Saginaw Hill Erosion Control

Design Report

Alex Meisner, Brooke Rhodes, and Tyler Shamburg

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NORTHERN ARIZONA UNIVERSITY
CENE 486 Capstone

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ACKNOWLEDGEMENTS

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1.0 PROJECT DESCRIPTION

1.1 Purpose

The purpose of this project is to assess erosion that has occurred on the Saginaw Hill Mine tailings repository cap and to determine a design solution to prevent further erosion. The client for this project is the Bureau of Land Management (BLM). The current cap, built in 2009, has eroded at a higher rate than expected [1]. Left unchecked, this could cause tailings to become exposed and migrate into the surrounding environment. Urban development has spread into the area surrounding Saginaw Hill since the mine's closure, and a breach into the tailings cap could cause heavy metals and other contaminants to spread. This project is necessary in order to reduce the risk of contaminant exposure from inhalation or ingestion of tailings particles in the area around Saginaw Hill.

1.2 Background

The Saginaw Hill Mine is a 290-acre area maintained by the BLM [1]. The project site is located roughly 10 miles southwest of Tucson, AZ. The exact location of the site is Township 15 South, Range 12 East, Sections 11 and 12 in Pima County, AZ [2]. Saginaw Hill's location within the Tucson area can be seen in Figure 1.1 [3]. A topographic rendering of the project site can be seen in Figure 1.2.

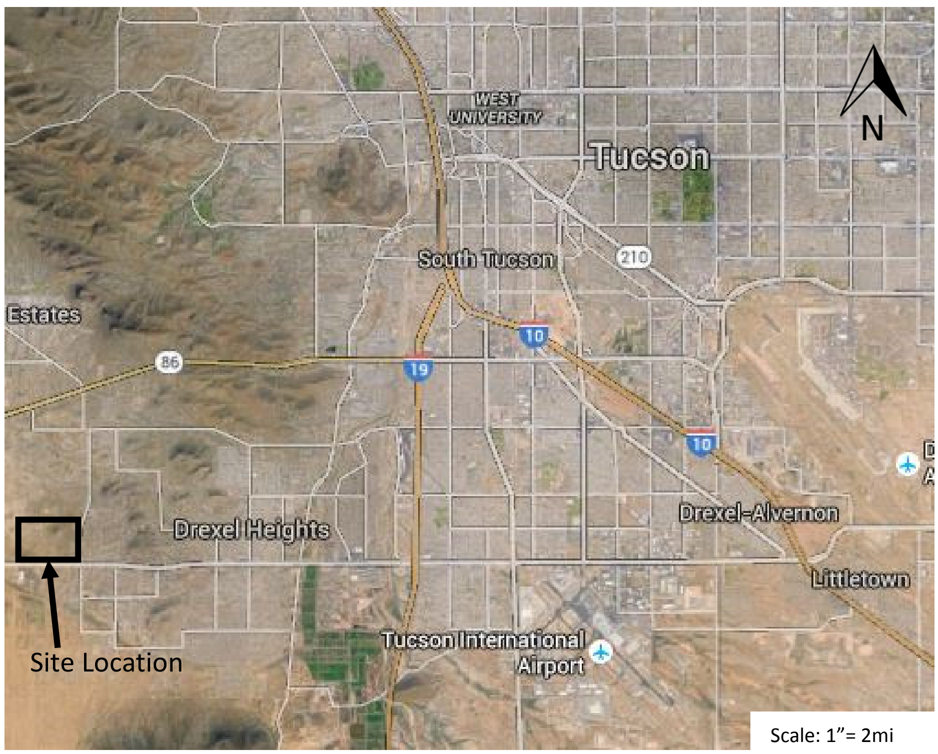

Figure 1.1: Location of project site within the Tucson, AZ area.

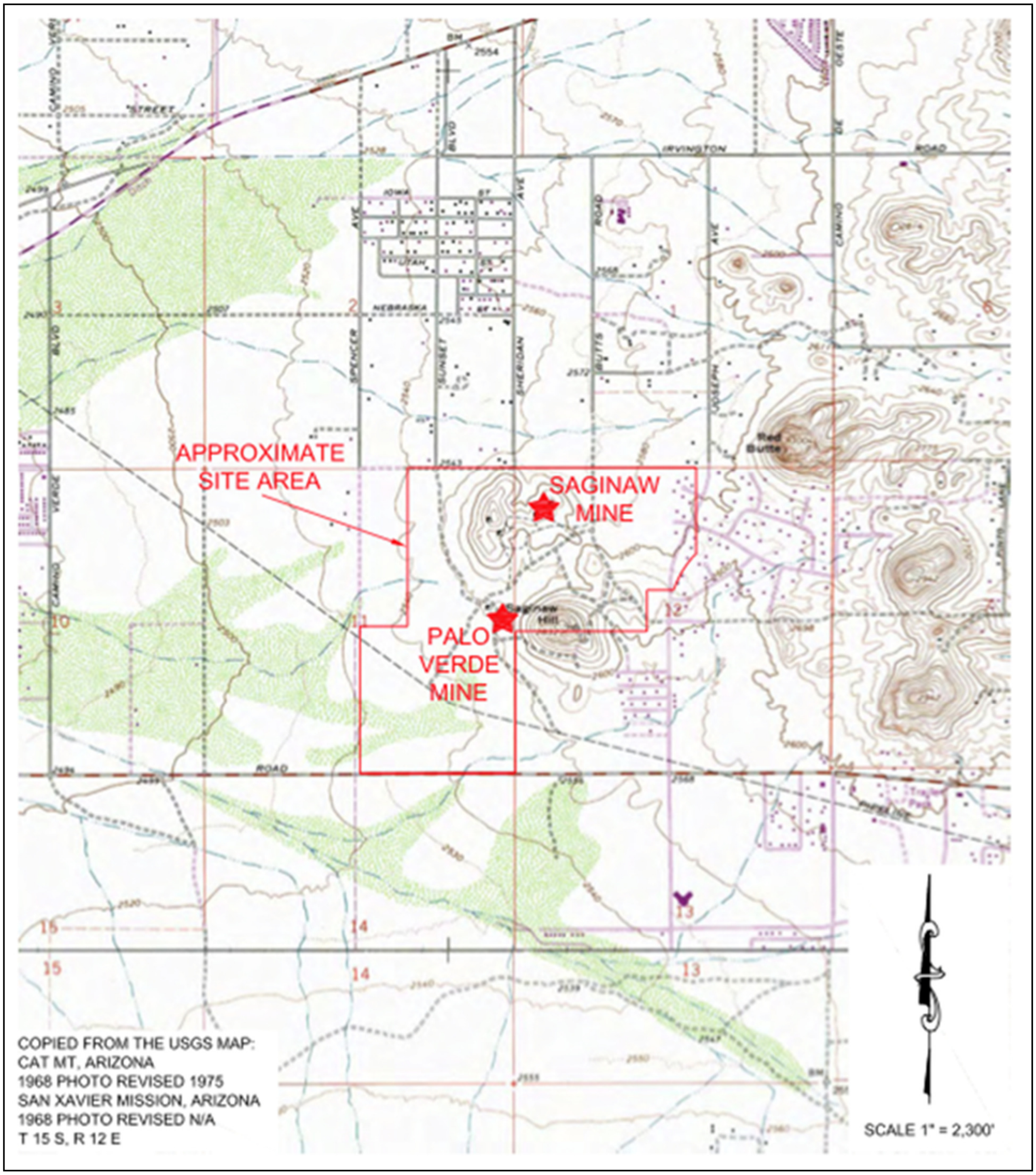

Figure 1.2: Topographic Map with Star indicating Saginaw Hill Mine location [2].

The Saginaw Hill mine was operated from the late 1800's to the mid 1950's. The mine was owned by Saginaw Mining Co. and Tucson Arizona Copper Co. [4]. The mine produced base metal sulfides, which were used to process valuable metal ores brought in from other locations. The metal sulfides produced at the mine include copper, lead, gold, silver, zinc, and molybdenum [4].

Currently, most of the 540-acre Saginaw Hill area is open to the public except for the contaminated areas located around the mine tailings pile.

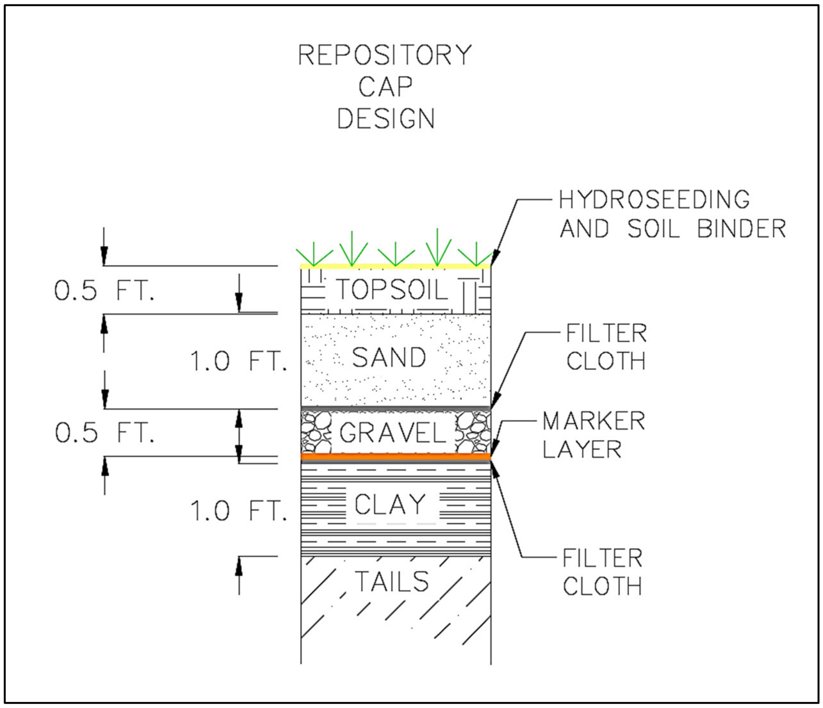

Figure 1.3 Repository Cap Design, as described in design report.

