feet. The stormwater entering this channel is largely road and parking lot runoff.

The final location for major stormwater inflow is the culvert at Point of Interest 2. It has a 2-year storm event flow of 2.6 CFS made up of mostly parking lot runoff. Figures 17 and 18 show the 6-inch culvert that facilitates stormwater runoff from the upstream culvert, underneath the pedestrian trail that cuts across the plot.

## **6.3 Proposed Design**

The goal of the proposed design is to mitigate the site's significant erosion and localized flooding. To achieve this, the team designed a vegetated swale that follows the path of the existing, inconsistent, erosive gully. The design was determined using guidelines provided by the COF LID manual and was selected to maximize onsite infiltration and maintain a low-cost profile by eliminating the need for complex underdrain systems [11]. Refer to Appendix L for the entire plan set for the proposed design.

### **6.3.1 Pine Knoll Inlet and Channel**

The upper flow path of the stormwater runoff inlet fed by Pine Knoll Drive shows early signs of erosion and incipient channelization. To prevent further channelization and limit ongoing headcut migration downstream, a protective layer of 4-inch gravel will be installed along the flow path. This treatment will promote shallow, distributed overland flow and help dissipate energy.

The actively eroding section currently exhibits a slope of 2.6% exceeding the 1% grade suitable for a vegetated swale as required by the COF LID design manual [11]. To mitigate this, a rock drop structure consisting of two 1-foot stones arranged in a stepped configuration will be constructed to stabilize the upstream flow path and reduce the downstream slope to approximately 0.88%. The inlet and outlet of the structure will be armored with gravel or riprap to prevent continued erosion.

The structure plan and profile details can be seen in Figures 19 and 20 below.

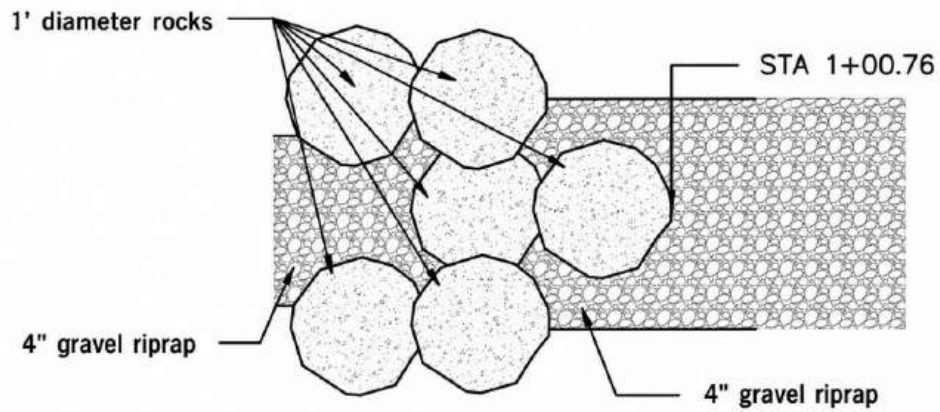


Figure 19: Rock Drop Structure Plan Detail

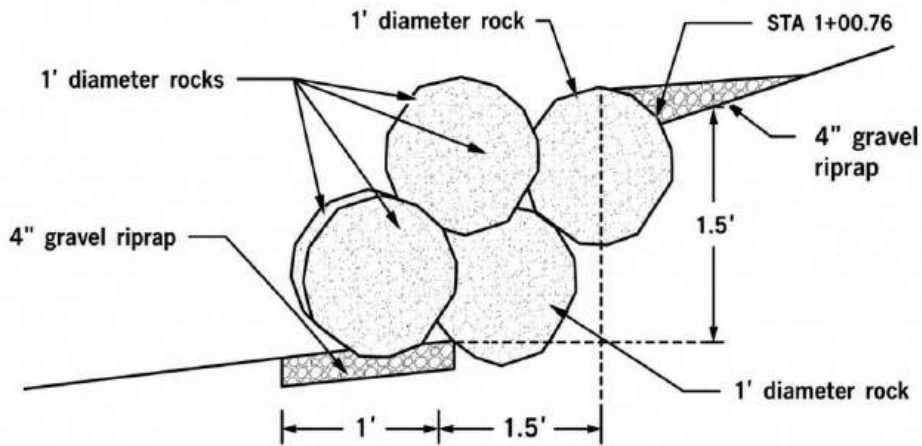


Figure 20: Rock Drop Structure Profile Detail

The vegetated swale can have maximum side slopes of 4:1 and a longitudinal slope of 1%. The swale is designed to convey a 2-year storm and slowly move stormwater off site while allowing for infiltration. The current erosion means a maximum depth of 1.25 feet which requires a width of 5 feet from the channel centerline. The swale is trapezoidal with a bed width of 1 foot. The channel bed consists of 6 inches of ASTM C-33 sand (in accordance with the COF LID design manual) topped with a layer of 4-inch gravel [11].

The swale feeds into Point of Interest 7 where all stormwater on site converges and enters the storm sewer.

Figures 21 below show the vegetated swale profile detail, refer to Appendix L to view the vegetated plan in more detail.

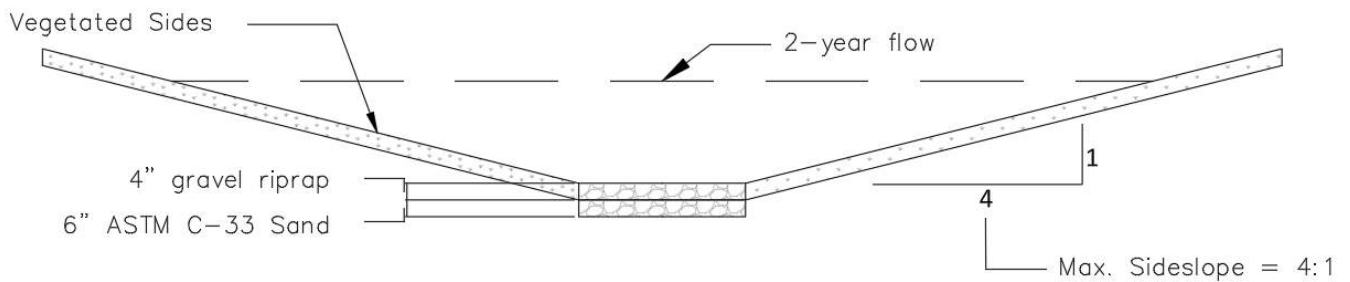


Figure 21: Vegetated Swale Cross Section Detail

### 6.3.2 Culvert Inlet and Channel

Previously shown, Figures 9 and 10 showed the current culvert inlet and channel conditions. With little to no erosion and overland flow conditions this area does not require any remediation. Figures 14 and 15 show the 6-inch culvert that facilitates stormwater runoff from the upstream culvert, underneath the pedestrian trail that cuts across the plot. The buildup of pine needles at the culvert inlet and outlet will be cleared and 4-inch gravel will be added at the culvert outlet to dissipate energy and halt the erosion that is beginning to occur downstream.

### 6.3.3 Parking Lot Curb Cut Inlets and Channels

Previously shown, Figures 11 and 12 show the parking lot curb cuts and subsequent channels. Four-inch gravel will be used to line both flow paths to dissipate energy and halt the erosion that is beginning to occur downstream.

## 6.4 Proposed Hydrology

Using the proposed design changes to the existing cross sections, the team completed hydrologic analysis in FlowMaster to determine if the design would be viable. The FlowMaster results indicate that the design is viable in accordance with the COF LID design standards because the channel has a normal depth below 1 ft, velocity less than 1 ft/s, and the flow is subcritical throughout all cross sections [11]. Refer to Appendix M.1 for the proposed hydrology reports from FlowMaster using the 2-year flowrate. In Appendix M.2, M.3, and M.4 there are Flowmaster results for the 10-year, 50-year, and 100-year flowrate respectively for the proposed design. This was done to verify that during larger storm events the design can continue to drain and help with flooding in the area.

The culvert inlet and channel have minor changes to hydrology. The addition of 4-inch gravel riprap on the downstream side of the 6-inch culvert passing underneath the pedestrian trail, will help prevent future erosion and slightly slow the flow of water due to a higher manning's roughness coefficient.

The parking lot curb cut channels have minor changes to hydrology. The addition of 4-inch gravel to the flow paths will help prevent future erosion and slightly slow the flow of water due to a higher Manning's roughness coefficient.

## **7.0 Final Design Recommendation**

### **7.1 Final Recommendation**

The proposed design at Rolle Activity Center serves as one example of how LID can be implemented across NAU Mountain Campus. This design meets the needs of this project by capturing stormwater runoff from Pine Knoll Drive and saving NAU money by lowering ERUs. The team has provided design sheets for Rolle Activity Center including general notes for any construction regulations/requirements and a topographic map showing the existing conditions of the site. Any low impact development implemented will only help with capturing stormwater runoff, filtering any possible contaminants, and enhance sustainability on NAU Mountain Campus.

However, this is just one location out of 70 that the team found for possible LID implementation. The team recommends implementing LID at multiple locations across campus to further lower ERUs and improve sustainability. Smaller areas wouldn't require the amount of design proposed at Rolle Activity Center and could be completed by landscapers employed by NAU. Maintenance at any sites where LID is implemented would be necessary to prevent any flooding. This could also be completed by NAU's landscaping employees which would involve clearing any pine needles or leaves blocking stormwater runoff to enter the site.

### **7.2 Cost of Implementing the Design**

A thorough cost analysis has been conducted for the project. The total project cost includes expenses for earthwork cut and fill, construction materials, and labor costs for excavation, install and staking. This project also qualifies NAU for stormwater credit discounts.

#### **7.2.1 Cost of Construction**

The construction cost was estimated factoring in materials and associated labor and construction. The soil on site is considered poor quality and therefore not of any value. It is however useful for backfill which saves some costs. All area calculations is given in cubic yards (CY). The greatest expense is the labor cost associated with excavation and installation. Our client requested that the project be completed by NAU which means a labor on-site rate of \$46.97/hr. With 17 hours of projected labor split between labor and cut and fill, this is the greatest expense at about \$800.

A few line items are split into proposed design and additional recommendation sections. The proposed design is the vegetated swale, rock drop structure, and channel reinforcement from the Pine Knoll Dr. curb cut. The additional recommendations are the channel linings for the culvert and parking lot curb cut inlets.

Table 5 below shows the complete cost breakdown and total cost of construction.

Component	Quantity	Unit	Cost per Unit	Total Cost
<b>Cut and Fill</b>				
Channel Cut Volume	5.01	CY	\$23	\$118
Clay-Loam Backfill	0.29	CY	\$23	\$7
ASTM C-33 Sand	1.23	CY	\$84	\$103
<b>Materials For Construction</b>				
4" gravel (Proposed Design)	3.29	CY	\$80	\$263
4" gravel (Add. Recommendation)	1.97	CY	\$80	\$158
1' rocks	6	EACH	\$9	\$54
Native Plants/grass seed	1	EACH	\$37	\$37
<b>Service Labor Costs</b>				
Excavation and Install (Proposed Design)	13	HR	\$46.97	\$611
Excavation and Install (Add. Recommendation)	4	HR	\$46.97	\$188
Staking	1	LS	\$500.00	\$500
<b>Projected Total Costs (Proposed Design)</b>				\$1,693
<b>Projected Total Costs (Proposed + Additional Design)</b>				<b>\$2,038</b>

Table 5: Cost of Construction

### 7.2.2 Stormwater Credits

This project implements LID to help manage stormwater runoff from 56,000 square feet of impervious surfaces. According to the City of Flagstaff Stormwater Utility Credit Manual, an equivalent rate unit (ERU), which is used to determine stormwater utility fees, is equal to 1,500 square feet [12]. Therefore, this project impacts 43.27 ERU's. Because of this LID implementation, these ERU's qualify for a 10% discount to their annual fees or an annual savings rate of 32\$ at the 2028 stormwater fee rate.

Assuming the fee never increases, the project will pay for itself in 65 years. If the fee continues to increase at its current rate (12%) then the project will pay for itself in 32 years.

## 8.0 Project Impacts

This analysis applies the Triple Bottom Line framework examining the societal, economic, and environmental impacts the proposed design will have on NAU Mountain campus. The proposed design serves as an example for implementing LID on campus; however, the team found 70 sites for potential LID. There will be a greater impact if the university chooses to carry out construction of LID at more locations. By assessing the proposed design and future development at more sites through these three lenses, the team is able to understand how this project promotes sustainable growth.

## **8.1 Societal Impacts**

One of the criteria for choosing suitable locations for LID on campus was visibility. This is to ensure that any constructed LID should not impact the pathways of pedestrians or bikers, and the aesthetics of NAU Mountain campus. Implementing LID will reduce the amount of standing water on campus which is expected to reduce the number of mosquitos; improving public welfare. LID limits the transport of stormwater and filtering contaminants which improves the water quality of downstream ecosystems.

The team's client has expressed that any construction of LID should be low cost, and something that could be implemented by landscaping employees. For the public this would mean that the construction would likely be slower which could interfere with noise pollution or pathways being blocked temporarily. If the university decides to implement LID at multiple locations, there should be proper planning and management to ensure it does not interfere with people walking through campus.

## **8.2 Environmental Impacts**

This project aims to infiltrate stormwater runoff into the groundwater supply rather than transporting it to the wastewater system. LID promotes water reuse which helps conserve water and the resources for treating wastewater. Additionally, the design of LID utilizes natural materials and native vegetation to slow and capture stormwater runoff. This adds to the existing landscape.

While the stormwater quality analysis completed for this project was within regulations for contaminants tested, there are many other sources of potential contamination. Other contamination can be the accumulation of heavy metals which can be very harmful if it were to enter the groundwater supply. Additionally, if LID is not maintained properly, it is possible for the sites to have operational issues. This could cause disruption to the existing landscape or potential flooding. Overall, the implementation of LID is mostly environmentally beneficial.

## **8.3 Economic Impacts**

One of the main purposes of this project is to propose low-cost designs to reduce stormwater transportation. NAU pays the City of Flagstaff ERUs for the transportation of stormwater. The university would be saving money if they were to implement LID at multiple sites to infiltrate stormwater. Constructing LID across campus will reduce flooding and the associated costs for flood damage. The team aims to provide a design that has low upfront costs for construction to ensure this could be completed across multiple sites on campus.

Negative economic impacts of this project include higher maintenance costs. LID needs to be maintained in order to be operational. Any sites where LID is constructed need to be properly managed to prevent erosion, degraded water quality, and infiltration of stormwater.

## 8.4 Global Impacts

The implementation of low impact development improves water quality and mitigates flooding hazards in urban areas. Globally, this can be a satisfying solution to problems with flooding and water security when climate change is rapidly becoming more destructive. Construction of LID is relatively low-cost and does not require intense technical training to construct. This solution does require maintenance and upfront construction costs but it can be favorable over a stormwater management project that will take years to build.

Climate change is causing a shift in how people are managing their water culturally. Water is becoming scarce and flooding disasters are becoming more frequent. This project is an example of how to combat this issue on a local level to create global change.

## 9.0 Summary of Engineering Work

The project timeline proposed in the Gantt chart in Appendix N.1 served as a general framework to keep the team on track with their deadlines. For the most part, the completion of this project followed this schedule with a few adjustments to the proposed project scope. Added to the project scope was the field survey of the design site which did not interfere with the deadlines for completing other tasks. There were changes to the stormwater sampling planned and the laboratory tests planned in the proposal [13]. Initially, the team was planning on completing tests for Biochemical Oxygen Demand, coliforms, COD, pH, and Fats, Oils, Grease. The team consulted their technical advisor who recommended they only test for COD, TSS, and nitrate because those results would be more valuable. Initially, the team was planning to sample stormwater runoff from a parking lot, road, field, and roof. The team decided the parking lot and road runoff would yield similar results, so they decided to sample only parking lot, field, and roof. These changes to the stormwater quality analysis ended up saving the team time which was used for the survey.

The adjusted Gantt chart showing the changes to the project timeline can be viewed in Appendix N.2. The team overestimated how long tasks would take to complete in the proposal, and the comparison of planned versus actual hours can be seen in Table 3.

## 10.0 Summary of Engineering Costs

In the team's proposal, the staffing hours and cost were greatly overestimated. For staffing hours, there were not as many hours of work put into the project by each team member as originally expected. This affected the time the tasks were done and kept the team on track for completing the project. The decrease in hours also affected the project cost with the biggest difference being the Senior Engineers hours significantly lowering, which then cut the cost in half.

## 10.1 Staffing Hours

The following table shows the comparison of the teams estimated hours for the project versus the actual hours that were spent to complete each task and the overall project.

Tasks	Estimated				Actual				Difference
	SENG	LT	SWT	EIT	SENG	LT	SWT	EIT	
<b>Task 1: Preliminary Laboratory Research &amp; Organization</b>	4	24	10	8	0	10	1	2	-33
<b>Task 2: Site Investigation Plan</b>	4	0	8	4	4	0	4	16	8
<b>Task 3: Creating the Location Inventory</b>	6	0	92	70	4	0	70	50	-44
<b>Task 4: Stormwater Quality Analysis</b>	10	51	14	4	0	30	10	5	-34
<b>Task 5: Identify Locations for LID Implementation</b>	8	4	8	4	3	1	2	1	-17
<b>Task 6: Design</b>	24	14	4	25	20	0	3	45	1
<b>Task 7: Project Impacts</b>	6	4	0	8	1	1	0	3	-13
<b>Task 8: Deliverables</b>	38	23	8	54	20	23	10	59	-11
<b>Task 9: Project Management</b>	50	33	30	25	25	32	40	45	4
<b>Total Hours</b>	<b>150</b>	<b>153</b>	<b>174</b>	<b>202</b>	<b>77</b>	<b>97</b>	<b>140</b>	<b>226</b>	<b>-139</b>
	<b>679</b>				<b>540</b>				

Table 6: Estimated vs Actual Staffing Hours [13]

The team ended up completing 540 hours to complete this project which is 139 hours less than expected.

## 10.2 Estimated vs Actual Cost

Below is the total cost of engineering services including the billable services and resources costs. The estimated total cost was \$61,936 while the actual cost is \$48,409. The personnel costs were lower due to less hours being spent on the project than predicted and the resource costs were greater because more time was spent using software than predicted.

Subsection	Classification	Estimated Quantity	Actual Quantity	Rate	Unit	Estimated Cost	Actual Cost
<b>1.0 Personnel</b>	SENG	150 hours	77 hours	\$136	\$/hr	\$20,400	\$10,472
	EIT	202 hours	226 hours	\$84	\$/hr	\$16,968	\$18,984
	LT	153 hours	97 hours	\$69	\$/hr	\$10,557	\$6,693
	SWT	174 hours	140 hours	\$69	\$/hr	\$12,006	\$9,660
<b>Subtotal</b>		679 hours	540 hours			<b>\$59,931</b>	<b>\$45,809</b>
<b>2.0 Resources</b>	Software	10 days	20 days	\$100	\$/day	\$1,000	\$2,000
	Lab Work	5 days	1 day	\$100	\$/day	\$500	\$100
	Lab Supplies	1	1	\$500	LS	\$500	\$500
<b>Subtotal</b>						<b>\$2,000</b>	<b>\$2,600</b>
<b>Total</b>						<b>\$61,931</b>	<b>\$48,409</b>

Table 7: Estimated vs Actual Engineering Costs [12]

The cost of resources is \$600 more than estimated initially and the personnel costs were lowered by about \$13,500.

## 11.0 Conclusion

Overall, the project met the majority of the original objectives provided. The team provided the client with a complete location inventory of NAU Mountain Campus including an ArcGIS map and field notes for 70 locations. These locations were then scored against the decision matrix made with the client's top priorities to help her decide where LID implementation would be most needed. One issue that does not fit the objectives is the total cost of the project. The client's top priority for these locations was mitigating the most stormwater so the team provided watershed delineations and completed the ADOT Rational Method for every location to understand how much stormwater can be mitigated at every site. Low impact development will filter stormwater so the team completed a stormwater quality analysis to understand what contaminants would be filtered at these sites. This analysis included testing for total suspended solids, nitrate, and chemical oxygen demand. Lastly, the team provided the client with one proposed design for the highest priority location that was determined with the client's input. This was communicated in the form of plan sets including a topographic map with the existing conditions determined from a field survey, design details, general notes, proposed design with proposed cross sections, and additional recommendations in the surrounding area.