Under the supervision of the BLM, the Saginaw Hill Mine underwent a remediation project in 2009 by Red J Environmental Corporation. The BLM hired Red J to prevent continued contamination from the mine tailings and to monitor the contaminated groundwater surrounding the mine. Red J's scope of work was to consolidate the waste tailings of the mine and sequester them from the surrounding environment. A layered clay and filter-cloth repository cap was constructed over the tailings, and is shown in Figure 1.3, to prevent the tailings from migrating to the nearby neighborhoods. The cap is composed of 3 layers including an orange marker layer to indicate where the top of the first clay layer is. Vegetation was planned for the top layer to minimize erosion, a picture of installation is shown in Figure 1.4 [2]. Gravel caps were used to cover the excavated areas. Additionally, Red J constructed arroyo riprap drainage channels to prevent runoff from getting to the cap and stabilized existing washes with multiple layers of soils, aggregate, and fabrics.

Figure 1.4: Revegetation efforts on top of repository cap [2].

Currently, the Saginaw Hill Mine cap is being inspected quarterly by Terracon Consultants. Terracon's quarterly reports show there are 13 metals in the groundwater surrounding the area. Terracon also inspects the arroyo riprap, repository cap, and diversion channels at the site. The arroyo riprap was deemed acceptable in a recent report, but it was noted that there was an area of bare geo-membrane filter fabric visible. The inspection also noted that the gravel caps were in good condition. However, the report noted that both the repository cap and diversion channels appeared to be damaged by erosion. There was sedimentation in the diversion channels and the repository cap's vegetation layer was missing entirely. Figure 1.5 shows the current condition of the cap. The exposed marker layer and wire-netting geotextile fabric can be seen above in Figure 1.6.

Figure 1.5: Vegetation is sparse and erosion is evident on the repository cap [5].

Figure 1.6: Exposed marker layer and mesh wire-netting

2.0 IDENTIFICATION OF EROSION SOURCE

2.1 Cap Geometry

Topographic surveying was completed during the site visit on December 2nd and 3rd 2015, to determine the cap's geometry. The existing cap geometry can be seen in Appendix A. Soil samples were taken from a rill located at survey point CP2 (see Appendix B for survey point locations). Design specifications from the Red J Environmental design plan require that the cap maintain a maximum slope of 3:1 horizontal [2]. This design specification was met and exceeded, with the maximum sloping on the cap at 3.5:1 horizontal. The typical cross section of the cap can be seen in Figure 2.1.

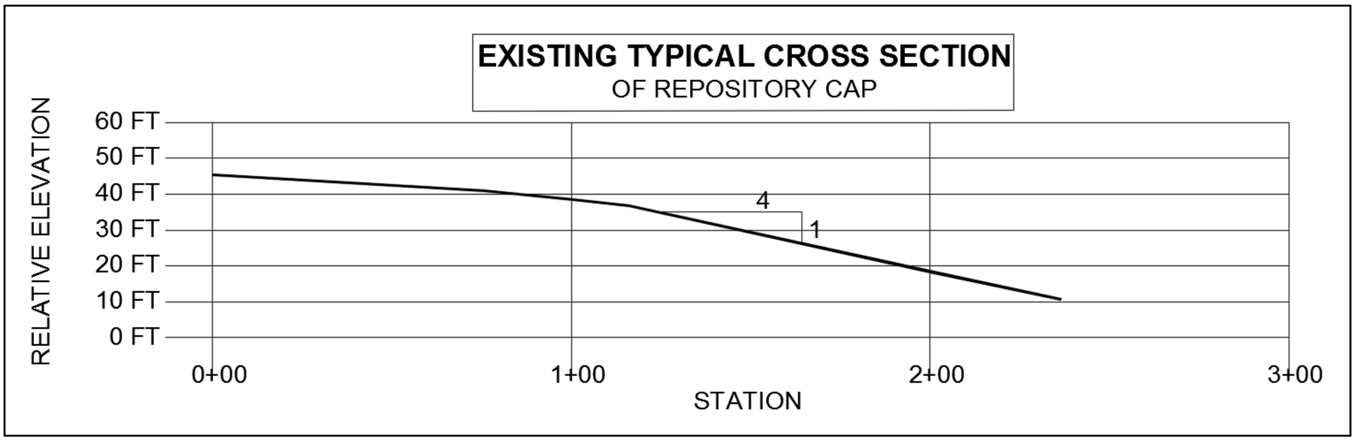

Figure 2.1: Typical cross section of cap.

2.2 Geotechnical Analysis

Samples were taken from the bottom of the rill immediately above the marker layer, at the midpoint of the rill and surface, and at the cap's surface. The soil above the marker layer was homogenous and the three samples were combined to create a composite sample. Gradation analysis, compression strength analysis, and permeability testing was completed on the soil to better understand the classification and mechanical properties.

2.2.1 Gradation Analysis

Sieve testing following the United States Army Corps of Engineers soil manual EM 1110-2-1906 Appendix V Section 2 was completed using 868.64 grams of the sample gathered during the site visit. The fine soil that passed the #200 sieve (0.074 mm opening) was subjected to hydrometer testing following the United States Army Corps of Engineers soil manual USACE EM 1110-2-1906 Appendix V Section 3. All lab results for the gradation testing are presented in Appendix C.

The soil was classified as "Sand" per the United States Department of Agriculture (USDA) Textural Soil Classification. The soil was determined to consist of 92.68% sand, 4.42% silt, and 2.90% clay based upon the gradation. The gradation curve for the sample representative of the top most layer of the cap shown with the USDA's soil separate limits can be seen in Figure 2.2.

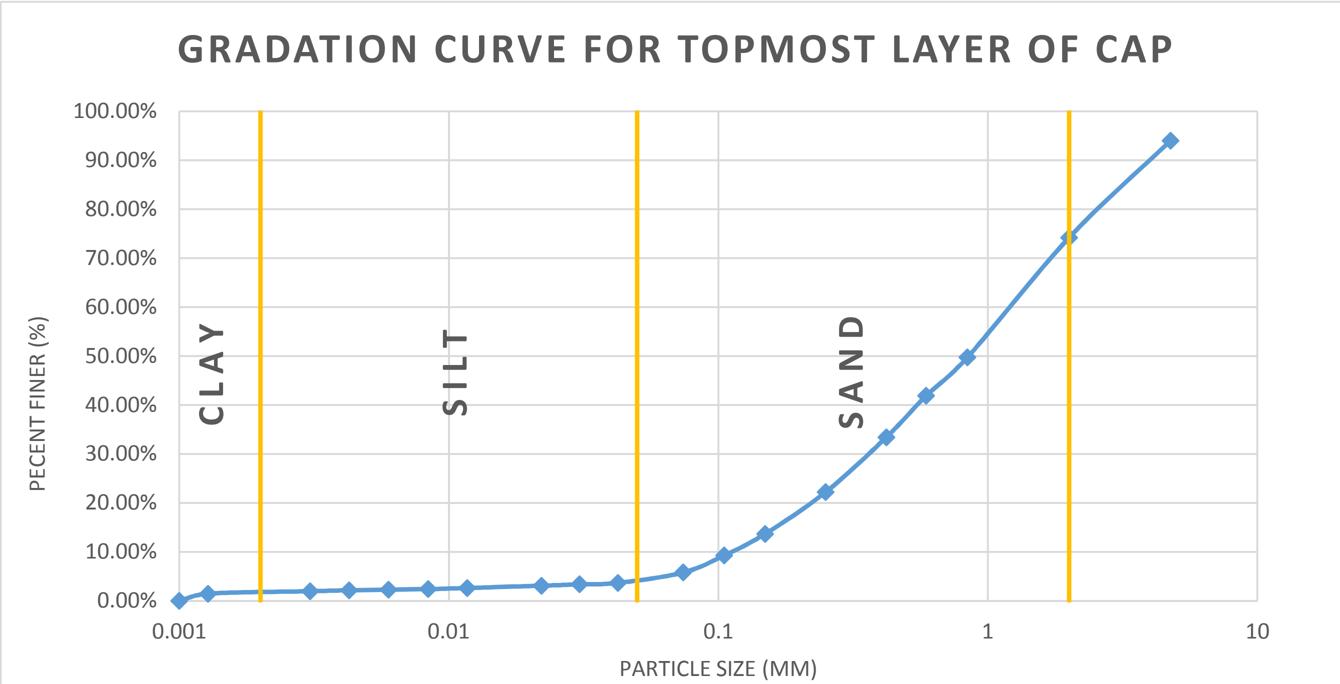

Figure 2.2: Gradation Curve of Upper Cap Layer

2.2.2 Shear Strength Analysis

The shear strength of the soil was determined empirically using compressive strength data collected from the United States Army Corps of Engineers soil manual EM 1110-2-1906 Appendix XI. Two specimens were prepared and loaded compressively until failure. The shear strength was empirically calculated as half of the compression load at failure. A shear strength value of 7.4 psi was determined for this test. This value is sufficient for slope stability, and the soil was noted as being cohesive during testing. Lab results from this test can be seen in Appendix D.

2.2.3 Permeability Testing

Permeability testing shows the tendency of soil to transmit water and air. This property is important in determining hydraulic conductivity of the soil layers on top of the repository cap.

Testing followed ASTM D2434. The soil was found to have a coefficient of permeability (hydraulic conductivity) of 0.003426 cm/s. This falls within the range of loamy sand. Sand has a moderate to rapid rate of flow. Lab results from this test can be seen in Appendix E.

2.3 Runoff Flows from Adjacent Hill

The repository cap sits immediately south and at a lower elevation of a hill that has the potential to contribute runoff during storms. A diversion channel was installed on this hill to divert water around the cap. The original design for the channel shows that it can adequately convey the flows from a 100-year storm, but the site visit revealed that the geometry and slope of the constructed channel differed from the original design. The original design versus the constructed design can be seen in Figures 2.3 and 2.4, respectively.

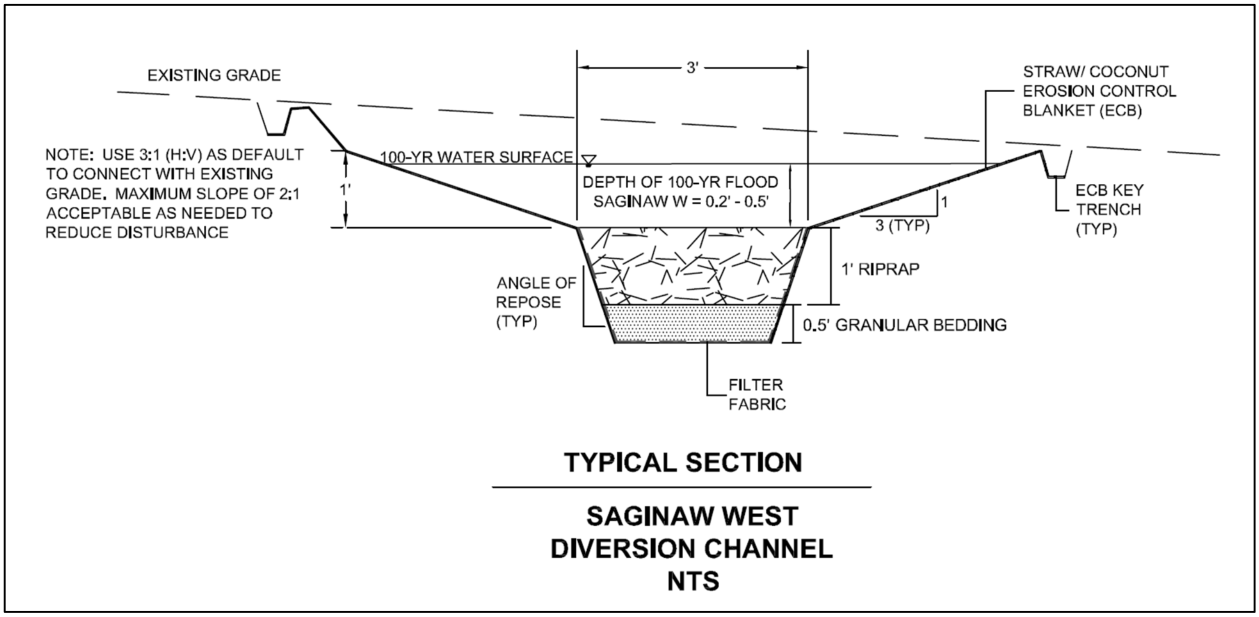

Figure 2.3 Design Geometry [2]

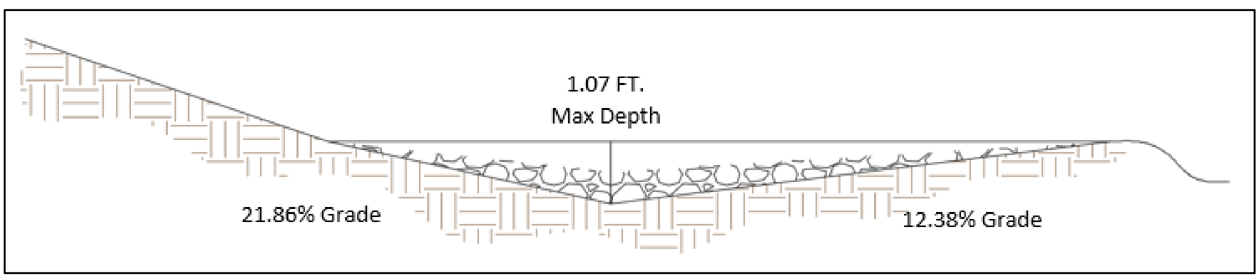

Figure 2.4 Observed Geometry

The slopes of the designed channel and the constructed channel also differed. In the original design, the highest elevation of the channel is on the northern side of the cap and slopes down towards the south. However, the constructed channel is the opposite of this, with the highest point towards the south and sloping downhill northwards. A comparison between the proposed drainage channel profile and the constructed (observed on site visit) drainage channel profile can be seen in Figures 2.5 and 2.6 below. The stationing of the channel can be seen in Appendix F.

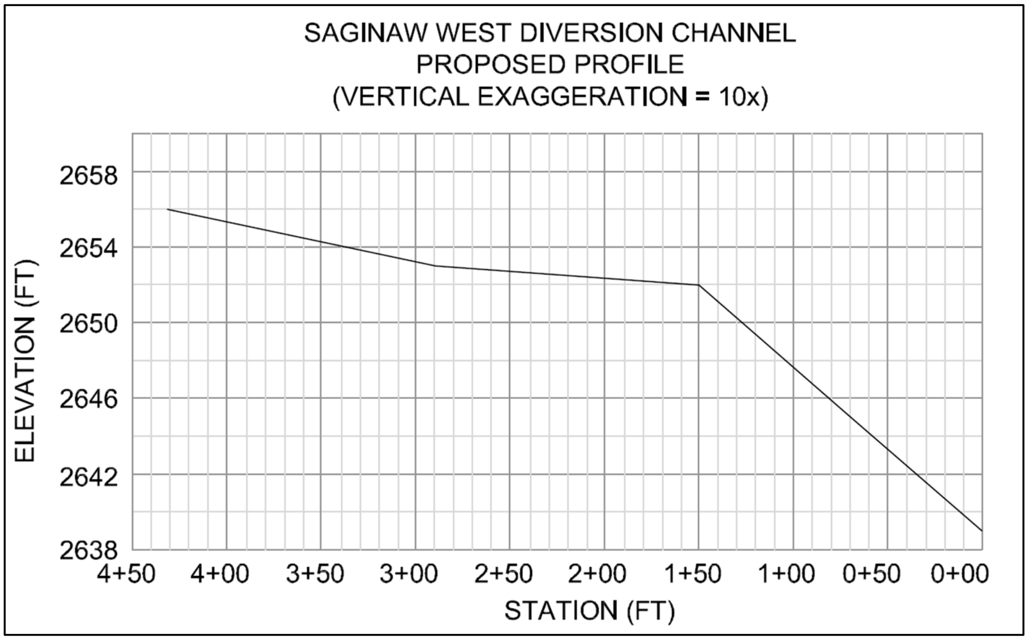

Figure 2.5 Design Profile

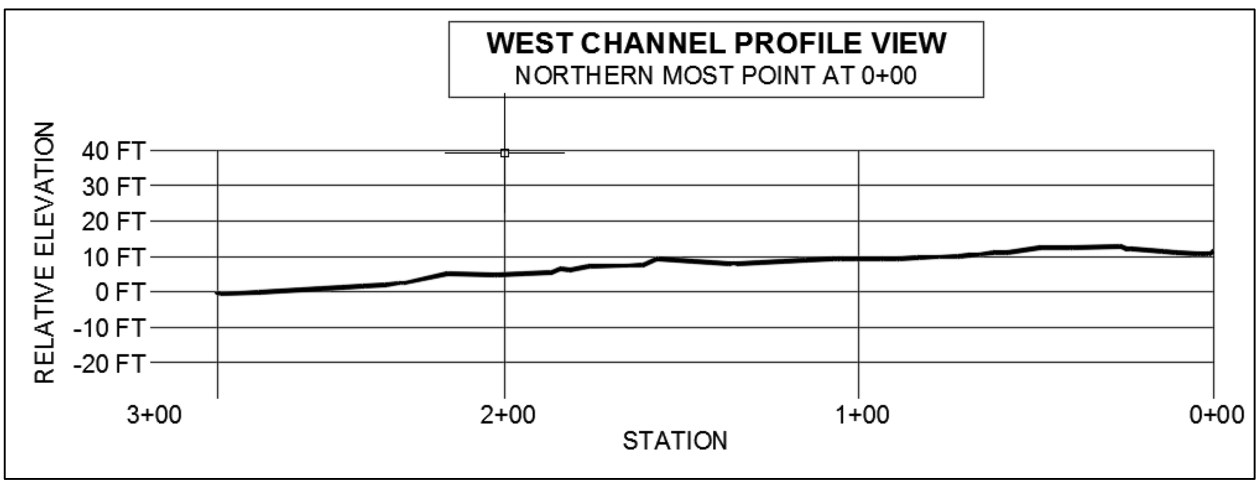

Figure 2.6 Observed Profile

Because of these discrepancies, the team performed a hydraulic analysis to ensure the constructed channel is able to adequately convey runoff from the hill. Using Bentley Flowmaster, it was determined that the design channel has a maximum discharge of 41.7 cfs and the constructed channel has a maximum discharge of 44.9 cfs. The constructed channel is therefore adequate for conveying runoff during a 100-year storm. The software output for this analysis can be seen in Appendix G.