The original goal was to have a low-cost design for NAU to implement. The selected site for the proposed design had more flooding and erosion issues to address than anticipated. Since there were more issues with the selected location to be fixed than anticipated, the cost for the project is not low cost. The team provided a technical engineering design of a vegetated swale, rock drop structure and proposed cross sections to address all flooding and erosion concerns in the area. This is not the only form of LID that can be implemented in this area but it was determined to be the most effective by the team. The team decided it was more important to provide a design that addressed these concerns and provide an estimate for the cost of construction for this design.

## 12.0 References

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# Appendices

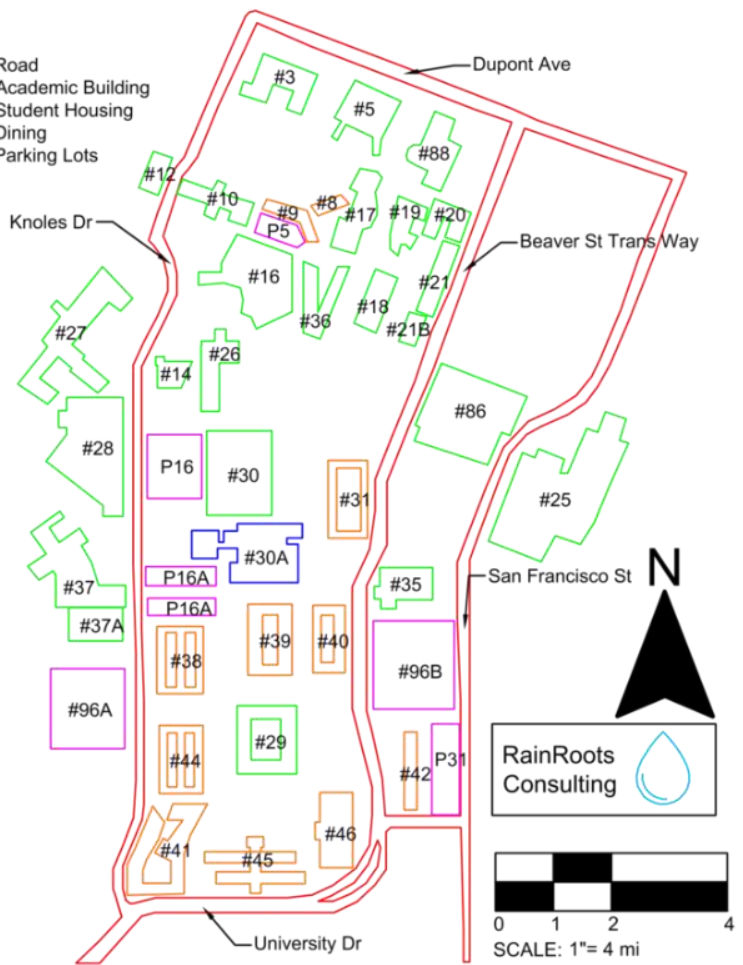
# Appendix A: NAU North Campus

**Legend:**

- P Parking Lot
- #96A Knoles Drive Parking Structure
- #37A Ardrey Auditorium
- #37 Performing & Fine Arts
- #28 Cline Library
- #27 Eastburn Education Center
- #12 Geology
- #41 Honors Living
- #45 Wilson Hall
- #46 Allen Hall
- #29 Ernest Calderon Learning Community
- #38 Cowden Hall
- #40 McDonald Hall
- #30A University Union Dining Services
- #30 University Union Fieldhouse
- #31 Gillenwater Hall
- #14 Native American Cultural Center
- #26 Adel Mathematics
- #16 Communications
- #36 Science & Health
- #18 Liberal Arts
- #21 Biological Sciences
- #21B Biological Sciences Annex
- #17 Science Laboratory
- #10 Old Main
- #9 Taylor Hall
- #8 Bury
- #19 Physical Sciences
- #20 Science Annex
- #88 Wettaw Biology & Biochemistry
- #5 North Hall
- #3 North Union
- #96B San Francisco Street Parking Structure
- #35 Bookstore
- #25 Health & Learning Center
- #86 Aquatic & Tennis Complex

**Key:**

- █ Road
- █ Academic Building
- █ Student Housing
- █ Dining
- █ Parking Lots



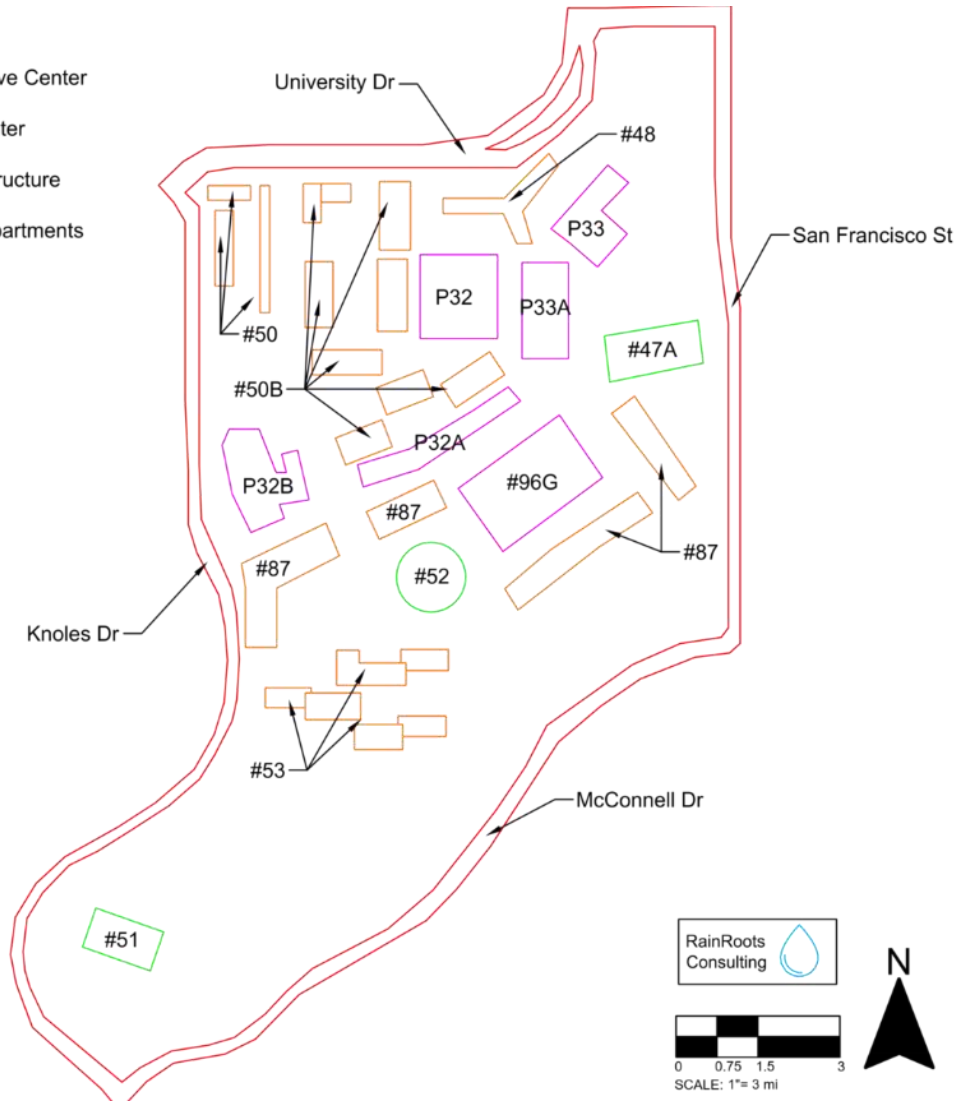
# Appendix B: NAU Central Campus

**Legend:**

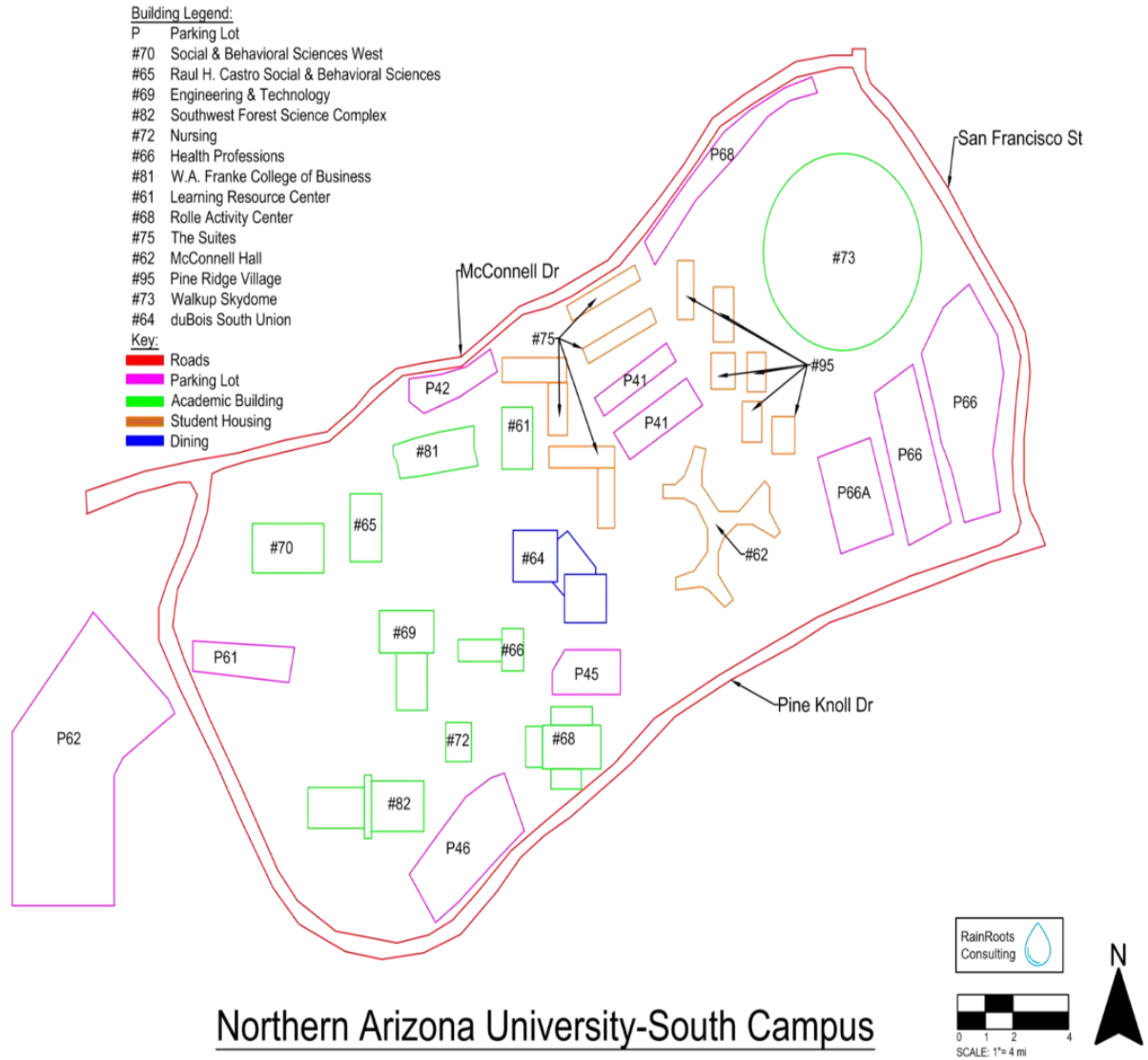
- P Parking Lot
- #51 Babbitt Administrative Center
- #53 Gabaldon Hall
- #52 Bilby Research Center
- #87 SkyView
- #98G Skyview Parking Structure
- #50B McKay Village
- #50 Campus Heights Apartments
- #47A ROTC
- #48 Reilly Hall

**Key:**

- Roads
- Parking Lot
- Student Housing
- Academic Building



# Appendix C: NAU South Campus



## Appendix D: Example of Field Assessment Form

Plot #:	Area:	Width:	Length:	Depth:	Slope:
Coordinates:					Soil Class:
Are there trees (If yes, # and size)?			Vegetation Overview:		
Is there brand new native landscaping?			Is it being irrigated/watered?		
Soil Description:			Is there a lot of stormwater inflow (explain)?		
Underdrain Requirements/channel or road proximity:			Proximity/impact on foot traffic?		
Maintenance/Construction Accessibility:			Existing Infrastructure (utilities/signs):		
General Notes:			Why is this a good or bad location?		

# Appendix E: NOAA Rainfall Data

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches) <sup>1</sup>										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	<b>0.242</b> (0.206-0.285)	<b>0.313</b> (0.266-0.367)	<b>0.424</b> (0.358-0.496)	<b>0.513</b> (0.432-0.599)	<b>0.640</b> (0.534-0.745)	<b>0.744</b> (0.614-0.864)	<b>0.855</b> (0.696-0.995)	<b>0.975</b> (0.786-1.14)	<b>1.15</b> (0.908-1.35)	<b>1.29</b> (1.00-1.52)
10-min	<b>0.369</b> (0.313-0.433)	<b>0.476</b> (0.405-0.559)	<b>0.645</b> (0.545-0.755)	<b>0.780</b> (0.657-0.912)	<b>0.974</b> (0.813-1.13)	<b>1.13</b> (0.935-1.32)	<b>1.30</b> (1.06-1.51)	<b>1.48</b> (1.20-1.73)	<b>1.75</b> (1.38-2.05)	<b>1.97</b> (1.53-2.32)
15-min	<b>0.457</b> (0.388-0.537)	<b>0.591</b> (0.502-0.693)	<b>0.799</b> (0.676-0.935)	<b>0.967</b> (0.815-1.13)	<b>1.21</b> (1.01-1.41)	<b>1.40</b> (1.16-1.63)	<b>1.61</b> (1.32-1.86)	<b>1.84</b> (1.48-2.14)	<b>2.16</b> (1.71-2.54)	<b>2.44</b> (1.90-2.88)
30-min	<b>0.616</b> (0.523-0.723)	<b>0.795</b> (0.675-0.933)	<b>1.08</b> (0.911-1.26)	<b>1.30</b> (1.10-1.52)	<b>1.62</b> (1.36-1.89)	<b>1.89</b> (1.56-2.20)	<b>2.17</b> (1.77-2.53)	<b>2.48</b> (2.00-2.89)	<b>2.92</b> (2.31-3.42)	<b>3.28</b> (2.55-3.88)
60-min	<b>0.762</b> (0.647-0.895)	<b>0.984</b> (0.836-1.16)	<b>1.33</b> (1.13-1.56)	<b>1.61</b> (1.36-1.88)	<b>2.01</b> (1.68-2.34)	<b>2.34</b> (1.93-2.72)	<b>2.69</b> (2.19-3.13)	<b>3.07</b> (2.47-3.57)	<b>3.61</b> (2.85-4.23)	<b>4.06</b> (3.16-4.80)
2-hr	<b>0.894</b> (0.777-1.03)	<b>1.14</b> (0.985-1.32)	<b>1.50</b> (1.30-1.73)	<b>1.80</b> (1.55-2.08)	<b>2.24</b> (1.91-2.58)	<b>2.60</b> (2.19-2.99)	<b>2.99</b> (2.49-3.44)	<b>3.41</b> (2.80-3.93)	<b>4.03</b> (3.24-4.65)	<b>4.54</b> (3.59-5.26)
3-hr	<b>0.977</b> (0.863-1.12)	<b>1.24</b> (1.09-1.41)	<b>1.59</b> (1.41-1.82)	<b>1.90</b> (1.66-2.16)	<b>2.33</b> (2.02-2.64)	<b>2.68</b> (2.31-3.05)	<b>3.07</b> (2.61-3.49)	<b>3.50</b> (2.93-3.99)	<b>4.12</b> (3.38-4.72)	<b>4.63</b> (3.73-5.34)
6-hr	<b>1.20</b> (1.08-1.35)	<b>1.50</b> (1.34-1.69)	<b>1.86</b> (1.66-2.10)	<b>2.18</b> (1.94-2.45)	<b>2.64</b> (2.32-2.96)	<b>3.01</b> (2.63-3.37)	<b>3.41</b> (2.94-3.83)	<b>3.84</b> (3.26-4.32)	<b>4.44</b> (3.70-5.03)	<b>4.95</b> (4.05-5.62)
12-hr	<b>1.49</b> (1.34-1.67)	<b>1.85</b> (1.66-2.08)	<b>2.27</b> (2.03-2.54)	<b>2.62</b> (2.34-2.92)	<b>3.09</b> (2.74-3.44)	<b>3.46</b> (3.05-3.86)	<b>3.84</b> (3.36-4.30)	<b>4.23</b> (3.66-4.74)	<b>4.79</b> (4.09-5.40)	<b>5.26</b> (4.43-5.97)
24-hr	<b>1.82</b> (1.65-2.01)	<b>2.28</b> (2.06-2.52)	<b>2.85</b> (2.58-3.13)	<b>3.31</b> (2.99-3.64)	<b>3.94</b> (3.54-4.32)	<b>4.43</b> (3.97-4.86)	<b>4.94</b> (4.41-5.42)	<b>5.47</b> (4.84-6.00)	<b>6.18</b> (5.43-6.80)	<b>6.74</b> (5.87-7.43)
2-day	<b>2.17</b> (1.94-2.42)	<b>2.71</b> (2.43-3.03)	<b>3.39</b> (3.03-3.79)	<b>3.95</b> (3.53-4.40)	<b>4.72</b> (4.19-5.26)	<b>5.32</b> (4.71-5.93)	<b>5.95</b> (5.24-6.63)	<b>6.60</b> (5.78-7.35)	<b>7.49</b> (6.49-8.37)	<b>8.18</b> (7.04-9.18)
3-day	<b>2.33</b> (2.10-2.58)	<b>2.91</b> (2.63-3.23)	<b>3.65</b> (3.29-4.05)	<b>4.25</b> (3.83-4.70)	<b>5.09</b> (4.56-5.62)	<b>5.74</b> (5.12-6.35)	<b>6.43</b> (5.71-7.11)	<b>7.15</b> (6.31-7.90)	<b>8.12</b> (7.10-9.01)	<b>8.90</b> (7.71-9.90)
4-day	<b>2.49</b> (2.26-2.74)	<b>3.12</b> (2.83-3.44)	<b>3.91</b> (3.55-4.31)	<b>4.56</b> (4.12-5.01)	<b>5.46</b> (4.92-5.99)	<b>6.17</b> (5.54-6.77)	<b>6.92</b> (6.18-7.59)	<b>7.70</b> (6.84-8.45)	<b>8.76</b> (7.71-9.65)	<b>9.61</b> (8.38-10.6)
7-day	<b>2.90</b> (2.63-3.20)	<b>3.62</b> (3.29-4.00)	<b>4.52</b> (4.10-4.99)	<b>5.25</b> (4.75-5.79)	<b>6.26</b> (5.64-6.89)	<b>7.05</b> (6.32-7.76)	<b>7.88</b> (7.03-8.67)	<b>8.72</b> (7.74-9.62)	<b>9.89</b> (8.69-10.9)	<b>10.8</b> (9.41-12.0)
10-day	<b>3.22</b> (2.93-3.53)	<b>4.03</b> (3.66-4.42)	<b>5.00</b> (4.54-5.48)	<b>5.76</b> (5.23-6.31)	<b>6.79</b> (6.14-7.44)	<b>7.58</b> (6.84-8.30)	<b>8.38</b> (7.54-9.19)	<b>9.19</b> (8.23-10.1)	<b>10.3</b> (9.15-11.3)	<b>11.2</b> (9.85-12.3)
20-day	<b>4.15</b> (3.80-4.50)	<b>5.17</b> (4.74-5.62)	<b>6.32</b> (5.79-6.87)	<b>7.18</b> (6.57-7.79)	<b>8.28</b> (7.56-8.98)	<b>9.08</b> (8.28-9.85)	<b>9.87</b> (8.96-10.7)	<b>10.6</b> (9.61-11.5)	<b>11.6</b> (10.4-12.6)	<b>12.3</b> (11.0-13.4)
30-day	<b>4.96</b> (4.53-5.43)	<b>6.18</b> (5.64-6.77)	<b>7.55</b> (6.89-8.26)	<b>8.58</b> (7.82-9.37)	<b>9.88</b> (9.00-10.8)	<b>10.8</b> (9.84-11.8)	<b>11.8</b> (10.6-12.9)	<b>12.6</b> (11.4-13.9)	<b>13.8</b> (12.4-15.1)	<b>14.6</b> (13.1-16.1)
45-day	<b>5.96</b> (5.45-6.55)	<b>7.44</b> (6.80-8.17)	<b>9.11</b> (8.33-9.99)	<b>10.4</b> (9.49-11.4)	<b>12.0</b> (11.0-13.2)	<b>13.2</b> (12.0-14.5)	<b>14.4</b> (13.1-15.8)	<b>15.6</b> (14.1-17.1)	<b>17.1</b> (15.4-18.8)	<b>18.1</b> (16.3-20.0)
60-day	<b>6.81</b> (6.26-7.41)	<b>8.50</b> (7.82-9.25)	<b>10.4</b> (9.53-11.2)	<b>11.7</b> (10.6-12.7)	<b>13.5</b> (12.3-14.6)	<b>14.7</b> (13.5-16.0)	<b>15.9</b> (14.5-17.3)	<b>17.1</b> (15.5-18.6)	<b>18.5</b> (16.8-20.1)	<b>19.5</b> (17.6-21.3)