2.4 Source of Erosion

Based on the analysis discussed above, the source of erosion is most likely due to the composition of the top layer of the cap. MARS Consultants analysis found that the top two feet of the cap is composed primarily of sand, with no topsoil or drainage layers as specified in the original design. See Figure 2.7. The sand performs adequately as an infiltration layer, but without a gravel layer there is nothing to convey the infiltrated water off of the cap. Additionally, sandy soil is a poor growth medium, so the absence of a topsoil layer is likely why the initial hydroseeding failed.

Our analysis shows that the geometry of the cap, runoff from the adjacent hill, and the shear strength of the soil do not significantly contribute to erosion of the cap.

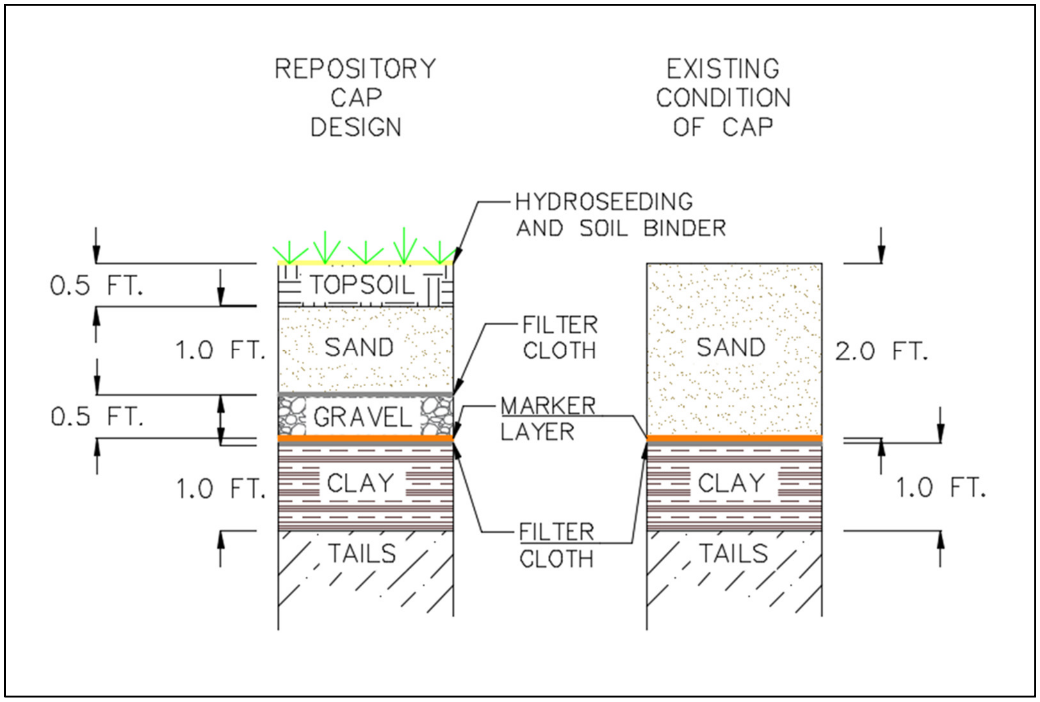

Figure 2.7: Repository cap design vs. existing condition of cap.

3.0 DESIGN ALTERNATIVES

3.1 Design Descriptions

Design alternatives were created to address the cause of erosion. Three alternatives were considered prior to the selection of the final design. Each are described and compared in this section.

3.1.1 Design Alternative 1

Design Alternative 1 would include excavating the existing sand from above the marker layer. A drainage layer system that would include, starting from the lowest layer, a 6 in. gravel drainage layer, a minimum of 6 in. transition layer composed of the sand that is currently above marker layer, and an 8 in. layer of topsoil (see Figure 3.1) would be implemented directly above the marker layer. The geometry of the cap will be altered to decrease the slope as far as possible by using the transition layer of recycled sand, with maximum sloping of 4.5:1, to decrease the velocity of the runoff. The length of the extension would vary based on the current caps geometry. Native grass hydroseeding would be spread across the entire cap to promote vegetation and reduce potential for erosion.

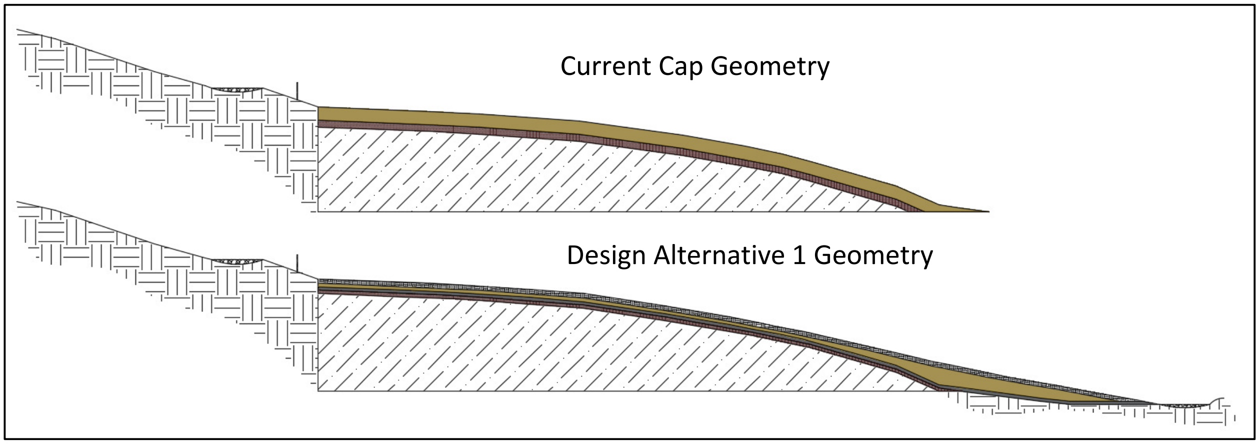

Figure 3.1: Cross section comparison of current cap and proposed geometry for Design Alternative 1.

3.1.2 Design Alternative 2

Design Alternative 2 involves excavating the existing sand from above the marker layer and using excess material to reshape the geometry of the cap. The new cap geometry would direct runoff into three rip-rap channels on the cap to assist with drainage during large storm events. A 6 in. gravel layer would also be installed under the sand layer to further facilitate drainage and a 12 in. topsoil layer would be placed on top of the sand layer to provide a suitable growth medium for hydroseeding.

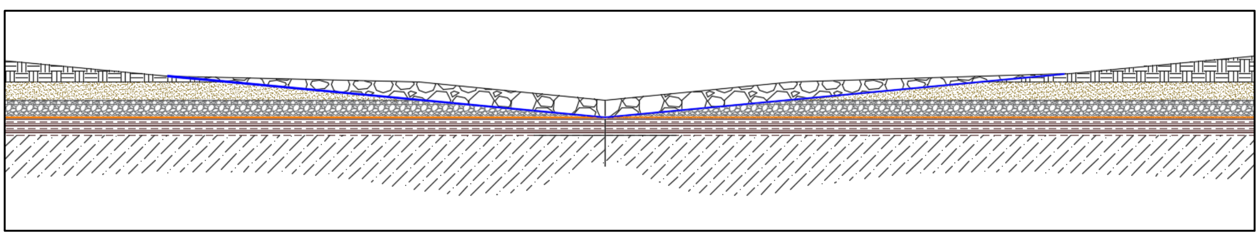

Figure 3.2: Design Alternative 2 Typical Channel Cross Section

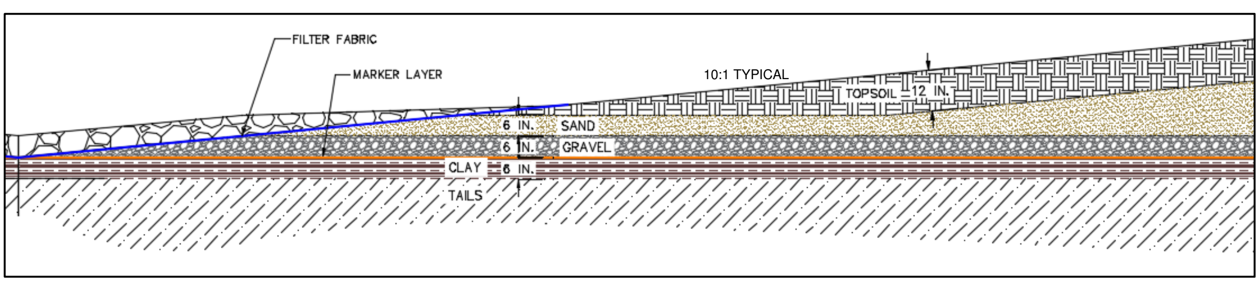

Figure 3.3 Design Alternative 2 Layer Details

3.1.3 Design Alternative 3

Design Alternative 3 involves leaving the cap as it is currently and adding additional layers on top of the existing sand. The sand would first be compacted and erosion rills filled in. The new layers would include, beginning with the layer directly above the existing sand, a 6 in. clay layer, a marker layer composed of orange construction fencing, a 1 ft. gravel layer with 4 in perforated pipe running down the slope of the cap to promote drainage at varying intervals, a 1.0 ft. sand infiltration layer, and a 6" topsoil layer. The new layer of clay would be vary in depth to create low points. The perforated pipe would be placed in these low points to direct drainage into the pipes. Native hydroseeding would be applied to the cap surface to promote vegetation and reduce erosion potential.

3.2 Layering Comparison

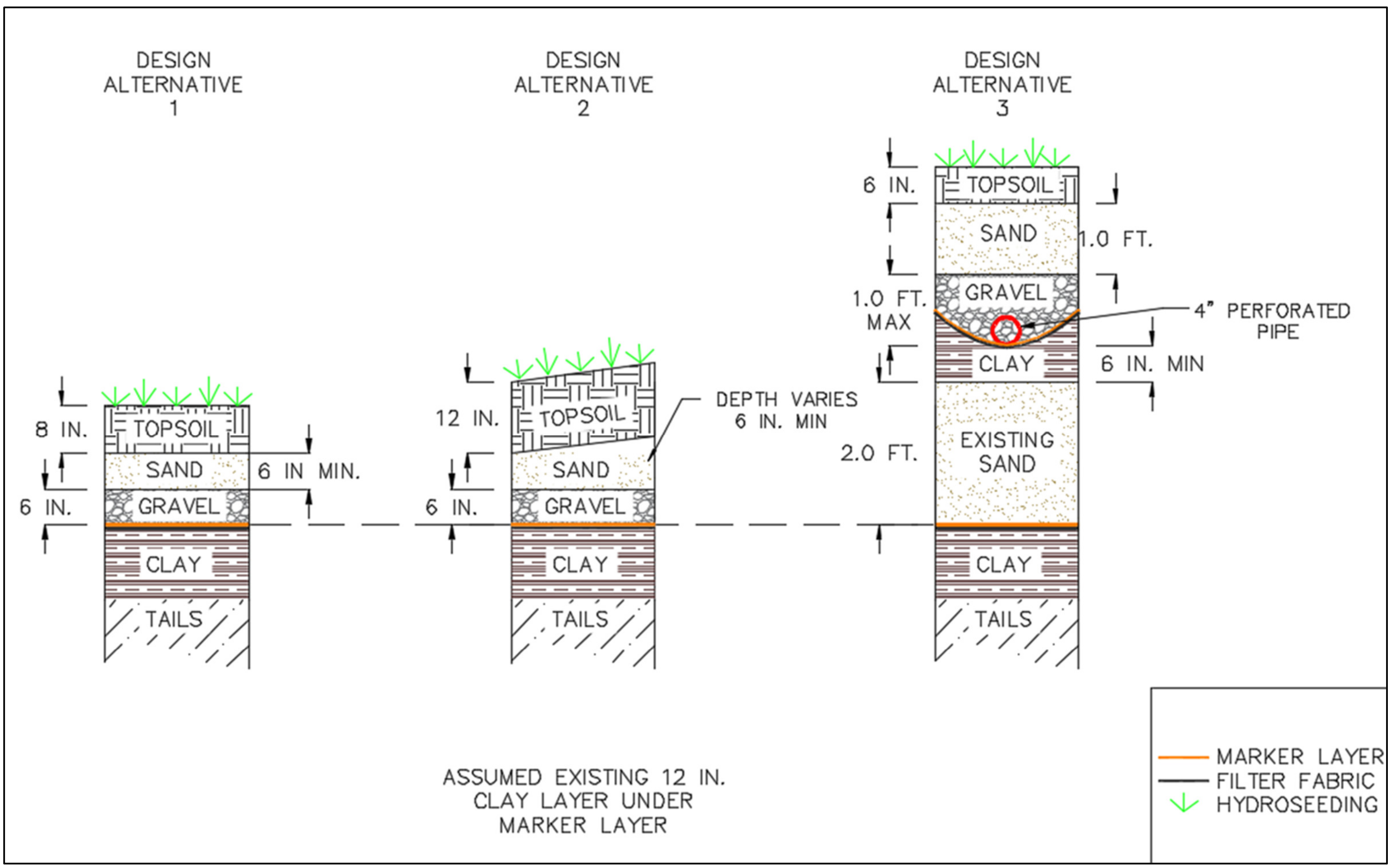

Figure 3.4: Cross section comparison design alternatives layering conventions

3.3 Cost Estimates

Costs were estimated for materials, labor, and maintenance. Materials costs were standardized between the design alternatives. A delivery rate of 10% of material cost was estimated for delivery to site. Material costs and labor costs were included in the initial costs. Maintenance costs were based on biennial maintenance and for the maximum maintenance required following inspection, although some designs would be maintenance at varying intervals. Design Alternatives 1 and 2 were very similar in cost, while Design Alternative 3 required higher material, labor, and maintenance costs. Refer to Table 3.1 for total costs associated for each design alternative.

Table 3.1: Design Alternatives Cost Estimate summary

Design Alternatives Cost Estimates			
Alternative	***Initial***	***Maintenance***	***Total***
Design Alternative 1	$ 127,500	$ 4,750	$ 132,250
Design Alternative 2	$ 126,950	$ 4,215	$ 131,165
Design Alternative 3	$ 144,975	$ 6,320	$ 151,295

4.0 IDENTIFICATION OF SELECTED DESIGN

Table 4.1: Decision matrix for Saginaw Hill Erosion Control project.

Criteria	Weight	Design Alternative 1		Design Alternative 2		Design Alternative 3	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Initial Cost	0.50	100%	0.50	100%	0.50	88%	0.44
Maintenance Costs	0.25	100%	0.25	100%	0.25	67%	0.17
Aesthetics	0.10	80%	0.08	100%	0.10	80%	0.08
Maintence Frequency	0.15	100%	0.15	100%	0.15	25%	0.04
Total	1		98%		100%		72%

MARS Consultants created a design matrix, shown in Table 4.1, based on what outcomes were most important to the client. Since BLM is funded through the federal government annually, designs with a high initial cost cannot be easily implemented. Because of this, the initial cost criteria received the highest weight. The score was based on giving the cheapest alternative a score of 100%, and then dividing the cost of each alternative by the lowest cost. The maintenance costs were ranked as the second highest criteria, also based on budget constraints. Scoring for maintenance was done in the same manner as the initial costs. Aesthetics was included because it was important to the BLM that the design blended in with the natural environment. It was scored based on the opinion of the MARS Consultants team as to how well it blended in with the environment. Maintenance frequency was included for convenience of the client. The longest maintenance period was awarded 100%. All other scores were based upon percentages of the longest maintenance period.

Design Alternative 3 had the highest costs and maintenance frequency, so was ruled out for use as the final design. Design Alternatives 1 and 2 were very similar in price and had the same maintenance frequency. The look of the cap of Design Alternative 1 was considered to be more natural, so received a slightly better score. After further analysis, it was discovered that the side slopes in Design Alternative 2 matched those of Design Alternative 1, so would perform the same in that regard but with the added benefit of the channels.

5.0 FINAL DESIGN

5.1 Design Specifications

Design Alternative 2 was chosen for the final design. This design includes fully recycling the existing sand layer to create the geometry necessary to include drainage channels. Three drainage channels would be used to convey water more quickly off the cap. The channels would be located in areas with the highest existing erosion issues. These channels would be 20 feet wide with varying lengths. The hydraulic analysis for these channels can be viewed in Appendix H. The drainage channels should extend a minimum of 5 feet beyond the capped area. The water from these channels will flow into the East Channel.

MARS consults recommends that it is definitively determined that there is a 1 foot clay layer beneath the marker layer. After this verification, special care should be taken to ensure that the tested areas are patched to ensure no waste escapes from the cap. This extends to all further use of equipment on the cap.

The cap geometry should follow topography in Appendix I. Sloping should not exceed 4.5:1 (H:V) in areas of the cap covered with topsoil. Sloping in the channels should not exceed 4:1. Sloping into the channels from the topsoil areas should be at a 10:1 typical. The riprap in the channels should extent out over the topsoil to protect the drainage layers near the channel. The channel shall be lined with filter fabric to prevent the riprap from settling into the drainage layers. Using the City of Tucson Drainage Manual, it was found that the maximum runoff discharge that can be expected during a 100-year storm is 10.4 cubic feet per second. The hydrology calculations can be seen in Appendix H. The rip-rap channels are oversized for this flow for the sake of armoring the sand and topsoil layers near the channel.

Each drainage layer that is installed should be sufficiently compacted. This should further prevent the soil layers from eroding and settling into one another. During the installation of the gravel layer above the clay layer, the marker layer should be kept intact and replaced where necessary with similar orange construction fencing.

Hydroseeding with a native seeding mixture should be applied to the cap after the topsoil is tilled. This would provide a better growth media than compacted soils. Vegetation helps reduce runoff velocity and helps better bind soil together to reduce erosion.