<sup>1</sup> Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

## Appendix F: Rational Method Results

Plot Number	A (acres)	L (Miles)	S (ft/mile)	C (runoff coeff)	i (inches/hr)	Tc Computed (min)	Tc Applied (min)	Q (5yr) (cfs)
N-1	0.571	0.0392	165.82	0.81	3.29	2	10	1.5
N-2	0.227	0.0343	116.49	0.56	3.29	4.4	10	0.4
N-3	0.085	0.0275	36.30	0.87	3.29	2.7	10	0.2
N-4	0.280	0.0323	108.25	0.62	3.29	3	10	0.6
N-5	0.273	0.0210	47.69	0.62	3.29	3.1	10	0.6
N-6	0.119	0.0237	84.30	0.81	3.29	1.9	10	0.3
N-7	0.151	0.0354	28.29	0.74	3.29	3.3	10	0.4
N-8	0.260	0.0374	107.05	0.62	3.29	8.3	10	0.5
N-9	0.189	0.0188	424.44	0.81	3.29	1	10	0.5
N-10	0.218	0.0312	96.22	0.56	3.29	3.1	10	0.4
N-11	0.078	0.0134	149.49	0.71	3.29	2.5	10	0.2
N-12	0.408	0.0405	222.11	0.5	3.29	3.9	10	0.7
N-13	0.446	0.0279	178.97	0.78	3.29	1.6	10	0.1
N-14	0.297	0.0382	52.38	0.74	3.29	2.8	10	0.7
N-15	0.139	0.0261	115.00	0.81	3.29	1.8	10	0.4
N-16	0.327	0.0362	55.29	0.56	3.29	4	10	0.6
N-17	0.555	0.0456	21.92	0.87	3.29	4.2	10	1.6
N-18	0.224	0.0274	72.87	0.74	3.29	2.1	10	0.5
C-1	0.087	0.0232	86.04	0.5	3.29	6.8	10	0.1
C-2	0.051	0.0129	77.50	0.68	3.29	2.1	10	0.1
C-3	0.072	0.0249	40.12	0.5	3.29	3.6	10	0.1
C-4	0.153	0.0265	37.71	0.56	3.29	3.8	10	0.3
C-5	0.111	0.0198	151.88	0.87	3.29	1.4	10	0.3
C-6	0.103	0.0170	264.00	0.5	3.29	3.9	10	0.2
C-7	0.797	0.0498	301.14	0.5	3.29	2.7	10	1.3
C-8	0.873	0.1348	237.30	0.62	2.91	13.3	13.3	1.6
C-9	0.222	0.0233	515.12	0.5	3.29	2.2	10	0.4
C-10	0.572	0.0394	304.62	0.71	3.29	3.5	10	1.3
C-11	0.072	0.0127	19.70	0.43	3.29	4.7	10	0.1
C-12	0.460	0.0492	10.15	0.81	3.29	5.6	10	1.2
S-1	1.813	0.0648	77.19	0.81	3.29	3.3	10	4.8
S-2	0.211	0.0242	247.50	0.5	3.29	4.8	10	0.3

S-3	0.084	0.0170	176.00	0.5	3.29	4.4	10	0.1
S-4	0.211	0.0199	377.14	0.5	3.29	3.7	10	0.3
S-5	0.292	0.0227	528.00	0.5	3.29	2.2	10	0.5
S-6	0.223	0.0288	555.79	0.5	3.29	2.4	10	0.4
S-7	0.180	0.0267	37.45	0.56	3.29	5.7	10	0.3
S-8	0.191	0.0498	10.04	0.74	3.29	5.7	10	0.5
S-9	0.045	0.0098	304.62	0.78	3.29	0.8	10	0.1
S-10	0.084	0.0116	173.11	0.56	3.29	1.5	10	0.2
S-11	0.088	0.0119	251.43	0.56	3.29	1.4	10	0.2
S-12	0.035	0.0129	38.82	0.78	3.29	1.8	10	0.1
S-13	0.007	0.0152	132.00	0.74	3.29	1.3	10	0
S-14	0.093	0.0203	444.11	0.78	3.29	1.5	10	0.2
S-15	0.191	0.0157	95.42	0.74	3.29	2.1	10	0.5
S-16	0.176	0.0242	82.50	0.56	3.29	2.8	10	0.3
S-17	0.114	0.0221	226.12	0.56	3.29	1.9	10	0.2
S-18	0.213	0.0363	275.49	0.43	3.29	3.4	10	0.3
S-19	0.189	0.0266	375.75	0.47	3.29	2.6	10	0.3
S-20	0.263	0.0256	468.95	0.43	3.29	2.4	10	0.4
S-21	0.052	0.0155	129.41	0.87	3.29	1.3	10	0.1
S-22	0.520	0.0478	146.38	0.5	3.29	4.9	10	0.9
S-23	0.050	0.0179	55.93	0.68	3.29	1.9	10	0.1
S-24	0.080	0.0210	47.59	0.68	3.29	2.1	10	0.2
S-25	0.162	0.0271	184.40	0.62	3.29	2.3	10	0.3
S-26	0.120	0.0314	159.19	0.62	3.29	3.8	10	0.2
S-27	0.168	0.0502	59.73	0.68	3.29	3.1	10	0.4
S-28	0.174	0.0222	135.34	0.5	3.29	3.3	10	0.3
S-30	0.220	0.0253	78.97	0.74	3.29	4.3	10	0.5
S-31	0.142	0.0227	175.90	0.47	3.29	3.1	10	0.2
S-32	0.028	0.0133	450.77	0.47	3.29	1.7	10	0
S-33	0.028	0.0092	108.91	0.74	3.29	1.1	10	0.1
S-34	0.076	0.0191	157.05	0.5	3.29	2.9	10	0.1
S-35	0.038	0.0082	121.74	0.62	3.29	2	10	0.1
S-36	0.112	0.0315	63.57	0.62	3.29	5.2	10	0.2
S-37	0.059	0.0212	330.65	0.81	3.29	1.2	10	0.2
S-38	0.059	0.0175	285.04	0.56	3.29	1.6	10	0.1

S-39	0.048	0.0123	1217.71	0.68	3.29	0.6	10	0.1
S-40	0.044	0.0157	636.91	0.5	3.29	1.7	10	0.1
S-41	0.072	0.0109	460.33	0.56	3.29	1.6	10	0.1

# Appendix G: Engineering Laboratory Project Plan Documentation



College of Engineering,  
Informatics, and  
Applied Sciences

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## Engineering Laboratory

Project Plan Documentation (Binder)

Requirements

### NAU Stormwater Runoff Quality and Quantity Mitigation

#### Project Description

The NAU Stormwater Team is compiling a list of all possible locations for low-impact design implementation on Northern Arizona University Mountain Campus. The team will analyze the locations that will aid in collecting stormwater runoff to recharge groundwater. The team will test the water quality of stormwater runoff to determine the impacts of low-impact design.

#### Project Date

09/25/2025 - 05/01/2026

#### Contact Information Page

##### Capstone Contacts

Team Member: Ethan Board - eeb325@nau.edu

Team Member: Faith Fortin - fgf9@nau.edu

Team Member: Chayton Powell - cdp299@nau.edu

Team Member: Araceli Romero - amr2576@nau.edu

Technical Advisor: Adam Bringhurst - adam.bringhurst@nau.edu

Grading Instructor: Mark Lamer - mark.lamer@nau.edu

### Emergency Contacts

Fire Marshal: Jeffrey Young - (928) 523-1873 - Jeffrey.Young@nau.edu

Laboratory Safety: Ryelan McDonough - (928) 679-5948 - Ryelan.McDonough@nau.edu

Biological Safety: Shelley Jones - (480) 248-0741 - Shelley.Jones@nau.edu

Hazardous Waste: Mick Kelly - (928) 308-6507 - Mick.Kelly@nau.edu

Radiation Safety Officer: Jim Biddle - (928) 220-1728 - James.Biddle@nau.edu

NAU Police - (928) 523-3611

Poison Control - (800) 222-1222

### Project Summary Page

NAU Stormwater will conduct a stormwater quality analysis in accordance with the City of Flagstaff stormwater quality standards. The team will sample stormwater runoff capturing the “first flush” from a parking lot, roof, field, and road. The stormwater samples will be analyzed for Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Nitrate.

## **Initial Project Plan**

**Project Title:** NAU Stormwater Quality and Quantity Mitigation

### **Individuals Entering the Lab Space:**

Faith Fortin- fgf9@nau.edu

Chayton Powell- cdp299@nau.edu

## **Lab Based Project Objectives**

1. Determine specific water quality standards from stormwater runoff and how they will affect LID basins and downstream ecosystems.

## **Lab Based Approach**

1. TSS-Using the gravimetric method from the Standard Methods Part 2540C. This method is also presented as HACH Method 8158 and 8164 which was accepted by the EPA and adapted from Standard Methods Part 2540C.
2. COD-Using a reactor digestion method and the test in tube vials from the HACH company to measure the COD at the Low Range (LR-between 3 and 150 mg/L)). This is HACH method 8000 which was adapted from the Standard Methods Part 5220 D and accepted by the EPA for COD ranges between 3 and 150 mg/L.
3. Nitrate- Using the test in tube vials from the HACH company to measure the nitrate content. This HACH Method 8039.

## **Lab Methods:**

**TSS Summary:** The water sample (a measure volume) is poured through a 1.5-micron (pore size) borosilicate glass microfiber filter (pre-cleaned, dried, and weighed). The liquid is pulled through with gravity or with the assistance of vacuum pressure. The difference in weight between the empty filter and the loaded filter after 24 hours in the during oven at 104°C is the mass of total suspended solids in the water sample. See the attached HACH Method 8136 at the end of this first divider.

**COD Summary:** The water sample (2.0 mL of sample) is added to a test in tube vial which is pre- loaded with reagent. The vial is mixed with several inversions and then digested in a pre-heated reactor at 150°C for 2 hours. The vials are slowly cooled in the turned off reactor to 120°C, then removed from the reactor and allowed to cool to room temperature. The vials are cleaned and the concentration of COD is read using spectrophotometry. See the attached HACH Method 8000 at the end of this first divider.

**Nitrate Summary:** Prepare a sample cell with 10 mL of sample and add the contents of one NitraVer 5 Nitrate Reagent powder pillow. Put a stopper on the vial and shake the cell for one minute. Allow the sample a reagent to reaction for 5 minutes and an amber color should appear if nitrate is present. Prepare a blank cell and place it in the instrument's cell holder to calibrate it.

The instrument should be set to program 355 N, Nitrate HR PP. Place the sample cell in the instrument and press read to get results in mg/L  $NO_3^- - N$ .

### **Necessary Laboratory Supplies & Chemicals:**

- Vacuum hose
- Vacuum Supply (ENE Lab Bench top)
- Suction Erlenmeyer Flask
- Filter Holder Funnel
- Filters
- Drying Oven (103°C)
- Filter Pans
- DI water
- Microbalance
- Tweezers
- Water Sample Bottle
- Lab glassware for measuring volumes of water sample COD Equipment:
- DR 3900 Spectrophotometer
- DRB200 Reactor
- COD TNT Vials (LR)
- Pipette and bulb
- Vial cooling rack
- Water Sample Bottle Nitrate Equipment:
- DR 3900 spectrometer
- Sample cells
- NitraVer 5 Nitrate Reagent Powder Pillow, 10 mL
- Pipette and bulb
- Timer
- Water sample bottle
- KimTech wipes

### **Hazards/Risks Associated with Each Planned Laboratory Activity**

#### **Water Sampling Risk**

- Weather-related risks of getting wet or slipping in the case of winter weather
- Vehicle striking pedestrian

#### **Environmental Lab Analysis Risk**

- Glassware in eyes or cutting skin
- Chemical exposure to eyes, skin, inhalation, or ingestion
- Burning skin with high temperature ovens or digestors

## **Safety Protocols Associated with Conducting Work in the Lab**

Online training including: NAU Biosafety and Biosecurity Training, NAU Chemical Hygiene Training

Engineering control devices including: fume hood, shield on COD digester

Personal protective equipment (required) including: latex gloves, eye protection, lab coat, closed toe shoes, safety vest for parking lots

Never working in the lab alone (required): No team member of this team will conduct any laboratory work alone, there will always be at least two team members present for any and all laboratory work.

### **Non-Hazardous and Hazardous Wastes That Will Be Generated and Their Waste Disposal Requirements**

1. Identify your hazardous waste cleanup plan for any workspace, tools, equipment, or any other items that may have become contaminated by hazardous materials.

Liquid hazardous waste from the

COD and nitrate methods will be collected in amber bottles and labeled following GHS Hazard communication standards. Should enough waste liquid be collected, EH&S will be contacted for proper waste disposal.

2. Any plan for hazardous waste/material; whether it be storage, disposal, or clean up requires collaboration with EH&S.

Include the CECMEE lab manager (cc'd) on all email communications with EH&S.

### **Training to be Completed to Perform the Work Correctly and Safely**

The team will complete the online chemical hygiene training offered through EH&S.

The team will work directly with their faculty sponsor to know the procedures prior to beginning analysis in the environmental engineering lab.

## Emergency Response Plan

*Table 1 Physical Hazards, Preventative Measures, and Emergency Response*

<b>Physical Hazard</b>	<b>Preventative Measures</b>	<b>Emergency Response Plan</b>
Adhesive on skin	Latex gloves	Wash with soap and water, seek medical attention if necessary
Glassware cutting skin	No handling of broken glassware by hand	Seek medical attention if necessary
Glassware in eyes	PPE- eye protection	Flush eyes in eye wash station, seek medical attention if necessary
Hypothermia	Proper clothing	Remove person from cold environment, seek medical attention if necessary
Vehicle pedestrian accidents	Safety vests	Seek medical attention if necessary

*Table 2 Chemical Hazards, Preventative Measures, and Emergency Response*

<b>Chemical Hazard</b>	<b>Preventative Measure</b>	<b>Emergency Response</b>
<b>Any Chemical Exposures COD</b>		<b>Immediately call a Poison Control Center or doctor/physician</b>
<b>Any Chemical Exposures Nitrate</b>		<b>Immediately call a Poison Control Center or doctor/physician</b>
Eye contact	Wear eye protection PPE. Use the COD digester shield, work in the fume hood with the door pulled down.	Rinse immediately with plenty of water, also under the eyelids for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing, keep eyes wide open while rinsing and do not rub the affected area. Get immediate medical attention/advice.

Ingestion	Do not eat, drink, smoke, or vape in the lab. Keep chemicals behind the fume hood door during digestion.	Clean mouth with water and drink plenty of water. Never give anything by mouth to an unconscious person. Do NOT
		induce vomiting. Get immediate medical attention/advice.
Inhalation	Work with open chemicals in a fume hood.	Remove to fresh air. If breathing has stopped, giving artificial respiration. Get medical attention immediately. Do not use mouth-to-mouth method if the victim ingested or inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device. If breathing is difficult, (trained personnel should) give oxygen. Delayed pulmonary edema may occur. Get immediate medical advice/attention.
Skin Contact	Wear PPE: Eye protection, latex lab gloves, lab coat, close toe shoes	Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes. Get immediate medical attention/advice.
Self-Protection of the first aider	Wear PPE	Avoid contact with skin, eyes or clothing. Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination. Avoid direct contact with skin. Use barrier to give mouth-to-mouth resuscitation.

## Chemical Handling and Safety

### COD:

1. Chemical Identification Page
  - a. Name of chemical: COD Test in Tube Reagent
  - b. Supplier or manufacture name: HACH
  - c. Chemical storage: Keep containers tightly closed in a dry, cool, and well-ventilated place. Protect from moisture and store locked up. Keep out of reach of children and store away from other materials.
  - d. Safe handling of chemical: Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, or clothing. Take off contaminated clothing and wash before reuse. In case of insufficient ventilation, wear suitable respiratory equipment. Handle products only in closed systems or provide appropriate exhaust ventilation. Do not eat, drink or smoke when using this product.
  - e. Waste accumulation procedure: Used test in tube vials will be stored in a vial holder (tube rack or previously emptied styrofoam test in tube container) until testing is completed or the tube holding capacity has been exceeded. These will be stored in the satellite accumulation area of the lab.
  - f. Waste Disposal Plan: Chemicals accumulated in the COD test in tubes will be moved from vials to 1 L amber vials. These will be labeled as having mercury contaminated material. The amber vial will be picked up by EH&S for the disposal at an EPA hazardous waste facility.

### Hazardous Materials Page

2. Description of Hazardous Materials-Aqueous solution of inorganic acids and salts
  - a. Sulfuric acid
  - b. Sulfuric acid, mercury (II) salt
  - c. Sulfuric acid, disilver (1+) salt
  - d. Chromic acid ( $H_2CrO_4$ )
3. Chemical SDS: **Nitrate**
  1. Chemical Identification Page:
    - a. Name of chemical: NitraVer 5 Nitrate Reagent Powder Pillow, contains cadmium
    - b. Supplier or manufacture name: HACH
    - c. Chemical storage: Keep containers tightly closed in a dry, cool, and well-ventilated place. Protect from moisture and store locked up. Keep out of reach of children and store away from other materials.
    - d. Safe handling of chemicals: Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes, or clothing. Take off

contaminated clothing and wash before reuse. In case of insufficient ventilation, wear suitable respiratory equipment. Handle products only in closed systems or provide appropriate exhaust ventilation. Do not eat, drink or smoke when using this product.

- e. Waste accumulation procedure: Used test in tube vials will be stored in a vial holder (tube rack or previously emptied Styrofoam test in tube container) until testing is completed or the tube holding capacity has been exceeded. These will be stored in the satellite accumulation area of the lab.
- f. Waste Disposal Plan: Chemicals accumulated in the Nitrate test in tubes will be moved from vials to 1 L amber vials. The liquid waste will be diluted to 3-5 times the volume with cold water.