5.2 Material Specifications

Materials for the cap are specified below in Table 5.1. Gradation values for the topsoil and gravel layers were chosen to promote bridging with the recycled sand. Bridging occurs when a finer soil is placed above a courser soil and has the ability to resist settling within the voids of the courser soil. To accomplish this, the 85% finer particle size diameter of the finer material must match the smallest 15% finer particle size diameter of the courser material. These values were interpolated from the gradation curve of the sand.

Table 5.1: Material specifications

Material	Specifications
Topsoil	Diameter of 85% finer particle size should equal = 0.16 mm (.006 in.) and shall meet requirments set by ADOT in standard specifications for Topsoil in Section 804
Fill Sand	Recycled from existing cap material above marker layer
Gravel	Diameter of 85% finer particle size should equal = 3.2 mm (1/8 in.)
Riprap	Riprap shall meet specification set by ADOT in standard specification for Riprap Gradation A in Section 810-2.03

Filter fabric should meet all requirements from ADOT's Standard Specifications Subsection 1014-4. A local vegetation expert should be consulted for the best seeding mixtures available for the area and conditions. If necessary, biodegradable netting or other technologies may be used to promote vegetation. The vegetation consultant should also make recommendations for the best season to seed the area.

Maintenance should be performed on a biennial basis. An inspection should be completed to determine what maintenance is necessary. It is predicted that occasionally, a maintenance crew would be necessary to clean channels from debris or patch minor erosion rills. It may be necessary to revegetate the cap occasionally due to the harsh climate. Consulting a local vegetation expert would provide more insight into maintenance required.

5.3 Impacts

The largest impact of this project is the prevention of wastes containing heavy metals from escaping the cap. The area is populated on all surrounding sides and could migrate very easily into human or fauna contact. The BLM has expressed interest in making this site available for public access. With the possible of contaminant escaping the cap, this would be a safety hazard to those who visit.

The economic impacts affect the general public since the BLM is funded through tax dollars. The BLM has a legal obligation to rehabilitate abandoned mine sites under the Federal Land Policy and Management Act of 1976 and could face legal and economic repercussions if they fail to meet this obligation. Since the BLM operates under a budget, the resources they allocate to this project cannot be used in other projects.

6.0 COST OF IMPLEMENTATION

The cost estimate for this project can be broken down into 2 sections; construction and maintenance costs. The construction costs can be further split into material costs and labor costs. Material costs were estimated by looking up bulk soil costs in the area of the project location. MARS Consultants included a delivery charge for importing the soils needed. This design saved money by recycling the existing sand above the marker layer. The use of bridging the layers reduces costs since filter cloth would not be needed to keep the layers separate.

The costs of labor were dependent on the type of work that would be performed, considering the different types of equipment that would be used to perform these tasks. MARS Consultants labeled these tasks chronologically in the order construction would be performed, as can be seen below in Table 6.1. Transporting and compacting the sand will be the longest task. The existing sand must first be removed from the cap area to make room for the clay and gravel layer installation. The construction of the geometry of the cap might cause difficulties due to the change in elevation on the cap.

The maintenance labor costs are based on the cost of an inspector plus the wages of a maintenance crew, should there be a need for them. The maintenance crew, seed mixture, and the labor costs to spread the mixture might not be needed based on the report from the inspector. This cap will need to be inspected once every two years.

The total construction costs for the project will be $126,950 after completion, with maintenance costs that will be no greater than $4,215 every two years. The maintenance cost could be as low as $720 if the inspector finds that the cap is in good condition. The largest maintenance costs would be accrued when the cap needed to be revegetated.

Table 6.1: Final design cost estimate

Final Design Cost Estimate							
Item		Amount	Unit	Amount	Unit	Price/Unit	Total Price
Materials							
	Topsoil	2700	CY	3105.0	TON	$15	$ 46,575
	Fill Sand	Onsite	CY	0.0	TON	$10	$ -
	Gravel	1500	CY	1725.0	TON	$18	$ 31,050
	Riprap	305	CY	350.8	TON	$27	$ 9,470
	Delivery	10%	Rate				$ 8,710
	Geotextile Filter Fabric	3	EA			$600	$ 1,800
	Seed Mixture	77000	SF	30.8	LBS	$42	$ 1,294
Labor							
	Clearing	4	Hours			$150	$ 600
	Remove Sand	15	Hours			$150	$ 2,250
	Spread and Compact Gravel	15	Hours			$150	$ 2,250
	Install geotextile and riprap	10	Hours			$150	$ 1,500
	Transport and Compact Sand	90	Hours			$150	$ 13,500
	Spread and Compact Topsoil	40	Hours			$150	$ 6,000
	Spread Seed Mixture	3	Hours			$200	$ 600
	Mobile/Demobile	5%	Rate				$ 1,335
TOTAL INITIAL							$ 126,950
Maintenance (Biennial)							
	Inspector	16	Hours			$45	$ 720
	Maintenance crew	48	Hours			$25	$ 1,200
	Seed Mixture	77000	SF	30.8	LBS	$42	$ 1,294
	Spread Seed Mixture	5	Hours			$200	$ 1,000
TOTAL MAINTENANCE							$4,215.00

7.0 SUMMARY OF PROJECT COSTS

MARS Consultants created an estimated schedule to complete the project. The estimated schedule can be seen in Appendix J. The actual schedule can be seen in Appendix K. During the completion of this project two tasks were removed from the design process. The shear strength test was removed due to the team calculating the shear strength of the soil from the results obtained in the compressive strength test. The HEC-RAS and HEC-HMS analysis were removed from the process after finding that the existing diversion channels surrounding the cap can withstand a 100 year storm event. The design team decided to include a permeability test on the soil to help identify the source of the erosion problem. The team estimated they would complete the design alternatives in five days. However, MARS Consultants decided to create in-depth design that included a full cost estimate for each design. All other tasks during the project were completed on time.

MARS Consultants also included an estimated costs of engineering services provided for the duration of the project. These wages can be broken down into five different labor classifications; senior engineer, staff engineer, lab technician, intern and an administrative assistant. The wages used for these workers include overhead in the cost estimation. Table 7.1 below, shows the estimated and actual hours performed by the team. In the table, section 2.0 shows the actual costs incurred from the site visit performed on December 2 and 3. The second part of this table shows the actual hours worked on this project. The largest differences between the estimated cost and the actual, come down to the staff engineering and administrative assistant work. The staff engineer performed over 300 hours less work than initially anticipated. This is due to the work performed by MARS getting completed quicker than expected. The administrative assistant work included more time than the team estimated, this was due largely to the fact the team didn't consider meeting minutes and other time spent on editing deliverables.

Table 7.1 Hours Worked Comparison

1.0 Personnel						
	Classification	Rate ($/hr)	Estimated Hours	Estimated Cost	Actual Hours	Actual Cost
	SENG	$ 160.00	61	$ 9,760	54	$ 8,640
	ENG	$ 75.00	500	$ 37,500	164	$ 12,300
	LAB	$ 45.00	68	$ 3,060	27.5	$ 1,238
	INT	$ 35.00	117	$ 4,095	45	$ 1,575
	AA	$ 62.00	47	$ 2,914	141	$ 8,742
2.0 Travel						
	Item	Rate	Estimated Amount	Cost	Actual Amount	Actual Cost
	Hotel	$ 76.00	3 Rooms	$ 228	3 Rooms	$ 228
	Gas	$ 0.45	552 Miles	$ 221	552 Miles	$ 221
	Per Diem	$ 15.00	22 Meals	$ 330	22 Meals	$ 330
	Vehicle	$ 75.00	2 days	$ 150.00	2 days	$ 150
3.0 Cost of Engineering Services						
			$ 58,108		$ 33,423	

8.0 WORKS CITED

[1] Terracon Consultants, Inc, "Second Quarter 2015 Quarterly Groundwater Monitoring and Remedy Inspection," Tuscon, 2015.

[2] Red J. Environmental Corperation, "Saginaw Hill Remedial Action Project Phase II," Gilbert, 2009.

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[4] J. Duhamel, "Saginaw Hill, Another Old Mine Site In A Tucson Area Neighborhood," 12 March 2014. [Online]. Available: https://arizonadailyindependent.com/2014/03/12/saginaw-hill-another-old-mine-site-in-a-tucson-area-neighborhood/. [Accessed 6 October 2015].

[5] Terracon Consultants, Inc., “Image,” Tuscon, 2015.

APPENDIX A

EXISTING TOPOGRAPHY

DATE: 03/10/16
DRAWN BY: ABR
SCALE: 1"=60'

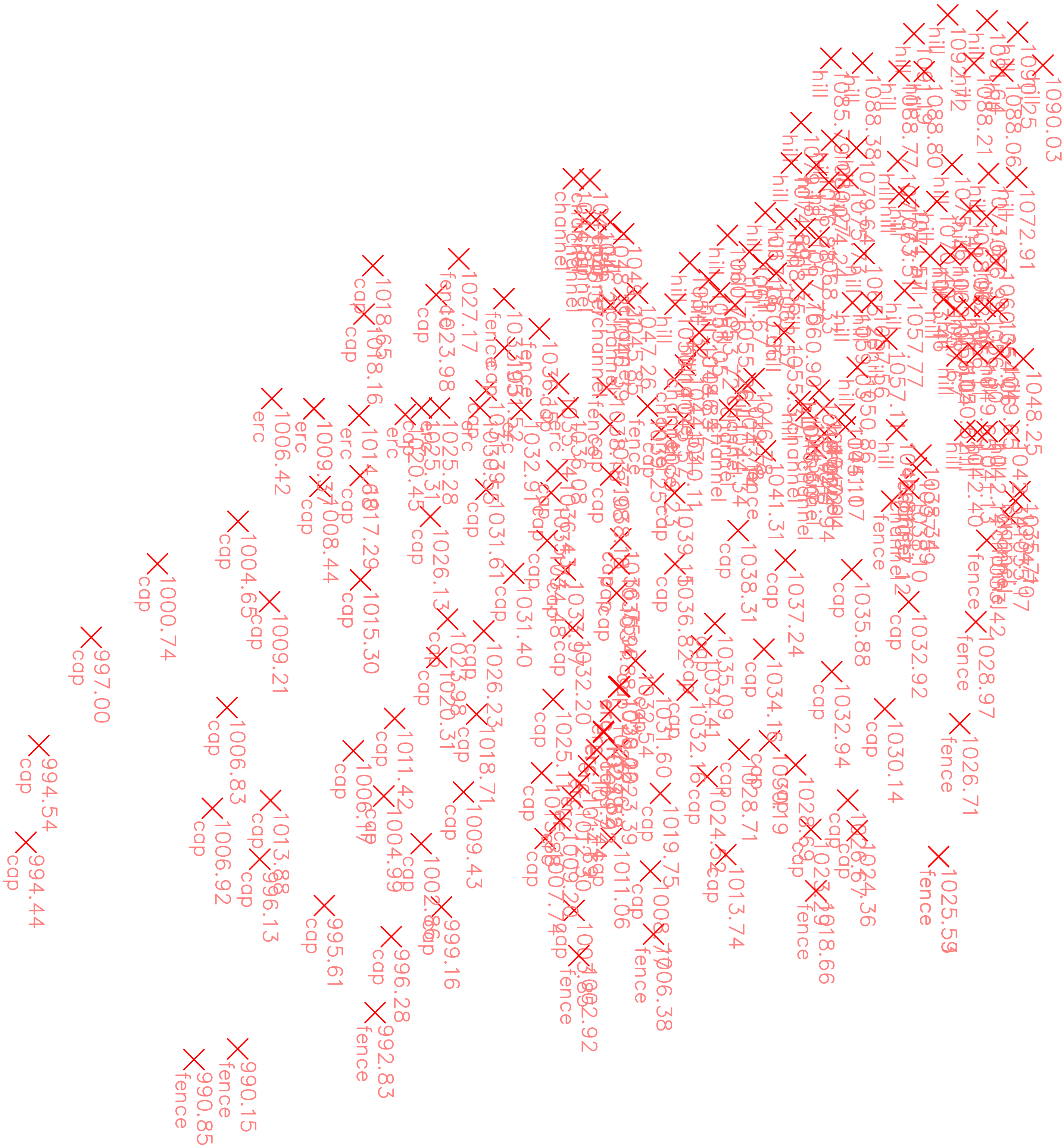
SAGINAW HILL
EROSION CONTROL

CENE 486
CAPSTONE

MARS CONSULTANTS
CIVIL ENGINEERING

ALEX MEISNER
BROOKE RHODES
TYLER SHAMBURG

NORTHERN
ARIZONA
UNIVERSITY



SAGINAW HILL
EROSION CONTROL

CENE 486
CAPSTONE

DATE: 03/10/16
DRAWN BY: ABR
SCALE: 1"=70'

0 35 70 Feet

RAW SURVEY POINTS

APPENDIX B

MARS CONSULTANTS
CIVIL ENGINEERING

ALEX MEISNER
BROOKE RHODES
TYLER SHAMBURG

NORTHERN ARIZONA UNIVERSITY

APPENDIX C: GRADATION ANALYSIS

Table C.1 Sieve Analysis Results

Total Weight (g)		868.64		
Sieve #	Opening (mm)	Weight Retained (g)	% Total	% Finer
4	4.76	51.43	6.00%	94.00%
10	2	170.05	19.83%	74.17%
20	0.84	209.59	24.44%	49.73%
30	0.59	67.27	7.84%	41.89%
40	0.42	72.75	8.48%	33.41%
60	0.25	96.22	11.22%	22.19%
100	0.149	73.2	8.54%	13.65%
140	0.105	37.86	4.41%	9.24%
200	0.074	29.82	3.48%	5.76%
Pan		49.38	5.76%	0.00%
Total		857.57		
% Retained		98.73%		

Table C.2: Hydrometer Results

Time	Elapsed Time	Temp	Hydro Reading	Corrected Reading	Effective Depth	SG Constant	Particle Diameter	Temp Correction	R-C_d+m	Percent Finer	
	MIN	*C°*			*CM*		*MM*			*Partial*	*Total*
	T		*R'*	*R*	*L*	*K*	*D*	*m*			
9:50	0	23.5	40	40.5	9.7		N/A	0.7	35.7	~~72.84%~~	~~4.11%~~
9:51	1	23	36	36.5	10.3	0.0132	0.042364	0.6	31.6	64.48%	3.64%
9:52	2	23	33.5	34	10.7	0.0132	0.030532	0.6	29.1	59.38%	3.35%
9:54	4	23	31	31.5	11.15	0.0132	0.022038	0.6	26.6	54.27%	3.06%
10:05	15	23	27	27.5	11.8	0.0132	0.011708	0.6	22.6	46.11%	2.60%
10:20	30	23	25	25.5	12.1	0.0132	0.008383	0.6	20.6	42.03%	2.37%
10:50	60	23	24	24.5	12.3	0.0132	0.005977	0.6	19.6	39.99%	2.26%
11:50	120	22.5	23	23.5	12.45	0.01325	0.004268	0.5	18.5	37.75%	2.13%
1:50	240	22	21.5	22	12.7	0.0133	0.003059	0.4	16.9	34.48%	1.95%
9:50	1440	22.5	17	17.5	13.4	0.01325	0.001278	0.5	12.5	25.50%	1.44%

Project Data							
Date:	2/5/2016	-	2/6/2016				
Sample Description:	Sample taken at CP3 (refer to survey data) in an existing rill.						
Dispersing Agent Used:	Sodium Hexametaphosphate						
Soil Quantity:	49.01	*g*	*> 200 sieve*	868.64	*g*	*Total Sample*	
Technician:	Brooke Rhodes						
Gs:	2.65	**Cm:**	0.5	**Cd:**	5.5		

APPENDIX D: SHEAR STRENGTH ANALYSIS

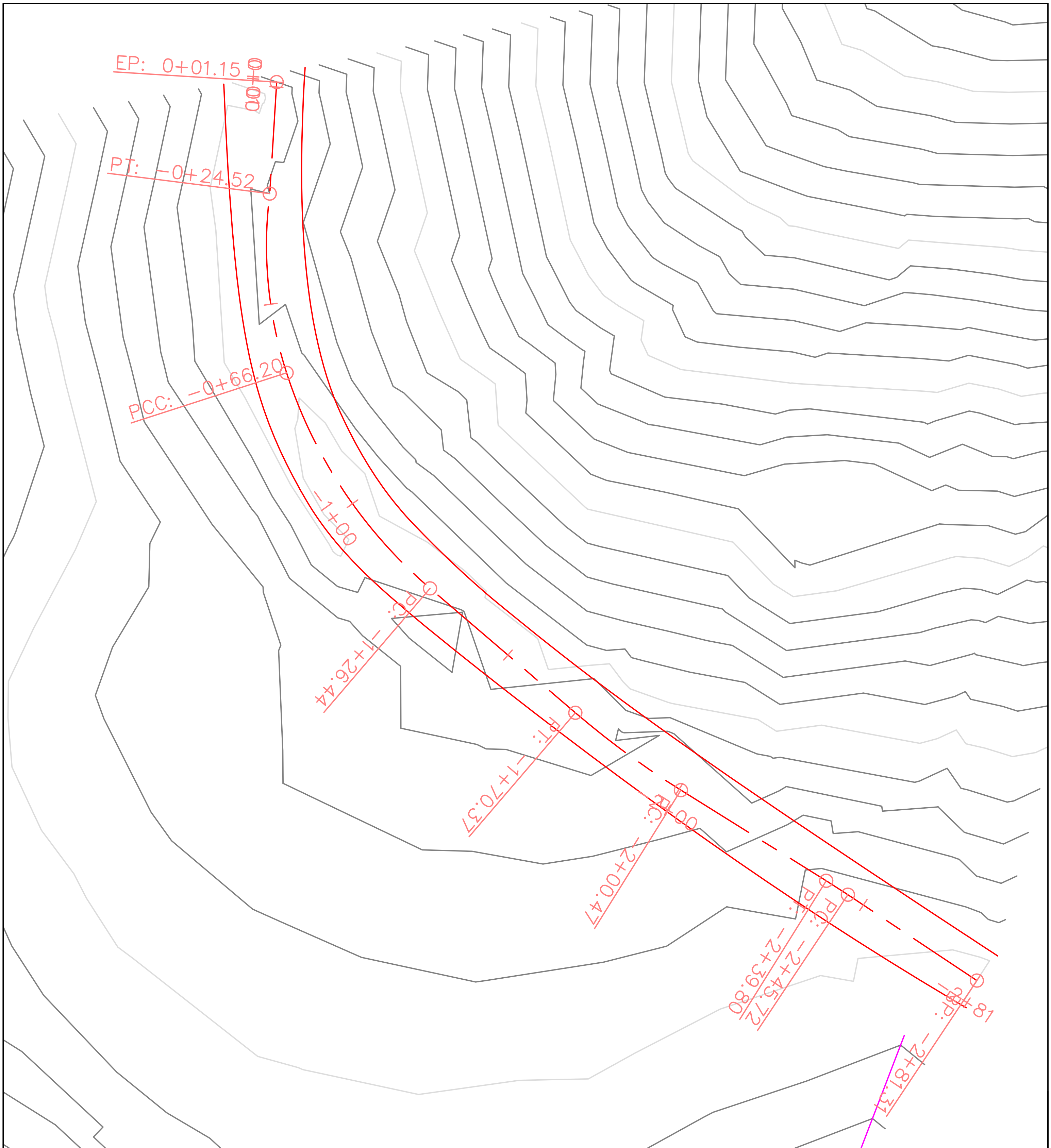
Table D.1: Unconfined Compression Results