**Project Activity Log**

CECMEE Engineering Laboratory and Field Station  
Project Activity Log

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Project: NAU Stormwater Name: Faith Fortin & Chayton Powell

Date:	03/20/26	Start Time:	1pm	End Time:	4:40pm
Work Description	Completed tests for TSS, COD, & Nitrate - 9 samples for each test - cleaned glassware used				

**Appendix H: Sampling Plan**

# NAU Stormwater Runoff Quality and Quantity Mitigation

Ethan Board, Faith Fortin, Chayton Powell, Araceli  
Romero

Sampling Plan

01/27/2026

1. A first flush will need to be simulated by the team. To do this we will take gallon buckets full of water to collect a parking lot, ~~road~~, roof, and field sample.
2. The goal will be to collect three separate samples at each location so accuracy of the lab testing can be taken into consideration.
3. The samples will be collected in jars that will be first rinsed with DI water prior. This will lead to a total of 36 tests to be completed.

The testing will include COD, Suspended Solids, and Nitrate. The following methods will be used.

COD – Method 8000

Suspended Solids – Standard Method 2540

Nitrate – Method 8039

The samples are planned to all be obtained on South Campus.

- The field samples will be taken from South Bowl, this is due to the slope of the ground.
- The parking lot samples will be taken from the sloped part of the parking lot outside of the engineering building.
- ~~The road samples will be taken from Pine Knoll Dr.~~
- The roof runoff needs to be determined.

## Appendix I.1: Raw Data for Nitrate Testing

Sample ID	mg/L NO <sub>3</sub> -N
Roof1	1.3
Roof2	3
Roof3	2.1
ParkingLot1	3.6
ParkingLot2	3.2
ParkingLot3	2.5
Lawn1	1.7
Lawn2	3.1
Lawn3	3.9

## Appendix I.2: Raw Data for Total Suspended Solids Testing

Sample ID	Volume (L)	Dry Filter (g)	Dry Filter w/ Solids (g)	TSS (g/L)
ParkingLot1	0.1	0.12133	0.18441	0.6308
ParkingLot2	0.1	0.1376	0.20234	0.6474
ParkingLot3	0.1	0.13293	0.19433	0.614
Roof1	0.1	0.13711	0.18068	0.4357
Roof2	0.1	0.13146	0.18717	0.5571
Roof3	0.1	0.14682	0.18749	0.4067
Lawn1	0.1	0.14729	0.26499	1.177
Lawn2	0.1	0.13846	0.22656	0.881
Lawn3	0.1	0.14167	0.32308	1.8141

## Appendix I.3: Raw Data for Chemical Oxygen Demand Testing

Sample ID	mg/L COD
Lot1	346
Lot2	261
Lot3	333
Roof1	309
Roof2	206
Roof3	260
Lawn1	865
Lawn2	788
Lawn3	1053

## Appendix J: Decision Matrix Results

Plot Number s	Stormwater Mitigation Potential	Presence of Existing Infrastructure	Presence of Existing Landscaping	Ease of Access for Construction and Maintenance	Visibility	Unweighted Score	Weighted Score
N-17	3	3	3	3	2	14	32
C-10	3	3	3	2	3	14	32
C-12	3	3	3	3	2	14	32
S-22	3	3	3	2	2	13	31
N-1	3	2	3	3	2	13	30
C-7	3	2	2	3	3	13	29
S-1	3	2	3	3	1	12	29
N-4	2	3	3	3	2	13	27
N-9	2	3	3	3	2	13	27
N-14	2	3	3	3	2	13	27
N-12	2	3	3	2	2	12	26
N-18	2	3	3	3	1	12	26
C-8	3	1	2	2	3	11	26
N-8	2	3	2	3	1	11	24
N-16	2	3	2	3	1	11	24
N-7	1	3	3	3	3	13	23
S-18	1	3	3	3	3	13	23
S-30	2	3	2	2	1	10	23
S-41	1	3	3	3	3	13	23
N-5	2	1	3	3	1	10	22
N-10	1	3	3	3	2	12	22
N-13	1	3	3	3	2	12	22
S-31	1	3	3	3	2	12	22
S-33	1	3	3	3	2	12	22
S-38	1	3	3	3	2	12	22
S-39	1	3	3	3	2	12	22
S-40	1	3	3	3	2	12	22

N-3	1	3	3	3	1	11	21
S-20	1	3	3	3	1	11	21
S-21	1	3	3	3	1	11	21
S-23	1	3	3	3	1	11	21
S-24	1	3	3	3	1	11	21
S-25	1	3	3	3	1	11	21
S-26	1	3	3	3	1	11	21
S-28	1	3	3	3	1	11	21
S-34	1	3	3	2	2	11	21
S-35	1	3	3	2	2	11	21
N-6	1	2	3	2	3	11	20
N-15	1	3	3	2	1	10	20
C-5	1	2	3	3	2	11	20
C-9	1	3	2	2	3	11	20
S-5	2	1	2	3	1	9	20
N-2	1	2	3	3	1	10	19
C-2	1	2	3	3	1	10	19
C-6	1	3	2	3	1	10	19
S-16	1	2	3	2	2	10	19
S-19	1	1	3	3	3	11	19
S-27	1	2	3	3	1	10	19
N-11	1	1	3	3	2	10	18
C-11	1	2	2	3	2	10	18
S-3	1	1	3	3	2	10	18
S-8	2	1	1	3	1	8	18
S-15	2	1	1	3	1	8	18
S-37	1	3	1	3	2	10	18
C-3	1	2	2	3	1	9	17
C-4	1	2	2	3	1	9	17
S-2	1	1	3	3	1	9	17
S-6	1	2	2	3	1	9	17
S-9	1	1	2	3	2	9	16
S-10	1	1	2	3	2	9	16

S-12	1	1	2	3	2	9	16
S-36	1	1	2	3	2	9	16
S-7	1	1	2	3	1	8	15
S-4	1	1	1	3	2	8	14
S-11	1	1	1	3	2	8	14
S-14	1	1	1	3	2	8	14
C-1	1	1	1	3	1	7	13
<del>S-32</del>	0					0	0
S-17	1	1	1	1	1	5	11
<del>S-13</del>	0					0	0
<del>S-29</del>						0	0

## Appendix K: 2-Year Existing FlowMaster Results

### Cross Section for Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.019 ft/ft
Normal Depth	0.2 in
Left Side Slope	407.000 H:V
Right Side Slope	4.904 H:V
Discharge	0.02 cfs



## Worksheet for Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.019 ft/ft
Left Side Slope	407.000 H:V
Right Side Slope	4.904 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.2 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	7.5 ft
Hydraulic Radius	0.1 in
Top Width	7.51 ft
Critical Depth	0.2 in
Critical Slope	0.069 ft/ft
Velocity	0.29 ft/s
Velocity Head	0.00 ft
Specific Energy	0.02 ft
Froude Number	0.540
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.2 in
Critical Depth	0.2 in
Channel Slope	0.019 ft/ft
Critical Slope	0.069 ft/ft

### Cross Section for Station 2

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

**Input Data**

---

Roughness Coefficient	0.030
Channel Slope	0.006 ft/ft
Normal Depth	0.9 in
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.02 cfs

---



## Worksheet for Station 2

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.006 ft/ft
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.9 in
Flow Area	-0.1 ft <sup>2</sup>
Wetted Perimeter	7.9 ft
Hydraulic Radius	-0.1 in
Top Width	-2.50 ft
Critical Depth	0.5 in
Critical Slope	(N/A) ft/ft
Velocity	0.00 ft/s
Velocity Head	0.00 ft
Specific Energy	0.08 ft
Froude Number	(N/A)
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	0.9 in
Critical Depth	0.5 in
Channel Slope	0.006 ft/ft
Critical Slope	(N/A) ft/ft

### Cross Section for Station 3

<b>Project Description</b>	
Friction Method	Manning Formula
Solve For	Normal Depth
<b>Input Data</b>	
Roughness Coefficient	0.030
Channel Slope	0.108 ft/ft
Normal Depth	0.3 in
Left Side Slope	26.916 H:V
Right Side Slope	29.333 H:V
Discharge	0.02 cfs



## Worksheet for Station 3

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.108 ft/ft
Left Side Slope	26.916 H:V
Right Side Slope	29.333 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.3 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	1.5 ft
Hydraulic Radius	0.2 in
Top Width	1.54 ft
Critical Depth	0.4 in
Critical Slope	0.052 ft/ft
Velocity	0.95 ft/s
Velocity Head	0.01 ft
Specific Energy	0.04 ft
Froude Number	1.423
Flow Type	Supercritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	$\infty$ ft/s
Upstream Velocity	$\infty$ ft/s
Normal Depth	0.3 in
Critical Depth	0.4 in
Channel Slope	0.108 ft/ft
Critical Slope	0.052 ft/ft

### Cross Section for Station 4

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.001 ft/ft
Normal Depth	1.3 in
Left Side Slope	8.309 H:V
Right Side Slope	5.967 H:V
Discharge	0.02 cfs



## Worksheet for Station 4

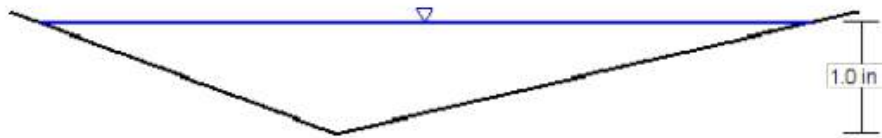
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.001 ft/ft
Left Side Slope	8.309 H:V
Right Side Slope	5.967 H:V
Discharge	0.02 cfs
Results	
Normal Depth	1.3 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	1.6 ft
Hydraulic Radius	0.6 in
Top Width	1.56 ft
Critical Depth	0.7 in
Critical Slope	0.044 ft/ft
Velocity	0.23 ft/s
Velocity Head	0.00 ft
Specific Energy	0.11 ft
Froude Number	0.177
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.3 in
Critical Depth	0.7 in
Channel Slope	0.001 ft/ft
Critical Slope	0.044 ft/ft

### Cross Section for Station 5

Project Description	
Friction Method	Manning
	Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.019 ft/ft
Normal Depth	1.0 in
Left Side Slope	2.727 H:V
Right Side Slope	4.350 H:V
Discharge	0.02 cfs



## Worksheet for Station 5

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.019 ft/ft
Left Side Slope	2.727 H:V
Right Side Slope	4.350 H:V
Discharge	0.02 cfs
Results	
Normal Depth	1.0 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	0.6 ft
Hydraulic Radius	0.5 in
Top Width	0.59 ft
Critical Depth	0.9 in
Critical Slope	0.042 ft/ft
Velocity	0.80 ft/s
Velocity Head	0.01 ft
Specific Energy	0.09 ft
Froude Number	0.690
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.0 in
Critical Depth	0.9 in
Channel Slope	0.019 ft/ft
Critical Slope	0.042 ft/ft

### Cross Section for Station 6

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.043 ft/ft
Normal Depth	0.4 in
Left Side Slope	38.167 H:V
Right Side Slope	5.490 H:V
Discharge	0.02 cfs



## Worksheet for Station 6

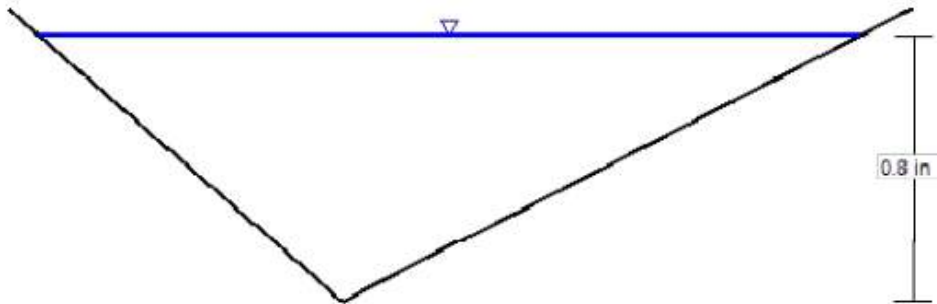
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.043 ft/ft
Left Side Slope	38.167 H:V
Right Side Slope	5.490 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.4 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	1.6 ft
Hydraulic Radius	0.2 in
Top Width	1.58 ft
Critical Depth	0.4 in
Critical Slope	0.051 ft/ft
Velocity	0.70 ft/s
Velocity Head	0.01 ft
Specific Energy	0.04 ft
Froude Number	0.922
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.4 in
Critical Depth	0.4 in
Channel Slope	0.043 ft/ft
Critical Slope	0.051 ft/ft

### Cross Section for Station 7

<b>Project Description</b>	
Friction Method	Manning Formula
Solve For	Normal Depth

<b>Input Data</b>	
Roughness Coefficient	0.030
Channel Slope	0.454 ft/ft
Normal Depth	0.8 in
Left Side Slope	1.147 H:V
Right Side Slope	1.948 H:V
Discharge	0.02 cfs



## Worksheet for Station 8

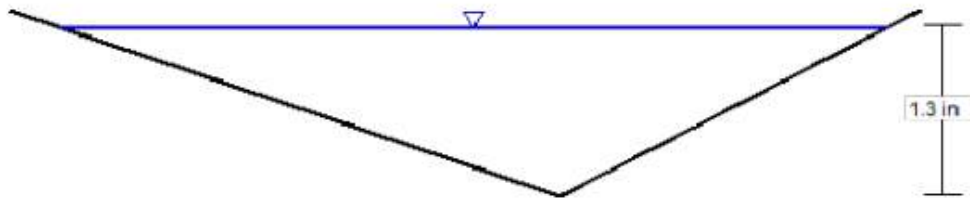
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.007 ft/ft
Left Side Slope	3.020 H:V
Right Side Slope	1.238 H:V
Discharge	0.02 cfs
Results	
Normal Depth	1.5 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	0.6 ft
Hydraulic Radius	0.7 in
Top Width	0.53 ft
Critical Depth	1.1 in
Critical Slope	0.043 ft/ft
Velocity	0.60 ft/s
Velocity Head	0.01 ft
Specific Energy	0.13 ft
Froude Number	0.427
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.5 in
Critical Depth	1.1 in
Channel Slope	0.007 ft/ft
Critical Slope	0.043 ft/ft

### Cross Section for Station 9

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.009 ft/ft
Normal Depth	1.3 in
Left Side Slope	3.000 H:V
Right Side Slope	1.961 H:V
Discharge	0.02 cfs



## Worksheet for Station 9

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.009 ft/ft
Left Side Slope	3.000 H:V
Right Side Slope	1.961 H:V
Discharge	0.02 cfs
Results	
Normal Depth	1.3 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	0.6 ft
Hydraulic Radius	0.6 in
Top Width	0.56 ft
Critical Depth	1.0 in
Critical Slope	0.042 ft/ft
Velocity	0.64 ft/s
Velocity Head	0.01 ft
Specific Energy	0.12 ft
Froude Number	0.475
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.3 in
Critical Depth	1.0 in
Channel Slope	0.009 ft/ft
Critical Slope	0.042 ft/ft

### Cross Section for Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.030
Channel Slope	0.009 ft/ft
Normal Depth	0.9 in
Left Side Slope	7.560 H:V
Right Side Slope	7.304 H:V
Discharge	0.02 cfs

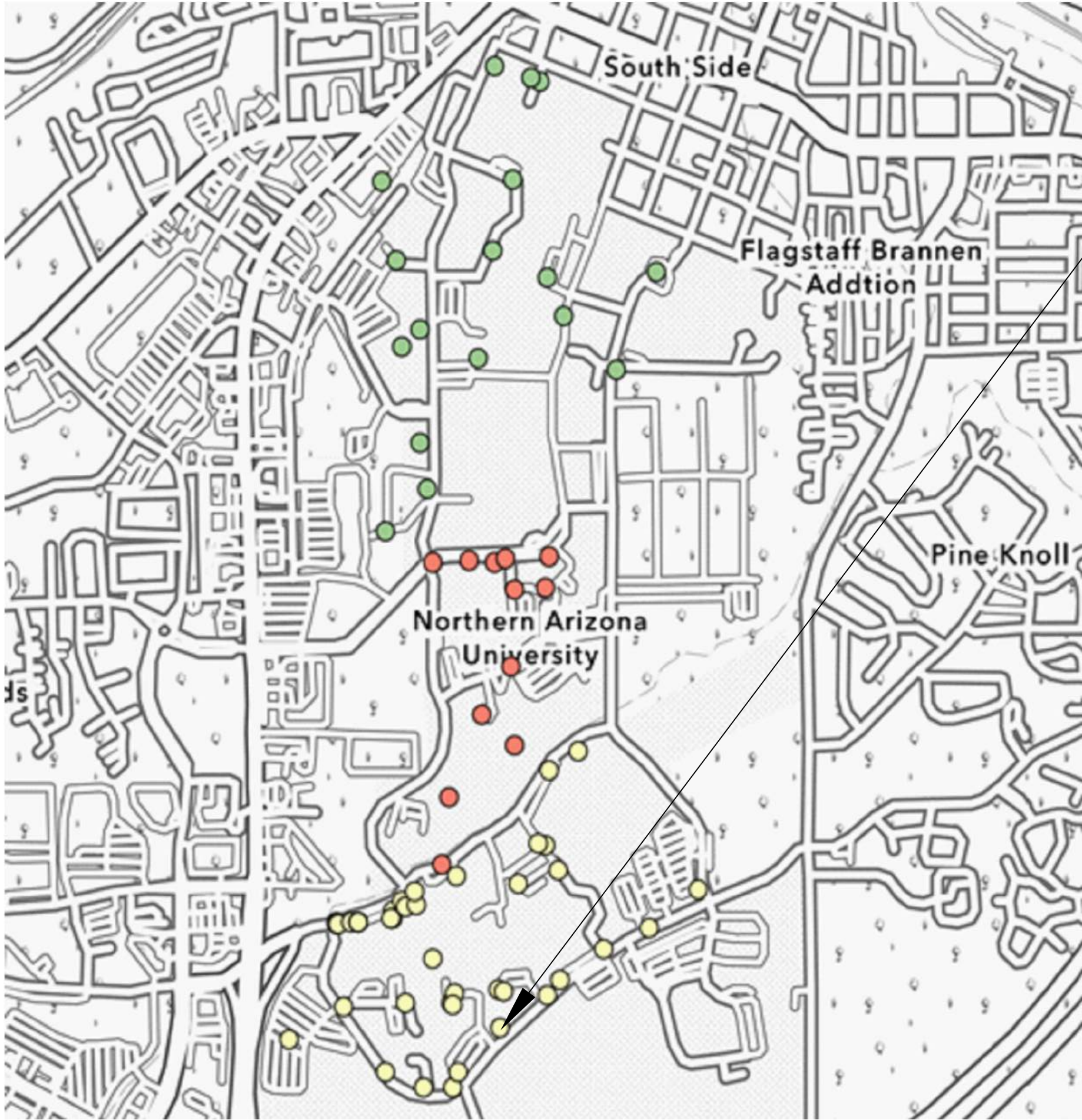


## Worksheet for Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.030
Channel Slope	0.009 ft/ft
Left Side Slope	7.560 H:V
Right Side Slope	7.304 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.9 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	1.1 ft
Hydraulic Radius	0.4 in
Top Width	1.08 ft
Critical Depth	0.6 in
Critical Slope	0.044 ft/ft
Velocity	0.51 ft/s
Velocity Head	0.00 ft
Specific Energy	0.08 ft
Froude Number	0.475
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.9 in
Critical Depth	0.6 in
Channel Slope	0.009 ft/ft
Critical Slope	0.044 ft/ft

**Appendix L: Plan Sets for Proposed Design**

# NAU Stormwater Quality and Quantity Mitigation

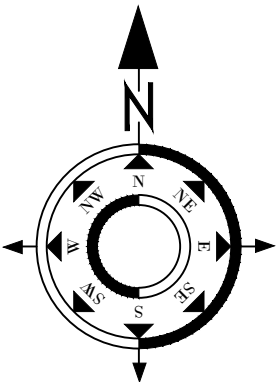
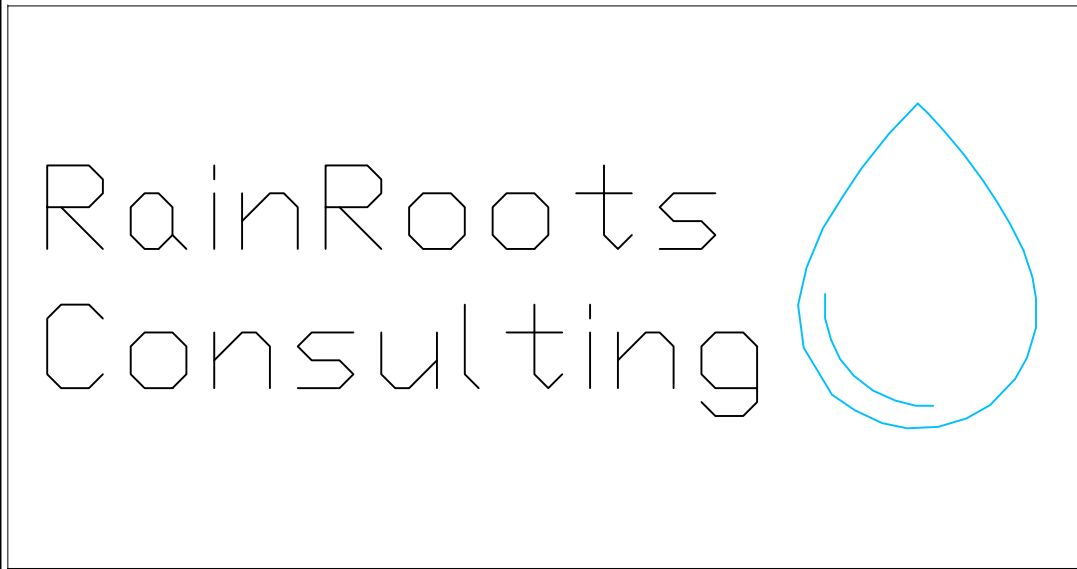


**Index of Sheets**

- 01 Cover & Index Sheet
- 02 General Notes
- 03 Topographic Map
- 04 LID Plan Design
- 05 Proposed Cross Sections
- 06 Design Details
- 07 Design Recommendations

**Project Staff**

- Ethan Board
- Faith Fortin
- Chayton Powell
- Araceli Romero



**Cover Sheet**  
05/05/2026



REVISIONS			
NO.	BY	DATE	DESCRIPTION
01		02/10/2026	Capstone 30% Submittal
02		03/24/2026	Capstone 60% Submittal
03		04/23/2026	Capstone 90% Submittal
04		05/05/2026	Capstone Final Submittal

Contact:	RainRoots Consulting
Phone:	(480)-980-2831
Email:	fgf9@nau.edu

**CITY OF FLAGSTAFF GENERAL NOTES**

The latest version of Coconino County's General Notes can be found on the Coconino County Public Works website. The County may periodically update these notes. At the time of the publication of these Standards, they were as follows:

1. Approval of these Standards by the County Engineer is for two years after the date of approval. If construction work is not started within two years or has been discontinued for any reason for longer than two years, the plans shall be resubmitted for review and re-approval by the Arizona Technical Board of Registration.
2. The County's plan review does not extend to material quantities shown on the plans.
3. An encroachment permit issued by the Community Development Department is required for all work in County rights-of-way or easements.
4. The County shall be notified forty-eight (48) hours before commencing each construction phase to schedule the County Inspector.
5. For construction purposes, the following precedence of standards will prevail: Current Coconino County Public Works Engineering Department Standards; current MAG Standards, IBC, project-specific plans and specifications, ADOT Standards — or other specifications approved by the County Engineer and with generally accepted good construction practice. All work and materials that do not conform to the standards and specifications are subject to removal and replacement at the Contractor's expense.
6. Any work performed without the knowledge and approval of the County Engineer is subject to removal and replacement at the Contractor's expense.
7. The County Engineer may suspend the work by written notice when, in their judgment, progress is unsatisfactory, work being done is unauthorized or defective, weather conditions are unsuitable, or there is danger to the public health or safety.
8. The County Engineer may order all materials used in the work to be tested according to MAG or ADOT Material Testing Requirements, American Association of State Highway and Transportation Officials (AASHTO), and the American Society for Testing and Materials (ASTM) Standards. At their expense, the Contractor shall hire a qualified testing laboratory to perform Quality Control (QC) during all construction phases, as stated in Coconino County Standards or as directed in the Special Provisions.
9. The Local Fire Department, the County Engineer, and other emergency responders must approve obstruction of access or water system shutdown, and traffic control plans must be submitted.
10. The Contractor shall be responsible for maintaining the streets and partially completed portions of the work until final acceptance of the work. Any roads requiring closure for the construction activity shall be reopened within a reasonable time or upon order of the County Engineer. The County Engineer shall regulate and control this traffic.
11. Approval of a portion of the work in progress does not guarantee its final acceptance. Testing and evaluation may continue until written final acceptance of a complete workable unit. Any defects that appear in the work within one year from the date of acceptance and are due to improper workmanship or inferior materials supplied shall be corrected by or at the expense of the owner/developer or the Contractor.
12. Completed public improvements will only be accepted once defective or unauthorized work is removed and the final clean-up is complete.

13. Location of underground utilities before work is begun is to be accomplished by ARS 40-360.22.
14. If work is done on private property abuts a project constructed under these standards, the Contractor will provide the County with written authorization from the property owner.
15. The establishment and use of temporary construction yards require written authorization from the County Engineer.
16. County approval of these plans is for concept only. The permittee and/or his consultants and employees are responsible for all liability resulting from errors or omissions. Coconino County does not verify or guarantee the accuracy of the measurements, calculations, ownership, or conclusions presented in these plans.
17. All construction staking shall be the responsibility of the contractor/developer and performed under the direct supervision of a registered land surveyor or civil engineer.
18. All traffic sign sheeting shall be Type VIII as designed by ASTM D4956-07e1 Standard Specifications for Retroreflective Sheeting for Traffic Control, unless specified otherwise on the construction plans.
19. When the construction plans specify graffiti control on bridges or other structures, the contractor shall seal the structure first using Monochem Aquaseal ME 12 and then apply Monochem PermaShield, Sacrificial Graffiti Control System (or approved equal).
20. All areas disturbed during construction shall be stabilized and reseeded in accordance with Chapter 13-17. In the event that the construction activity disturbs more than one (1) acre, a stormwater pollution prevention plan (SWPPP) shall be prepared in order to obtain a construction general permit from ADEQ.
21. All survey monuments within or around the construction area shall be protected in place. Any monuments that are disturbed or displaced by construction shall be reset by the RLS at the contractor's expense in accordance with City of Flagstaff Engineering Standards Section 13-03-005-0004 and A.R.S. Section 33-103.
22. The use of trench plating shall be prohibited from November 1st to April 1st unless specifically allowed by the City Engineer. (Ord. 2017-22, Rep&ReEn, 07/05/2017; Ord. 2024-13, Amended, 04/16/2024 (Res. 2024-15))

**GRADING AND DRAINAGE STATEMENT**

Adequate drainage, erosion and sediment control measures, best management practices, and/or other stormwater management facilities shall be provided and maintained at all times during construction. Damages to adjacent property and/or the construction site caused by the contractor's or property owner's failure to provide and maintain adequate drainage and erosion/sediment control for the construction area shall be the responsibility of the contractor and/or property owner.

**CITY OF FLAGSTAFF PAVING NOTES**

- A. Exact point of matching termination and overlay, if necessary, shall be determined in the field by the City Engineer or his authorized representative. When a longitudinal joint associated with a trench path, pavement matchup or other occurs on a street that includes a bike lane, the joint shall be located outside the bike lane.
- B. No job will be considered complete until:
  1. All curbs, pavements, sidewalks, catch basins, storm drains, and manholes have been cleaned of all dirt and debris;
  2. Survey monuments are installed and stamped; and
  3. All frames, covers, and valve boxes are adjusted to grade.

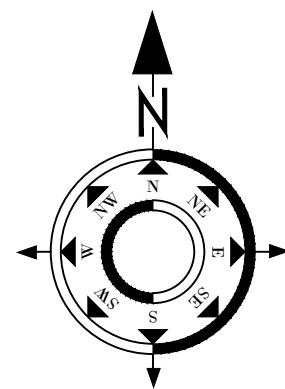
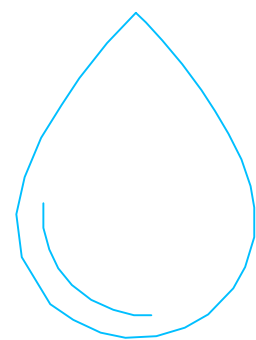
- C. No paving construction shall be started until all utility lines are completed and approved under proposed paved areas.
  - D. Base course will not be placed until subgrade has been approved by the City Engineer or his authorized representative.
  - E. The location of all water valves, fire hydrants, and manholes must at all times during construction be referenced and made accessible to the City.
  - F. Utility facilities in conflict with this work will be relocated by the permittee or the utility owner. This activity shall be coordinated with the owner of the utility to prevent any unnecessary interruption of service to existing customers.
  - H. Existing street name signs, traffic signs and devices associated with the project shall be maintained during construction and relocated by the contractor as shown on the approved plans.
  - I. Any changes or additions to pavement markings caused by pavement overlay, chip seal, or installation of underground facilities shall be shown on the approved plans.
  - J. On projects where the contractor causes excessive damage to an existing paved street or there are multiple street cuts (maximum of four (4) in five hundred (500) feet) an asphalt overlay shall be required.
  - K. A prime coat is not required unless so specified in the soils and pavement report and/or shown on the plans.
  - L. All curb and gutter, sidewalk, driveways, and sidewalk ramps shall be constructed on a minimum three (3) inches of aggregate base course (ABC). The ABC shall be constructed in accordance with MAG Section 310, and shall be compacted to ninety-five percent (95%) relative density. All precast structures such as manhole bases, catch basins, and box culverts shall be constructed on a minimum of three (3) inches of ABC.
  - M. Permanent Pavement Markings.
    1. Longitudinal pavement markings shall be installed in accordance with Section 13-16-006-0001.
    2. Transverse pavement markings such as stop bars, crosswalks, arrows, and legends shall be installed in accordance with Section 13-16-006-0002.
  - M. Temporary Pavement Markings.
    1. Temporary pavement markings, when approved, shall be installed in accordance with Sections 13-16-006-0001 and 13-16-006-0002.
- NOTES:
1. The use of temporary markings is strongly discouraged and may only be used with prior approval. When it is used, the contractor must be available to restripe as needed until the permanent markings can be installed.
  2. When it is impracticable for the contractor to provide permanent markings, the City Public Works Department may install the markings on behalf of the contract provided the fee for the work is agreed upon and paid for in advance.
- N. The maximum thickness of a single lift of pavement shall be four (4) inches. (Ord. 2017-22, Rep&ReEn, 07/05/2017)

**CITY OF FLAGSTAFF LANDSCAPING NOTES**

Adjacent site improvements, pavement construction, irrigation installation and finish grading shall be completed prior to planting work. Do not plant when conditions are not suitable for digging, mixing, raking and/or grading. Planting needs to occur during the months that irrigation systems are in operation. Therefore, planting may occur between April 1st and September 30th.

- A. Tree and Shrub Installation.
  1. Soil excavated from the planting pit shall be typically considered acceptable as backfill material for planting.
  2. All containers shall be removed prior to plant installation in a manner that does not disturb the potted soil or root ball.
  3. Set the root ball on six (6) inches of firm planting soil, plumb and in the center of the pit with the root ball crown slightly above the same elevation as adjacent finished landscape grades. Remove any wire, twine, burlap, or other material from the upper one-third (1/3) of the root ball of balled and burlapped Wire baskets and synthetic burlap shall be completely removed after the root ball has been placed in its final location.
  4. Once plant is set, place backfill material around base and sides of root ball and work each layer to settle backfill and eliminate voids. When backfilling is two-thirds (2/3) complete, water thoroughly. Place the remainder of the backfill and repeat watering until no more is absorbed. Place the final layer of backfill and water.
  5. All deciduous trees shall be wrapped from the ground line up to and including the first primary crotch formed by the first major branch. Wrapping shall be done after the plant has been installed.
  6. Two (2) to three (3) inches of specified mulch shall be placed in the area disturbed by excavation of the planting well.
- B. Ground Cover Installation.
  1. Prior to planting activities, completely remove existing weeds, including roots. Immediately prior to installation, cultivate ground cover areas to a depth of six (6) inches and grade smoothly and uniformly. Plant ground cover so the root crown is at or slightly above the bed's finish grade. After planting of ground cover and prior to mulching, spread pre-emergent weed control over planting bed soil surface in accordance with manufacturer's written directions. Install the specified mulch to a depth of two (2) inches over the entire ground cover bed.
- C. Landscape Completion.
  1. Prune dead or damaged branches, making all cuts at branch collar. Maintain the natural habit, shape and specified size. Remove all tags, labels, and other material. (Ord. 2017-22, Rep&ReEn, 07/05/2017)

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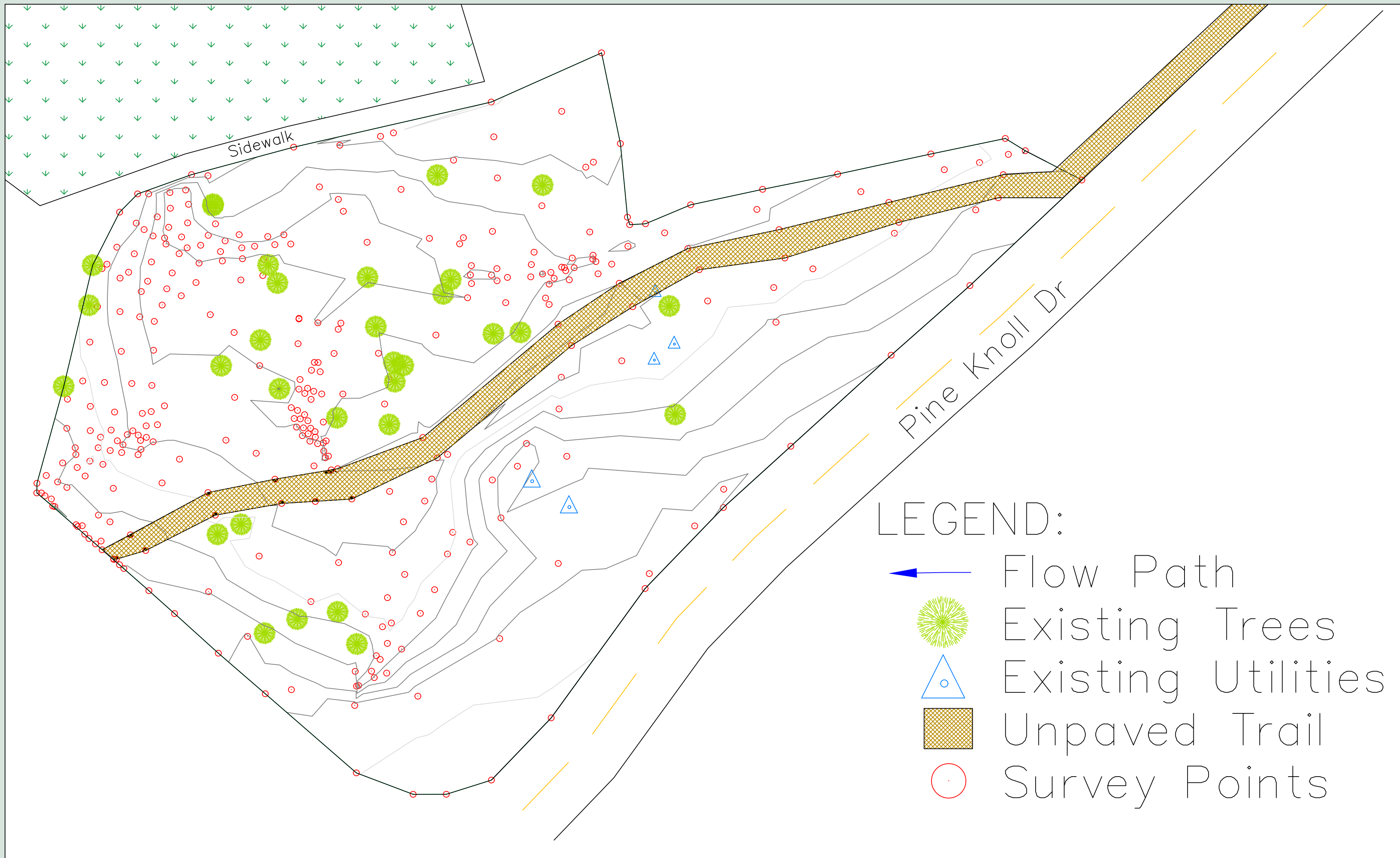
General Notes

05/05/2026




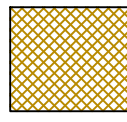

REVISIONS

NO.	BY	DATE	DESCRIPTION
01		02/10/2026	Capstone 30% Submittal
02		03/20/2026	Capstone 60% Submittal
03		04/23/2026	Capstone 90% Submittal
04		05/05/2026	Capstone Final Submittal

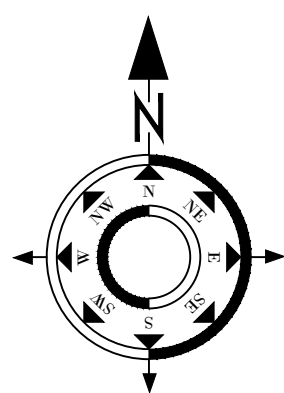
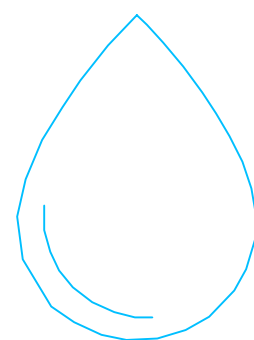
Contact: NAU Stormwater Team  
 Phone: (480)-980-2831  
 Email: fgf9@nau.edu



LEGEND:

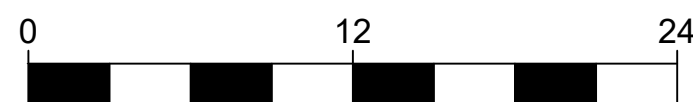
-  Flow Path
-  Existing Trees
-  Existing Utilities
-  Unpaved Trail
-  Survey Points

RainRoots Consulting



Topographic Map

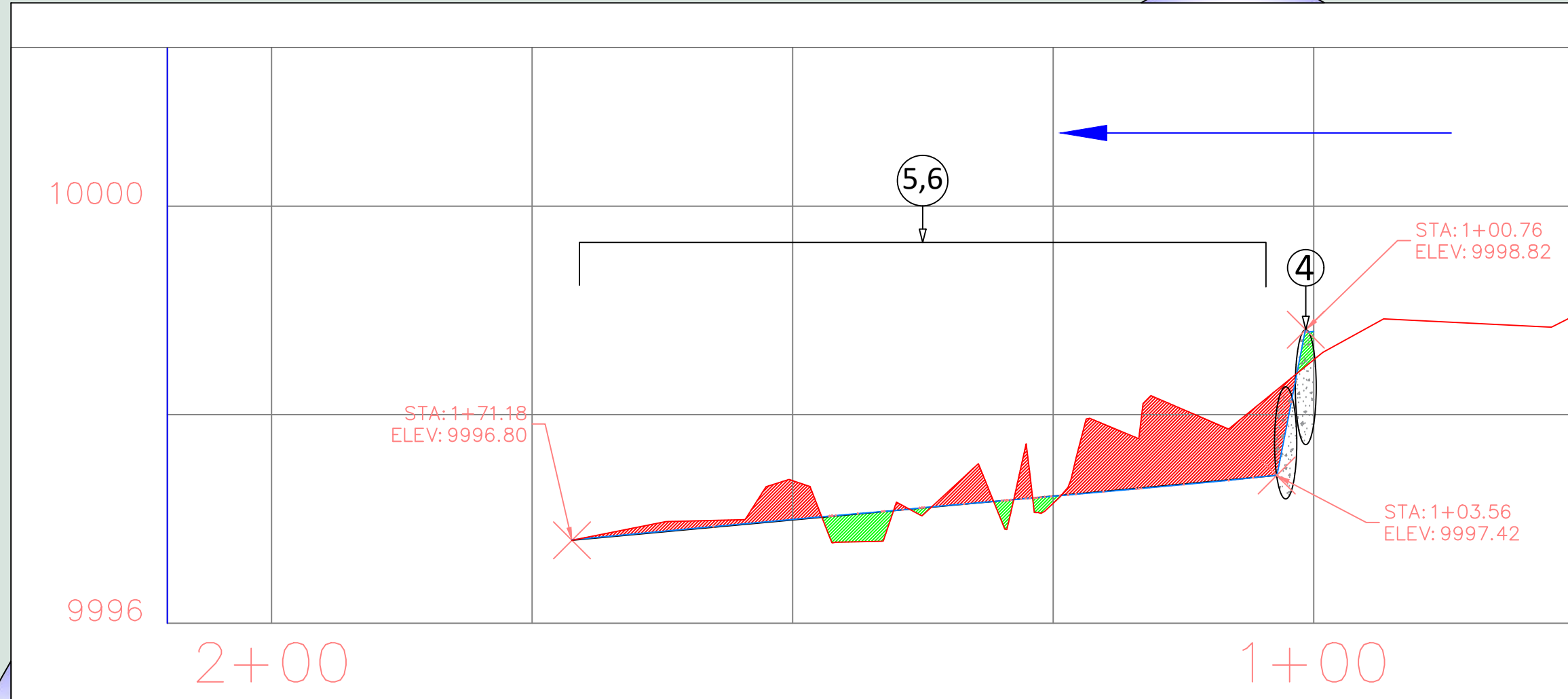
05/05/2026



REVISIONS

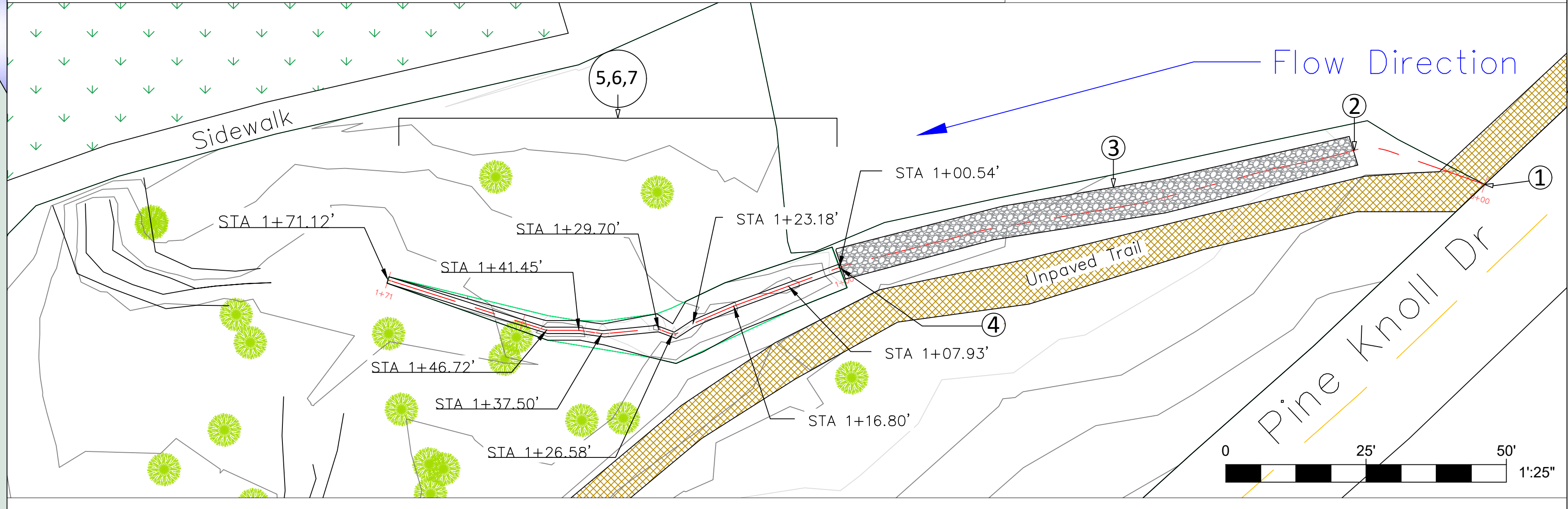
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01		02/10/2026	Capstone 30% Submittal
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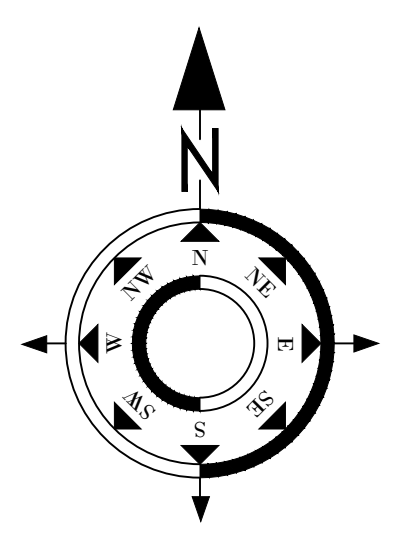


Notes

- 1) Existing Pine Knoll Curb Cut and start of existing concrete channel
- 2) End of existing concrete channel
- 3) 4" gravel riprap, 2' wide following existing flow path (3.29 cy)
- 4) Rock drop structure (see details)
- 5) Vegetated swale (see details)
- 6) Cut=3.78cu yd and Fill=0.29cu yd
- 7) Proposed cross sections. Left and right side of channel is defined facing upstream.



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LID Plan Design  
05/05/2026

REVISIONS

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03		04/23/2026	Capstone 90% Submittal
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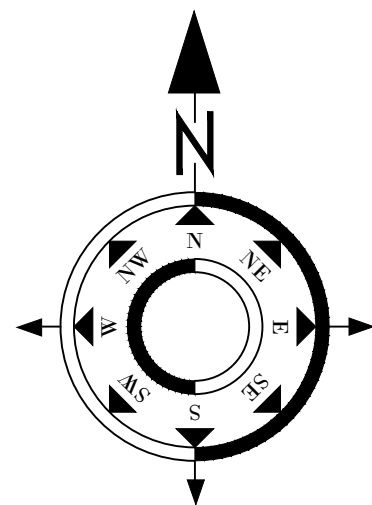
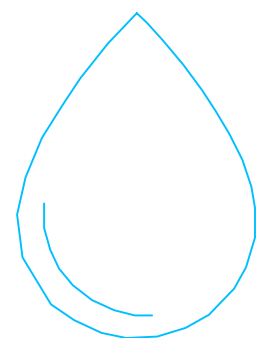
Contact: NAU Stormwater Team  
Phone: (480)-980-2831  
Email: fgf9@nau.edu

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Proposed Cross Sections

Station	Left Top of Bank		Left Bottom of Bank		Right Bottom of Bank		Right Top of Bank	
	Elev (ft)	Offset (ft)	Elev (ft)	Offset (ft)	Elev (ft)	Offset (ft)	Elev (ft)	Offset (ft)
1+00.54'	9998.8600	3.2500	9998.8000	0.5000	9998.8000	-0.5000	9998.5500	-3.2500
1+07.93'	9998.2500	3.5000	9997.3800	0.5000	9997.3800	-0.5000	9998.3000	-3.5000
1+16.80'	9998.0000	3.7500	9997.3000	0.5000	9997.3000	-0.5000	9998.0900	-3.7500
1+23.18'	9997.9500	3.5000	9997.2300	0.5000	9997.2300	-0.5000	9998.4000	-4.2500
1+26.58'	9997.4500	1.2500	9997.2100	0.5000	9997.2100	-0.5000	9998.1200	-4.5000
1+29.70'	9997.6000	1.2500	9997.1800	0.5000	9997.1900	-0.5000	9998.0400	-4.2500
1+37.50'	9997.2700	1.5000	9997.1100	0.5000	9997.1100	-0.5000	9997.2700	-1.7000
1+41.45'	9997.2700	1.5000	9997.0800	0.5000	9997.0800	-0.5000	9997.1100	-1.5000
1+46.72'	9997.1900	1.4000	9997.0300	0.5000	9997.0300	-0.5000	9997.2400	-1.4500
1+71.12'	9996.8100	0.5000	9996.8100	0.5000	9996.8000	-0.5000	9996.8000	-0.5000

RainRoots Consulting



LID Plan Design

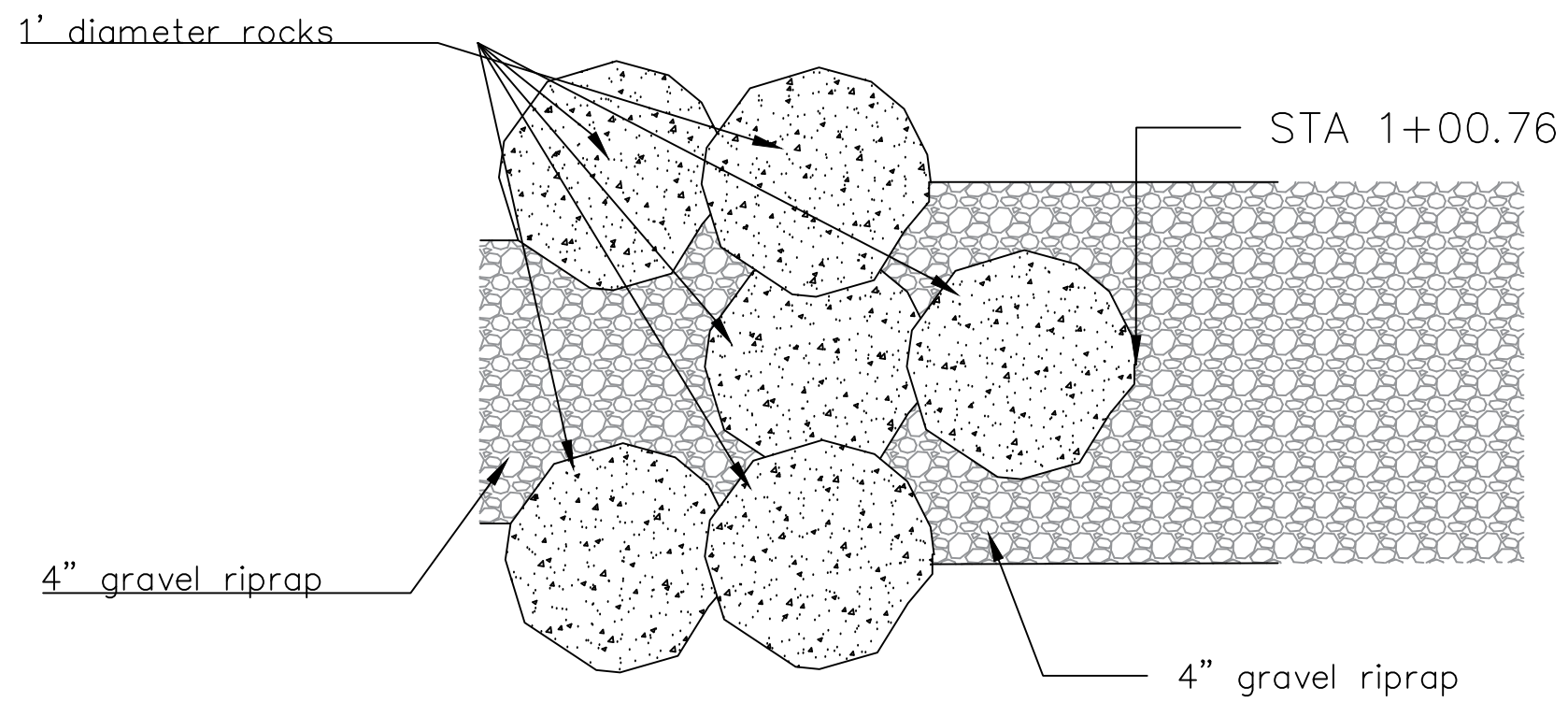
05/05/2026

REVISIONS

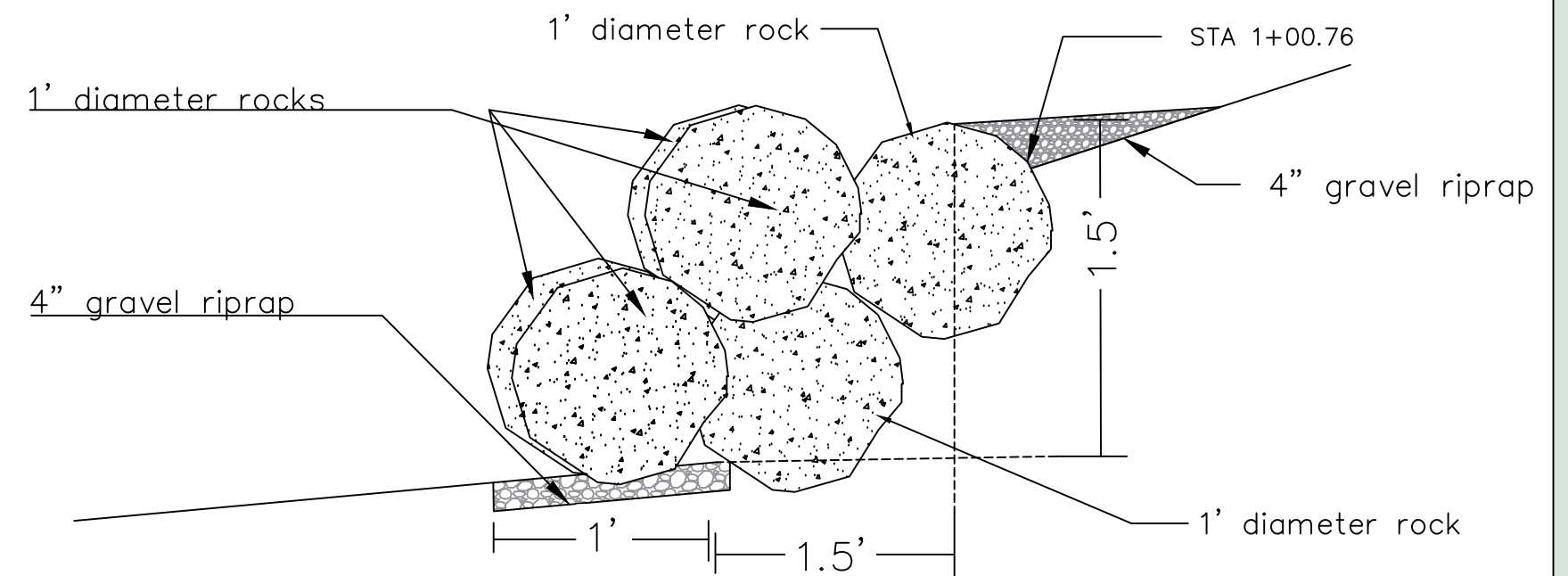
NO.	BY	DATE	DESCRIPTION
01		04/23/2026	Capstone 90% Submittal
02		05/05/2026	Capstone Final Submittal

Contact: NAU Stormwater Team  
 Phone: (480)-980-2831  
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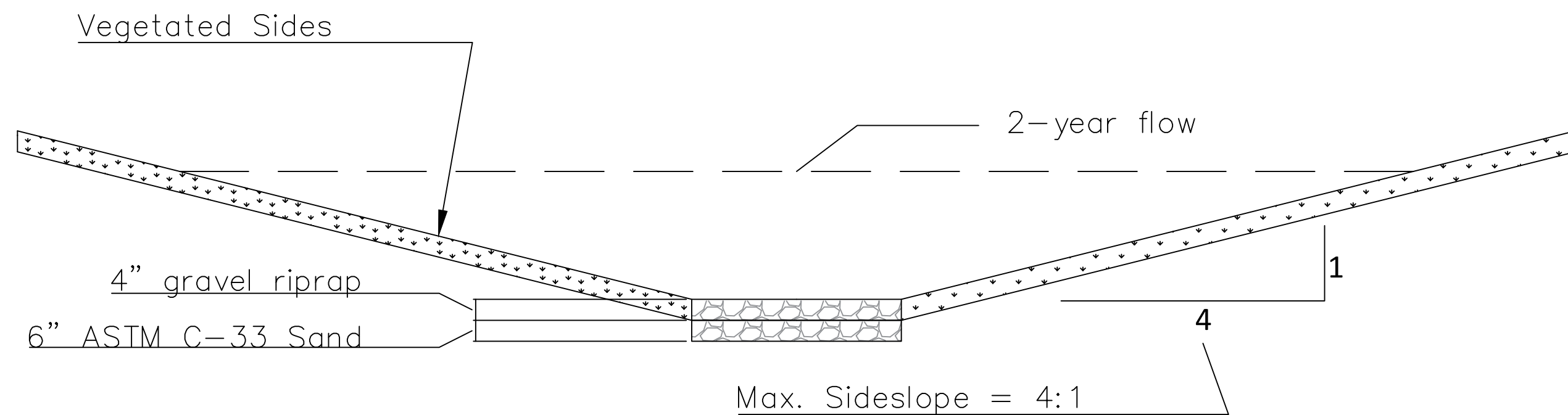
### Rock Drop Structure Detail – Plan



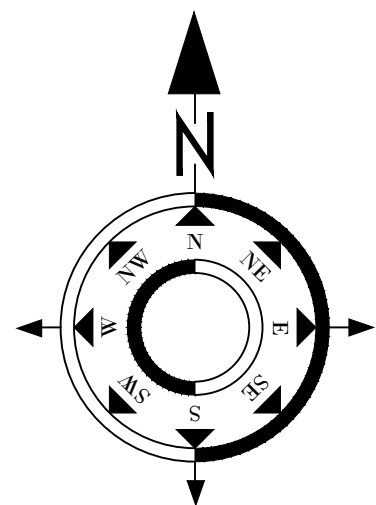
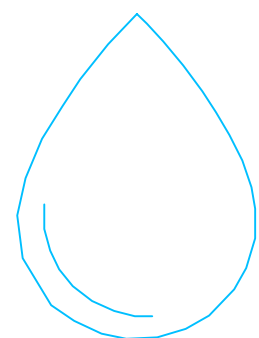
### Rock Drop Structure Detail – Profile



### Vegetated Swale Detail – Cross Section



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Design Details

05/05/2026

#### REVISIONS

NO.	BY	DATE	DESCRIPTION
01		02/10/2026	Capstone 30% Submittal
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03		04/23/2026	Capstone 90% Submittal
04		05/05/2026	Capstone Final Submittal

Contact: NAU Stormwater Team

Phone: (480)-980-2831

Email: fgf9@nau.edu

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# Culvert Inlet and Channel

Notes

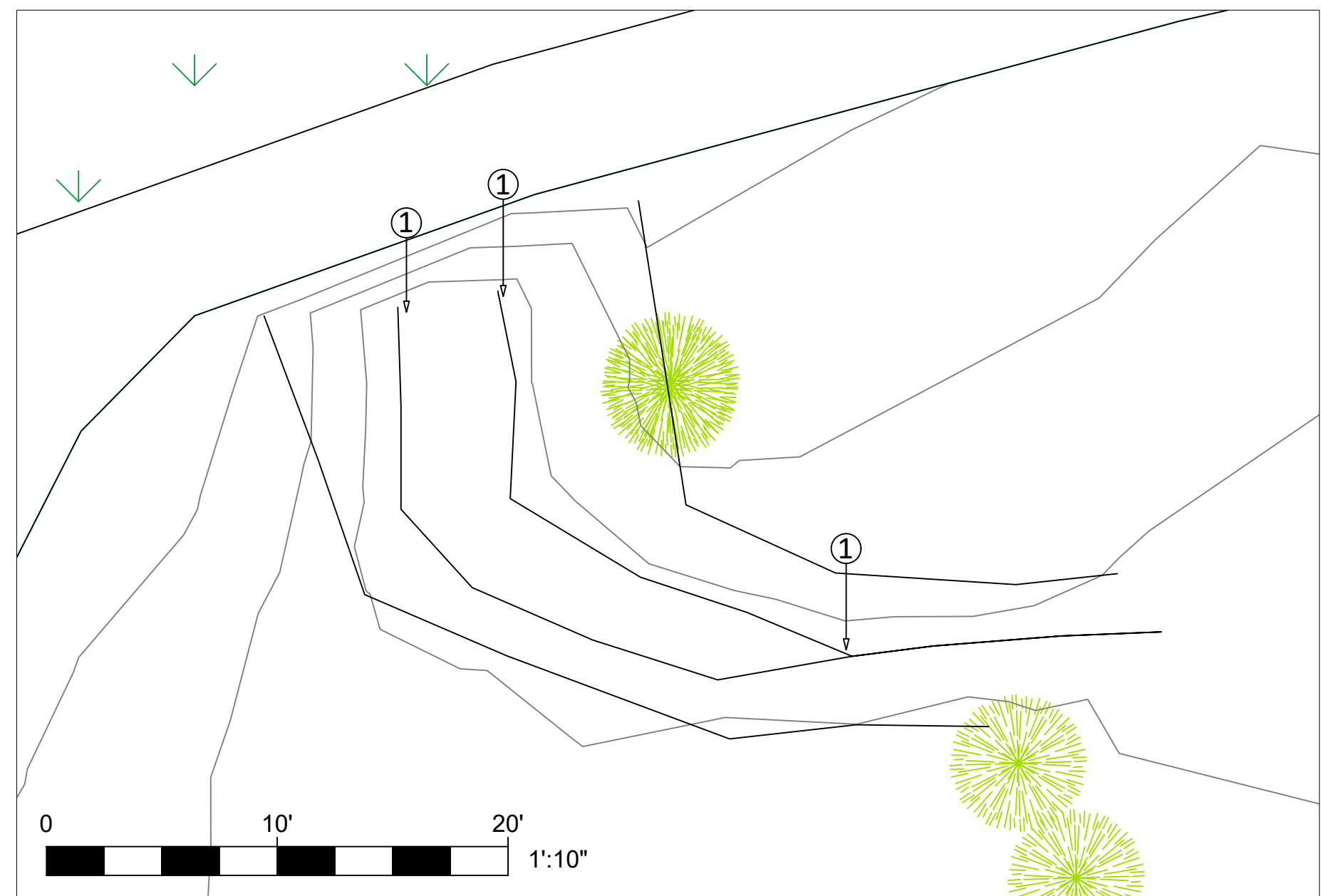
- 1) Clear 6" culvert of pine needles
- 2) Line flow path with 4" gravel (1.18 cy)



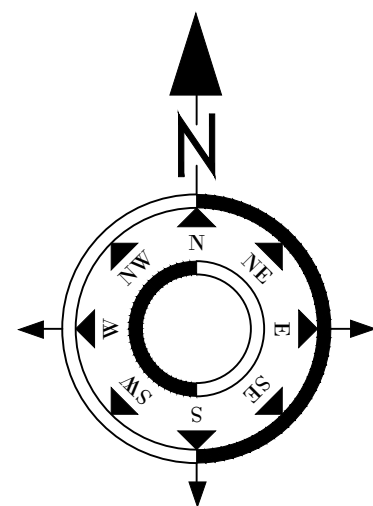
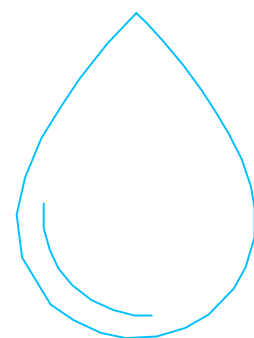
# Parking Lot Curb Cuts

Notes

- 1) Line flow path with 4" gravel (0.79 cy)



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Design Rec.

05/05/2026

REVISIONS

NO.	BY	DATE	DESCRIPTION
01		03/24/2026	Capstone 60% Submittal
02		04/23/2026	Capstone 90% Submittal
03		05/05/2026	Capstone Final Submittal

Contact: NAU Stormwater Team

Phone: (480)-980-2831

Email: fgf9@nau.edu

## Appendix M.1 : 2-Year Proposed FlowMaster Results

### Cross Section for Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.000 ft/ft
Normal Depth	0.9 in
Left Side Slope	407.000 H:V
Right Side Slope	4.903 H:V
Discharge	0.02 cfs



## Worksheet for Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.000 ft/ft
Left Side Slope	407.000 H:V
Right Side Slope	4.903 H:V
Discharge	0.02 cfs
Results	
Normal Depth	0.9 in
Flow Area	1.3 ft <sup>2</sup>
Wetted Perimeter	32.2 ft
Hydraulic Radius	0.5 in
Top Width	32.22 ft
Critical Depth	0.2 in
Critical Slope	0.360 ft/ft
Velocity	0.02 ft/s
Velocity Head	0.00 ft
Specific Energy	0.08 ft
Froude Number	0.014
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	0.9 in
Critical Depth	0.2 in
Channel Slope	0.000 ft/ft
Critical Slope	0.360 ft/ft

### Cross Section for Station 2

Project Description	
Friction Method	Manning
	Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.020 ft/ft
Normal Depth	1.0 in
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.02 cfs

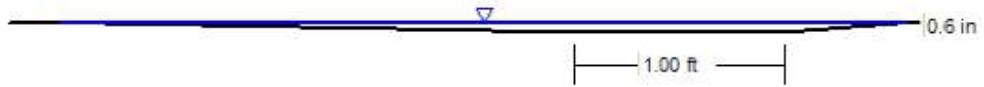
1.0 in

## Worksheet for Station 2

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.020 ft/ft
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.02 cfs
Results	
Normal Depth	1.0 in
Flow Area	-0.1 ft <sup>2</sup>
Wetted Perimeter	8.7 ft
Hydraulic Radius	-0.2 in
Top Width	-2.73 ft
Critical Depth	0.5 in
Critical Slope	(N/A) ft/ft
Velocity	0.00 ft/s
Velocity Head	0.00 ft
Specific Energy	0.09 ft
Froude Number	(N/A)
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	1.0 in
Critical Depth	0.5 in
Channel Slope	0.020 ft/ft
Critical Slope	(N/A) ft/ft

### Cross Section for Station 3

<b>Project Description</b>	
Friction Method	Manning
Solve For	Formula Normal Depth
<b>Input Data</b>	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Normal Depth	0.6 in
Left Side Slope	54.167 H:V
Right Side Slope	13.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 3

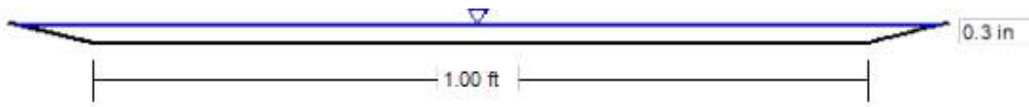
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	54.167 H:V
Right Side Slope	13.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.6 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	4.1 ft
Hydraulic Radius	0.3 in
Top Width	4.09 ft
Critical Depth	0.2 in
Critical Slope	0.291 ft/ft
Velocity	0.17 ft/s
Velocity Head	0.00 ft
Specific Energy	0.05 ft
Froude Number	0.177
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.6 in
Critical Depth	0.2 in
Channel Slope	0.007 ft/ft
Critical Slope	0.291 ft/ft

### Cross Section for Station 4

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.185 ft/ft
Normal Depth	0.3 in
Left Side Slope	4.023 H:V
Right Side Slope	3.804 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 4

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.185 ft/ft
Left Side Slope	4.023 H:V
Right Side Slope	3.804 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.3 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	1.2 ft
Hydraulic Radius	0.3 in
Top Width	1.19 ft
Critical Depth	0.3 in
Critical Slope	0.253 ft/ft
Velocity	0.74 ft/s
Velocity Head	0.01 ft
Specific Energy	0.03 ft
Froude Number	0.871
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.3 in
Critical Depth	0.3 in
Channel Slope	0.185 ft/ft
Critical Slope	0.253 ft/ft

### Cross Section for Station 5

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**Project Description**

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Friction Method	Manning Formula
Solve For	Normal Depth

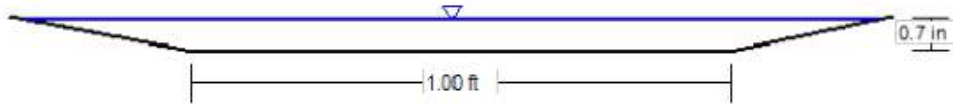
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**Input Data**

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Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Normal Depth	0.7 in
Left Side Slope	5.357 H:V
Right Side Slope	4.747 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs

---



## Worksheet for Station 5

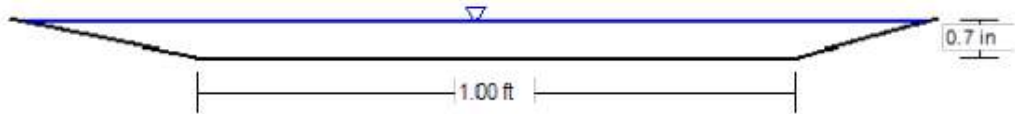
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	5.357 H:V
Right Side Slope	4.747 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.7 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	1.6 ft
Hydraulic Radius	0.6 in
Top Width	1.58 ft
Critical Depth	0.3 in
Critical Slope	0.255 ft/ft
Velocity	0.27 ft/s
Velocity Head	0.00 ft
Specific Energy	0.06 ft
Froude Number	0.219
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.7 in
Critical Depth	0.3 in
Channel Slope	0.009 ft/ft
Critical Slope	0.255 ft/ft

### Cross Section for Station 6

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Normal Depth	0.7 in
Left Side Slope	4.861 H:V
Right Side Slope	3.632 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 6

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	4.861 H:V
Right Side Slope	3.632 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.7 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	1.5 ft
Hydraulic Radius	0.6 in
Top Width	1.51 ft
Critical Depth	0.3 in
Critical Slope	0.254 ft/ft
Velocity	0.27 ft/s
Velocity Head	0.00 ft
Specific Energy	0.06 ft
Froude Number	0.213
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.7 in
Critical Depth	0.3 in
Channel Slope	0.009 ft/ft
Critical Slope	0.254 ft/ft

### Cross Section for Station 7

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

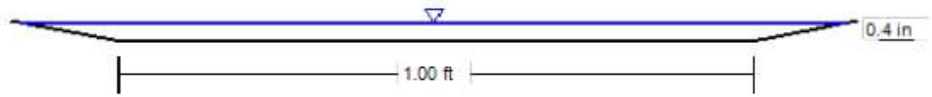
---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.096 ft/ft
Normal Depth	0.4 in
Left Side Slope	5.208 H:V
Right Side Slope	4.945 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs

---



## Worksheet for Station 7

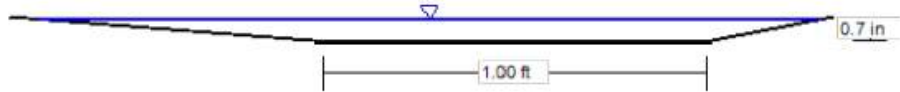
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.096 ft/ft
Left Side Slope	5.208 H:V
Right Side Slope	4.945 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.4 in
Flow Area	0.0 ft <sup>2</sup>
Wetted Perimeter	1.3 ft
Hydraulic Radius	0.3 in
Top Width	1.30 ft
Critical Depth	0.3 in
Critical Slope	0.255 ft/ft
Velocity	0.59 ft/s
Velocity Head	0.01 ft
Specific Energy	0.03 ft
Froude Number	0.641
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.4 in
Critical Depth	0.3 in
Channel Slope	0.096 ft/ft
Critical Slope	0.255 ft/ft

### Cross Section for Station 8

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Normal Depth	0.7 in
Left Side Slope	12.500 H:V
Right Side Slope	5.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 8

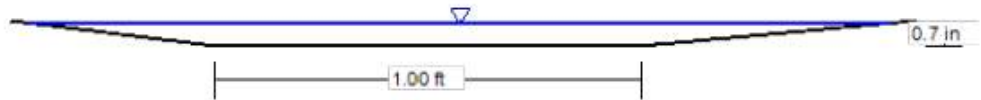
Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	12.500 H:V
Right Side Slope	5.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.7 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	2.0 ft
Hydraulic Radius	0.5 in
Top Width	2.04 ft
Critical Depth	0.3 in
Critical Slope	0.262 ft/ft
Velocity	0.22 ft/s
Velocity Head	0.00 ft
Specific Energy	0.06 ft
Froude Number	0.186
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.7 in
Critical Depth	0.3 in
Channel Slope	0.007 ft/ft
Critical Slope	0.262 ft/ft

### Cross Section for Station 9

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Normal Depth	0.7 in
Left Side Slope	7.895 H:V
Right Side Slope	10.625 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 9

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	10.625 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.7 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	2.0 ft
Hydraulic Radius	0.5 in
Top Width	2.02 ft
Critical Depth	0.3 in
Critical Slope	0.262 ft/ft
Velocity	0.24 ft/s
Velocity Head	0.00 ft
Specific Energy	0.06 ft
Froude Number	0.208
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.7 in
Critical Depth	0.3 in
Channel Slope	0.009 ft/ft
Critical Slope	0.262 ft/ft

### Cross Section for Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Normal Depth	0.5 in
Left Side Slope	7.895 H:V
Right Side Slope	50.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs



## Worksheet for Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	50.000 H:V
Bottom Width	1.00 ft
Discharge	0.02 cfs
Results	
Normal Depth	0.5 in
Flow Area	0.1 ft <sup>2</sup>
Wetted Perimeter	3.6 ft
Hydraulic Radius	0.3 in
Top Width	3.60 ft
Critical Depth	0.2 in
Critical Slope	0.287 ft/ft
Velocity	0.19 ft/s
Velocity Head	0.00 ft
Specific Energy	0.05 ft
Froude Number	0.201
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	0.5 in
Critical Depth	0.2 in
Channel Slope	0.009 ft/ft
Critical Slope	0.287 ft/ft

## Appendix M.2: 10-Year Proposed FlowMaster Results

### Worksheet for Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.000 ft/ft
Left Side Slope	407.000 H:V
Right Side Slope	4.903 H:V
Discharge	0.30 cfs
Results	
Normal Depth	2.6 in
Flow Area	9.6 ft <sup>2</sup>
Wetted Perimeter	89.1 ft
Hydraulic Radius	1.3 in
Top Width	89.06 ft
Critical Depth	0.5 in
Critical Slope	0.251 ft/ft
Velocity	0.03 ft/s
Velocity Head	0.00 ft
Specific Energy	0.22 ft
Froude Number	0.017
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	2.6 in
Critical Depth	0.5 in
Channel Slope	0.000 ft/ft
Critical Slope	0.251 ft/ft

## Worksheet for Station 2

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.020 ft/ft
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.30 cfs
Results	
Normal Depth	2.8 in
Flow Area	-0.9 ft <sup>2</sup>
Wetted Perimeter	24.0 ft
Hydraulic Radius	-0.4 in
Top Width	-7.54 ft
Critical Depth	1.4 in
Critical Slope	(N/A) ft/ft
Velocity	0.00 ft/s
Velocity Head	0.00 ft
Specific Energy	0.24 ft
Froude Number	(N/A)
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	2.8 in
Critical Depth	1.4 in
Channel Slope	0.020 ft/ft
Critical Slope	(N/A) ft/ft

### Worksheet for Station 3

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	54.167 H:V
Right Side Slope	13.000 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	1.8 in
Flow Area	0.9 ft <sup>2</sup>
Wetted Perimeter	11.0 ft
Hydraulic Radius	1.0 in
Top Width	10.98 ft
Critical Depth	0.9 in
Critical Slope	0.198 ft/ft
Velocity	0.34 ft/s
Velocity Head	0.00 ft
Specific Energy	0.15 ft
Froude Number	0.209
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.8 in
Critical Depth	0.9 in
Channel Slope	0.007 ft/ft
Critical Slope	0.198 ft/ft

## Worksheet for Station 4

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.185 ft/ft
Left Side Slope	4.023 H:V
Right Side Slope	3.804 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	1.4 in
Flow Area	0.2 ft <sup>2</sup>
Wetted Perimeter	1.9 ft
Hydraulic Radius	1.0 in
Top Width	1.90 ft
Critical Depth	1.4 in
Critical Slope	0.158 ft/ft
Velocity	1.81 ft/s
Velocity Head	0.05 ft
Specific Energy	0.17 ft
Froude Number	1.077
Flow Type	Supercritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	$\infty$ ft/s
Upstream Velocity	$\infty$ ft/s
Normal Depth	1.4 in
Critical Depth	1.4 in
Channel Slope	0.185 ft/ft
Critical Slope	0.158 ft/ft

## Worksheet for Station 5

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	5.357 H:V
Right Side Slope	4.747 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	2.8 in
Flow Area	0.5 ft <sup>2</sup>
Wetted Perimeter	3.4 ft
Hydraulic Radius	1.8 in
Top Width	3.37 ft
Critical Depth	1.4 in
Critical Slope	0.160 ft/ft
Velocity	0.59 ft/s
Velocity Head	0.01 ft
Specific Energy	0.24 ft
Froude Number	0.265
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.8 in
Critical Depth	1.4 in
Channel Slope	0.009 ft/ft
Critical Slope	0.160 ft/ft

## Worksheet for Station 6

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	4.861 H:V
Right Side Slope	3.632 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	3.0 in
Flow Area	0.5 ft <sup>2</sup>
Wetted Perimeter	3.2 ft
Hydraulic Radius	1.9 in
Top Width	3.10 ft
Critical Depth	1.4 in
Critical Slope	0.158 ft/ft
Velocity	0.59 ft/s
Velocity Head	0.01 ft
Specific Energy	0.25 ft
Froude Number	0.258
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.0 in
Critical Depth	1.4 in
Channel Slope	0.009 ft/ft
Critical Slope	0.158 ft/ft

## Worksheet for Station 7

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.096 ft/ft
Left Side Slope	5.208 H:V
Right Side Slope	4.945 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	1.6 in
Flow Area	0.2 ft <sup>2</sup>
Wetted Perimeter	2.4 ft
Hydraulic Radius	1.1 in
Top Width	2.33 ft
Critical Depth	1.4 in
Critical Slope	0.160 ft/ft
Velocity	1.37 ft/s
Velocity Head	0.03 ft
Specific Energy	0.16 ft
Froude Number	0.789
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.6 in
Critical Depth	1.4 in
Channel Slope	0.096 ft/ft
Critical Slope	0.160 ft/ft

## Worksheet for Station 8

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	12.500 H:V
Right Side Slope	5.000 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	2.6 in
Flow Area	0.6 ft <sup>2</sup>
Wetted Perimeter	4.9 ft
Hydraulic Radius	1.6 in
Top Width	4.86 ft
Critical Depth	1.3 in
Critical Slope	0.169 ft/ft
Velocity	0.46 ft/s
Velocity Head	0.00 ft
Specific Energy	0.22 ft
Froude Number	0.224
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.6 in
Critical Depth	1.3 in
Channel Slope	0.007 ft/ft
Critical Slope	0.169 ft/ft

## Worksheet for Station 9

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	10.625 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	2.5 in
Flow Area	0.6 ft <sup>2</sup>
Wetted Perimeter	4.8 ft
Hydraulic Radius	1.5 in
Top Width	4.82 ft
Critical Depth	1.2 in
Critical Slope	0.170 ft/ft
Velocity	0.50 ft/s
Velocity Head	0.00 ft
Specific Energy	0.21 ft
Froude Number	0.250
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.5 in
Critical Depth	1.2 in
Channel Slope	0.009 ft/ft
Critical Slope	0.170 ft/ft

## Worksheet for Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth
Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	50.000 H:V
Bottom Width	1.00 ft
Discharge	0.30 cfs
Results	
Normal Depth	1.8 in
Flow Area	0.8 ft <sup>2</sup>
Wetted Perimeter	9.5 ft
Hydraulic Radius	1.0 in
Top Width	9.50 ft
Critical Depth	0.9 in
Critical Slope	0.195 ft/ft
Velocity	0.39 ft/s
Velocity Head	0.00 ft
Specific Energy	0.15 ft
Froude Number	0.241
Flow Type	Subcritical
GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0
GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.8 in
Critical Depth	0.9 in
Channel Slope	0.009 ft/ft
Critical Slope	0.195 ft/ft

## Appendix M.3: 50-Year Proposed FlowMaster Results

### Station 1

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

---

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.000 ft/ft
Left Side Slope	407.000 H:V
Right Side Slope	4.903 H:V
Discharge	0.40 cfs

---

Results	
Normal Depth	2.9 in
Flow Area	11.9 ft <sup>2</sup>
Wetted Perimeter	99.2 ft
Hydraulic Radius	1.4 in
Top Width	99.17 ft
Critical Depth	0.6 in
Critical Slope	0.242 ft/ft
Velocity	0.03 ft/s
Velocity Head	0.00 ft
Specific Energy	0.24 ft
Froude Number	0.017
Flow Type	Subcritical

---

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s

Upstream Velocity	-∞ ft/s
Normal Depth	2.9 in
Critical Depth	0.6 in
Channel Slope	0.000 ft/ft
Critical Slope	0.242 ft/ft

---

### Station 2

---

#### Project Description

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.020 ft/ft
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.40 cfs

---

#### Results

---

Normal Depth	3.2 in
Flow Area	-1.1 ft <sup>2</sup>
Wetted Perimeter	26.7 ft
Hydraulic Radius	-0.5 in
Top Width	-8.41 ft
Critical Depth	1.6 in
Critical Slope	(N/A) ft/ft
Velocity	0.00 ft/s
Velocity Head	0.00 ft
Specific Energy	0.26 ft
Froude Number	(N/A)
Flow Type	Subcritical

---

#### GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

#### GVF Output Data

---

Upstream Depth	0.0 in
----------------	--------

---

Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	3.2 in
Critical Depth	1.6 in
Channel Slope	0.020 ft/ft
Critical Slope	(N/A) ft/ft

---

### Station 3

---

#### Project Description

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	54.167 H:V
Right Side Slope	13.000 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---

#### Results

---

Normal Depth	2.0 in
Flow Area	1.1 ft <sup>2</sup>
Wetted Perimeter	12.2 ft
Hydraulic Radius	1.1 in
Top Width	12.22 ft
Critical Depth	1.0 in
Critical Slope	0.191 ft/ft
Velocity	0.36 ft/s
Velocity Head	0.00 ft
Specific Energy	0.17 ft
Froude Number	0.213
Flow Type	Subcritical

---

#### GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.0 in
Critical Depth	1.0 in
Channel Slope	0.007 ft/ft
Critical Slope	0.191 ft/ft

---

**Station 4**

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.185 ft/ft
Left Side Slope	4.023 H:V
Right Side Slope	3.804 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---

**Results**

---

Normal Depth	1.6 in
Flow Area	0.2 ft <sup>2</sup>
Wetted Perimeter	2.1 ft
Hydraulic Radius	1.2 in
Top Width	2.04 ft
Critical Depth	1.7 in
Critical Slope	0.151 ft/ft
Velocity	1.97 ft/s
Velocity Head	0.06 ft
Specific Energy	0.19 ft
Froude Number	1.101
Flow Type	Supercritical

---

---

---

**GVF Input Data**

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	$\infty$ ft/s
Upstream Velocity	$\infty$ ft/s
Normal Depth	1.6 in
Critical Depth	1.7 in
Channel Slope	0.185 ft/ft
Critical Slope	0.151 ft/ft

---

**Station 6**

---

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	4.861 H:V
Right Side Slope	3.632 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---

---

**Results**

---

Normal Depth	3.4 in
Flow Area	0.6 ft <sup>2</sup>
Wetted Perimeter	3.5 ft
Hydraulic Radius	2.2 in
Top Width	3.41 ft
Critical Depth	1.7 in
Critical Slope	0.152 ft/ft
Velocity	0.64 ft/s
Velocity Head	0.01 ft
Specific Energy	0.29 ft

Froude Number	0.264
Flow Type	Subcritical

---

---

#### GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

#### GVF Output Data

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.4 in
Critical Depth	1.7 in
Channel Slope	0.009 ft/ft
Critical Slope	0.152 ft/ft

---

### Station 5

---

---

#### Project Description

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	5.357 H:V
Right Side Slope	4.747 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---

---

#### Results

---

Normal Depth	3.2 in
Flow Area	0.6 ft <sup>2</sup>
Wetted Perimeter	3.8 ft
Hydraulic Radius	2.0 in
Top Width	3.71 ft
Critical Depth	1.6 in

---

Critical Slope	0.154 ft/ft
Velocity	0.63 ft/s
Velocity Head	0.01 ft
Specific Energy	0.27 ft
Froude Number	0.270
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

#### GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.2 in
Critical Depth	1.6 in
Channel Slope	0.009 ft/ft
Critical Slope	0.154 ft/ft

### Station 7

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

Roughness Coefficient	0.069
Channel Slope	0.096 ft/ft
Left Side Slope	5.208 H:V
Right Side Slope	4.945 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

#### Results

Normal Depth	1.8 in
Flow Area	0.3 ft <sup>2</sup>

Wetted Perimeter	2.6 ft
Hydraulic Radius	1.3 in
Top Width	2.55 ft
Critical Depth	1.6 in
Critical Slope	0.154 ft/ft
Velocity	1.48 ft/s
Velocity Head	0.03 ft
Specific Energy	0.19 ft
Froude Number	0.801
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

#### GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	1.8 in
Critical Depth	1.6 in
Channel Slope	0.096 ft/ft
Critical Slope	0.154 ft/ft

### Station 8

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	12.500 H:V
Right Side Slope	5.000 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---

**Results**

---

Normal Depth	3.0 in
Flow Area	0.8 ft <sup>2</sup>
Wetted Perimeter	5.4 ft
Hydraulic Radius	1.8 in
Top Width	5.39 ft
Critical Depth	1.5 in
Critical Slope	0.162 ft/ft
Velocity	0.50 ft/s
Velocity Head	0.00 ft
Specific Energy	0.25 ft
Froude Number	0.229
Flow Type	Subcritical

---

---

**GVF Input Data**

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.0 in
Critical Depth	1.5 in
Channel Slope	0.007 ft/ft
Critical Slope	0.162 ft/ft

---

**Station 10**

---

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	50.000 H:V

---

Bottom Width	1.00 ft
Discharge	0.40 cfs

Results

Normal Depth	2.0 in
Flow Area	1.0 ft <sup>2</sup>
Wetted Perimeter	10.6 ft
Hydraulic Radius	1.1 in
Top Width	10.57 ft
Critical Depth	1.1 in
Critical Slope	0.187 ft/ft
Velocity	0.42 ft/s
Velocity Head	0.00 ft
Specific Energy	0.17 ft
Froude Number	0.245
Flow Type	Subcritical

GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.0 in
Critical Depth	1.1 in
Channel Slope	0.009 ft/ft
Critical Slope	0.187 ft/ft

Station 9

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	10.625 H:V
Bottom Width	1.00 ft
Discharge	0.40 cfs

---



---

Results

---

Normal Depth	2.8 in
Flow Area	0.7 ft <sup>2</sup>
Wetted Perimeter	5.4 ft
Hydraulic Radius	1.7 in
Top Width	5.34 ft
Critical Depth	1.4 in
Critical Slope	0.163 ft/ft
Velocity	0.54 ft/s
Velocity Head	0.00 ft
Specific Energy	0.24 ft
Froude Number	0.255
Flow Type	Subcritical

---



---

GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---



---

GVF Output Data

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.8 in
Critical Depth	1.4 in
Channel Slope	0.009 ft/ft
Critical Slope	0.163 ft/ft

---

## Appendix M.4: 100-Year Proposed FlowMaster Results

### Station 10

Project Description	
Friction Method	Manning Formula
Solve For	Normal Depth

---

Input Data	
Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	50.000 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---

Results	
Normal Depth	2.2 in
Flow Area	1.1 ft <sup>2</sup>
Wetted Perimeter	11.5 ft
Hydraulic Radius	1.2 in
Top Width	11.47 ft
Critical Depth	1.2 in
Critical Slope	0.182 ft/ft
Velocity	0.44 ft/s
Velocity Head	0.00 ft
Specific Energy	0.18 ft
Froude Number	0.249
Flow Type	Subcritical

---

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft

Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.2 in
Critical Depth	1.2 in
Channel Slope	0.009 ft/ft
Critical Slope	0.182 ft/ft

---

### Station 1

---

#### Project Description

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.000 ft/ft
Left Side Slope	407.000 H:V
Right Side Slope	4.903 H:V
Discharge	0.50 cfs

---

#### Results

---

Normal Depth	3.1 in
Flow Area	14.1 ft <sup>2</sup>
Wetted Perimeter	107.9 ft
Hydraulic Radius	1.6 in
Top Width	107.85 ft
Critical Depth	0.6 in
Critical Slope	0.235 ft/ft
Velocity	0.04 ft/s
Velocity Head	0.00 ft
Specific Energy	0.26 ft
Froude Number	0.017
Flow Type	Subcritical

---

#### GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

#### GVF Output Data

---

Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	3.1 in
Critical Depth	0.6 in
Channel Slope	0.000 ft/ft
Critical Slope	0.235 ft/ft

### Station 2

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

Roughness Coefficient	0.069
Channel Slope	0.020 ft/ft
Left Side Slope	-66.714 H:V
Right Side Slope	34.750 H:V
Discharge	0.50 cfs

#### Results

Normal Depth	3.4 in
Flow Area	-1.3 ft <sup>2</sup>
Wetted Perimeter	29.0 ft
Hydraulic Radius	-0.5 in
Top Width	-9.14 ft
Critical Depth	1.7 in
Critical Slope	(N/A) ft/ft
Velocity	0.00 ft/s
Velocity Head	0.00 ft
Specific Energy	0.29 ft
Froude Number	(N/A)
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	-∞ ft/s
Upstream Velocity	-∞ ft/s
Normal Depth	3.4 in
Critical Depth	1.7 in
Channel Slope	0.020 ft/ft
Critical Slope	(N/A) ft/ft

---

**Station 3**

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	54.167 H:V
Right Side Slope	13.000 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---

**Results**

---

Normal Depth	2.2 in
Flow Area	1.3 ft <sup>2</sup>
Wetted Perimeter	13.3 ft
Hydraulic Radius	1.2 in
Top Width	13.26 ft
Critical Depth	1.1 in
Critical Slope	0.185 ft/ft
Velocity	0.38 ft/s
Velocity Head	0.00 ft
Specific Energy	0.18 ft
Froude Number	0.216
Flow Type	Subcritical

---

---

---

**GVF Input Data**

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.2 in
Critical Depth	1.1 in
Channel Slope	0.007 ft/ft
Critical Slope	0.185 ft/ft

---

**Station 4**

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.185 ft/ft
Left Side Slope	4.023 H:V
Right Side Slope	3.804 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---

---

**Results**

---

Normal Depth	1.8 in
Flow Area	0.2 ft <sup>2</sup>
Wetted Perimeter	2.2 ft
Hydraulic Radius	1.3 in
Top Width	2.17 ft
Critical Depth	1.9 in
Critical Slope	0.146 ft/ft
Velocity	2.10 ft/s
Velocity Head	0.07 ft
Specific Energy	0.22 ft

Froude Number	1.119
Flow Type	Supercritical

---

---

#### GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

#### GVF Output Data

---

Upstream Depth	0.0 in
Profile Description	Dry
Profile Headloss	0.00 ft
Downstream Velocity	$\infty$ ft/s
Upstream Velocity	$\infty$ ft/s
Normal Depth	1.8 in
Critical Depth	1.9 in
Channel Slope	0.185 ft/ft
Critical Slope	0.146 ft/ft

---

### Station 5

---

---

#### Project Description

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	5.357 H:V
Right Side Slope	4.747 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---

---

#### Results

---

Normal Depth	3.6 in
Flow Area	0.7 ft <sup>2</sup>
Wetted Perimeter	4.1 ft
Hydraulic Radius	2.2 in
Top Width	4.01 ft
Critical Depth	1.8 in

---

Critical Slope	0.149 ft/ft
Velocity	0.67 ft/s
Velocity Head	0.01 ft
Specific Energy	0.30 ft
Froude Number	0.274
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

#### GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.6 in
Critical Depth	1.8 in
Channel Slope	0.009 ft/ft
Critical Slope	0.149 ft/ft

### Station 6

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	4.861 H:V
Right Side Slope	3.632 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

#### Results

Normal Depth	3.8 in
Flow Area	0.7 ft <sup>2</sup>

Wetted Perimeter	3.8 ft
Hydraulic Radius	2.4 in
Top Width	3.68 ft
Critical Depth	1.9 in
Critical Slope	0.147 ft/ft
Velocity	0.68 ft/s
Velocity Head	0.01 ft
Specific Energy	0.32 ft
Froude Number	0.267
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

#### GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.8 in
Critical Depth	1.9 in
Channel Slope	0.009 ft/ft
Critical Slope	0.147 ft/ft

### Station 7

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

Roughness Coefficient	0.069
Channel Slope	0.096 ft/ft
Left Side Slope	5.208 H:V
Right Side Slope	4.945 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---

**Results**

---

Normal Depth	2.0 in
Flow Area	0.3 ft <sup>2</sup>
Wetted Perimeter	2.8 ft
Hydraulic Radius	1.4 in
Top Width	2.73 ft
Critical Depth	1.8 in
Critical Slope	0.149 ft/ft
Velocity	1.58 ft/s
Velocity Head	0.04 ft
Specific Energy	0.21 ft
Froude Number	0.815
Flow Type	Subcritical

---

---

**GVF Input Data**

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---

---

**GVF Output Data**

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	2.0 in
Critical Depth	1.8 in
Channel Slope	0.096 ft/ft
Critical Slope	0.149 ft/ft

---

**Station 8**

---

---

**Project Description**

---

Friction Method	Manning Formula
Solve For	Normal Depth

---

---

**Input Data**

---

Roughness Coefficient	0.069
Channel Slope	0.007 ft/ft
Left Side Slope	12.500 H:V
Right Side Slope	5.000 H:V

---

Bottom Width	1.00 ft
Discharge	0.50 cfs

#### Results

Normal Depth	3.3 in
Flow Area	0.9 ft <sup>2</sup>
Wetted Perimeter	5.9 ft
Hydraulic Radius	1.9 in
Top Width	5.84 ft
Critical Depth	1.6 in
Critical Slope	0.157 ft/ft
Velocity	0.53 ft/s
Velocity Head	0.00 ft
Specific Energy	0.28 ft
Froude Number	0.232
Flow Type	Subcritical

#### GVF Input Data

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

#### GVF Output Data

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.3 in
Critical Depth	1.6 in
Channel Slope	0.007 ft/ft
Critical Slope	0.157 ft/ft

### Station 9

#### Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

#### Input Data

---

Roughness Coefficient	0.069
Channel Slope	0.009 ft/ft
Left Side Slope	7.895 H:V
Right Side Slope	10.625 H:V
Bottom Width	1.00 ft
Discharge	0.50 cfs

---



---

Results

---

Normal Depth	3.1 in
Flow Area	0.9 ft <sup>2</sup>
Wetted Perimeter	5.8 ft
Hydraulic Radius	1.8 in
Top Width	5.78 ft
Critical Depth	1.6 in
Critical Slope	0.158 ft/ft
Velocity	0.57 ft/s
Velocity Head	0.01 ft
Specific Energy	0.26 ft
Froude Number	0.258
Flow Type	Subcritical

---



---

GVF Input Data

---

Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

---



---

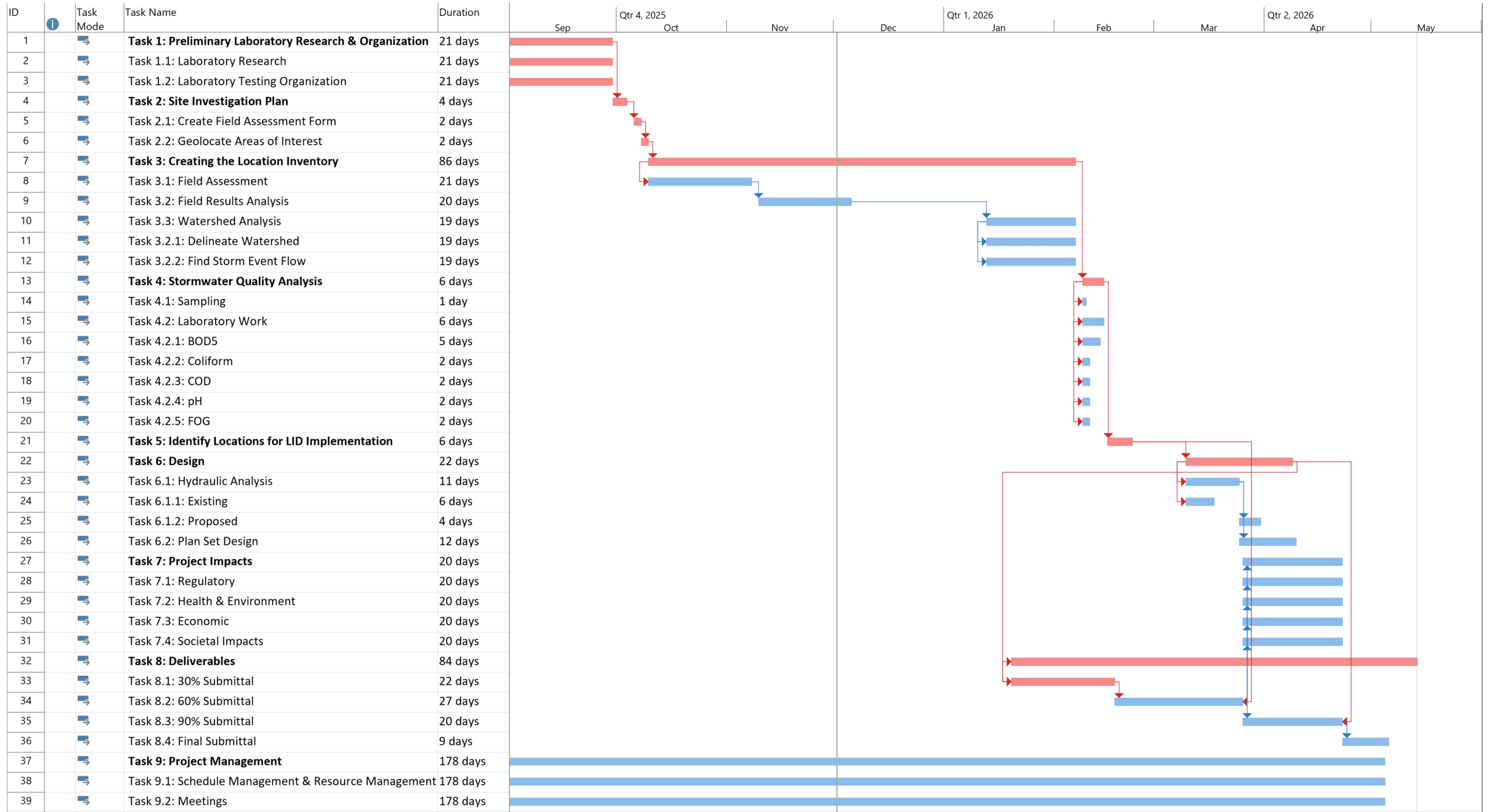
GVF Output Data

---

Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	3.1 in
Critical Depth	1.6 in
Channel Slope	0.009 ft/ft
Critical Slope	0.158 ft/ft

---

**Appendix N.1: Original Gantt Chart**



Project: Project1  
Date: Tue 12/2/25

Task		Project Summary		Manual Task		Start-only		Deadline		Manual Progress
Split		Inactive Task		Duration-only		Finish-only		Critical		
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Critical Split		
Summary		Inactive Summary		Manual Summary		External Milestone		Progress		

**Appendix N.2: Adjusted Gantt Chart**



Project: Project1  
Date: Wed 4/22/26

Task		Inactive Task		Manual Summary Rollup		External Milestone		Manual Progress	
Split		Inactive Milestone		Manual Summary		Deadline			
Milestone		Inactive Summary		Start-only		Critical			
Summary		Manual Task		Finish-only		Critical Split			
Project Summary		Duration-only		External Tasks		Progress			