Strain Gage	Total Strain		Proving Ring Reading		Normal Load (lb)		Initial Area		Corrected Area		Compressive Strength (psi)		Undrained Shear Strength (psi)	
	Trial 2	Trial 3	Trial 2	Trial 3	Trial 2	Trial 3	Trial 2	Trial 3	Trial 2	Trial 3	Trial 2	Trial 3	Trial 2	Trial 3
0.00	0.000	0.000	0	0	0	0	1.301	1.281	1.301	1.281	0.00	0.00	0.00	0.00
0.01	0.004	0.004	0.006	0.005	3.311	3.000	1.301	1.281	1.306	1.286	2.54	2.33	1.27	1.17
0.02	0.007	0.008	0.012	0.01	5.179	4.557	1.301	1.281	1.310	1.291	3.95	3.53	1.98	1.76
0.03	0.011	0.012	0.016	0.018	6.424	7.047	1.301	1.281	1.315	1.296	4.89	5.44	2.44	2.72
0.04	0.014	0.015	0.019	0.024	7.358	8.914	1.301	1.281	1.320	1.301	5.58	6.85	2.79	3.43
0.05	0.018	0.019	0.021	0.027	7.980	9.848	1.301	1.281	1.324	1.306	6.03	7.54	3.01	3.77
0.06	0.021	0.023	0.024	0.032	8.914	11.404	1.301	1.281	1.329	1.311	6.71	8.70	3.35	4.35
0.07	0.025	0.027	0.025	0.036	9.225	12.649	1.301	1.281	1.334	1.316	6.92	9.61	3.46	4.80
0.08	0.028	0.031	0.029	0.039	10.471	13.583	1.301	1.281	1.339	1.322	7.82	10.28	3.91	5.14
0.09	0.032	0.035	0.031	0.041	11.093	14.206	1.301	1.281	1.344	1.327	8.26	10.71	4.13	5.35
0.10	0.035	0.038	0.032	0.043	11.404	14.828	1.301	1.281	1.349	1.332	8.46	11.13	4.23	5.57
0.11	0.039	0.042	0.035	0.046	12.338	15.762	1.301	1.281	1.354	1.337	9.11	11.79	4.56	5.89
0.12	0.042	0.046	0.038	0.049	13.272	16.696	1.301	1.281	1.359	1.343	9.77	12.43	4.88	6.22
0.13	0.046	0.050	0.04	0.051	13.894	17.318	1.301	1.281	1.364	1.348	10.19	12.85	5.09	6.42
0.14	0.050	0.054	0.04	0.054	13.894	18.252	1.301	1.281	1.369	1.354	10.15	13.48	5.08	6.74
0.15	0.053	0.058	0.043	0.056	14.828	18.875	1.301	1.281	1.374	1.359	10.79	13.89	5.40	6.94
0.16	0.057	0.061	0.045	0.058	15.451	19.497	1.301	1.281	1.379	1.365	11.20	14.29	5.60	7.14
0.17	0.060	0.065	0.047	0.059	16.073	19.808	1.301	1.281	1.384	1.370	11.61	14.46	5.81	7.23
0.18	0.064	0.069	0.05	0.061	17.007	20.431	1.301	1.281	1.390	1.376	12.24	14.85	6.12	7.42
0.19	0.067	0.073	0.052	0.062	17.630	20.742	1.301	1.281	1.395	1.382	12.64	15.01	6.32	7.51
0.20	0.071	0.077	0.054	0.059	18.252	19.808	1.301	1.281	1.400	1.387	13.04	14.28	6.52	7.14
0.21	0.074	0.081	0.054	0.063	18.252	21.054	1.301	1.281	1.405	1.393	12.99	15.11	6.49	7.56
0.22	0.078	0.084	0.055	0.064	18.563	21.365	1.301	1.281	1.411	1.399	13.16	15.27	6.58	7.64
0.23	0.081	0.088	0.055	0.063	18.563	21.054	1.301	1.281	1.416	1.405	13.11	14.99	6.55	7.49
0.24	0.085	0.092	0.056	0.064	18.875	21.365	1.301	1.281	1.422	1.411	13.28	15.14	6.64	7.57
0.25	0.088	0.096	0.058	0.066	19.497	21.987	1.301	1.281	1.427	1.417	13.66	15.52	6.83	7.76
0.26	0.092	0.100	0.06	0.065	20.120	21.676	1.301	1.281	1.433	1.423	14.04	15.23	7.02	7.62
0.27	0.096	0.104	0.06	0.065	20.120	21.676	1.301	1.281	1.438	1.429	13.99	15.17	6.99	7.58
0.28	0.099	0.107	0.06	0.065	20.120	21.676	1.301	1.281	1.444	1.435	13.93	15.10	6.97	7.55
0.29	0.103	0.111	0.061	0.064	20.431	21.365	1.301	1.281	1.450	1.441	14.09	14.82	7.05	7.41
0.30	0.106	0.115	0.06	0.062	20.120	20.742	1.301	1.281	1.456	1.447	13.82	14.33	6.91	7.17
0.31	0.110	0.119	0.06	0.061	20.120	20.431	1.301	1.281	1.461	1.454	13.77	14.05	6.88	7.03
0.32	0.113	0.123	0.06	0.06	20.120	20.120	1.301	1.281	1.467	1.460	13.71	13.78	6.86	6.89
0.33	0.117	0.127	0.06	0.059	20.120	19.808	1.301	1.281	1.473	1.467	13.66	13.51	6.83	6.75
0.34	0.120		0.059		19.808		1.301		1.479		13.39		6.70	
0.35	0.124		0.058		19.497		1.301		1.485		13.13		6.57	
0.36	0.127		0.057		19.186		1.301		1.491		12.87		6.43	
0.37	0.131		0.057		19.186		1.301		1.497		12.82		6.41	
0.38	0.134		0.056		18.875		1.301		1.503		12.56		6.28	

APPENDIX E: PERMEABILITY

Table E.1: Permeability Results

Diameter of specimen	2.5065	in	6.36651	
Length of Specimen	5	in	12.7	
Area of Specimen	4.931796	in^2	31.81797	
Volume of specimen	24.67	in^3	404.2698	
Specific gravity	2.65			
Q	25	cm^3		
Trial		1	2	3
Time	(sec)	28.74	28.56	30.61
Discharge	q(cm^3)	0.870	0.875	0.817
Height of Water	h(cm)	99.5	99.5	99.5
Temperature	(C)	21	20	20
Coefficient of Permeability	k	0.003489	0.003511	0.003276
	k	**0.003426**	**cm/s**	



APPENDIX F

WEST CHANNEL STATIONING

DATE: 03/10/16
DRAWN BY: ABR
SCALE: 1"=30'

SAGINAW HILL
EROSION CONTROL

CENE 486
CAPSTONE

MARS CONSULTANTS
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APPENDIX G: HYDRAULIC ANALYSIS OF WEST CHANNEL

Table G.1: Design Channel Analysis

Design Channel

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.01400	ft/ft
Normal Depth	2.00	ft
Section Definitions		

Station (ft)	Elevation (ft)
0+00	5.00
0+03	4.00
0+04	3.00
0+06	3.00
0+06	4.00
0+09	5.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 5.00)	(0+03, 4.00)	0.028
(0+03, 4.00)	(0+06, 4.00)	0.035
(0+06, 4.00)	(0+09, 5.00)	0.028

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	41.72	ft³/s
Elevation Range	3.00 to 5.00 ft	
Flow Area	8.50	ft²
Wetted Perimeter	10.56	ft
Hydraulic Radius	0.80	ft

Table G.2: Constructed Channel Analysis

Constructed Channel

Project Description		
Friction Method	Manning Formula	
Solve For	Discharge	
Input Data		
Roughness Coefficient	0.035	
Channel Slope	0.05000	ft/ft
Normal Depth	1.07	ft
Left Side Slope	4.57	ft/ft (H:V)
Right Side Slope	8.07	ft/ft (H:V)
Results		
Discharge	44.87	ft^3/s
Flow Area	7.24	ft^2
Wetted Perimeter	13.71	ft
Hydraulic Radius	0.53	ft
Top Width	13.52	ft
Critical Depth	1.26	ft
Critical Slope	0.02122	ft/ft
Velocity	6.20	ft/s
Velocity Head	0.60	ft
Specific Energy	1.67	ft
Froude Number	1.49	
Flow Type	Supercritical	
GVF Input Data		
Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	
GVF Output Data		
Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.07	ft
Critical Depth	1.26	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.02122	ft/ft

City of Tucson

Hydrologic Data Sheet for Computing 100-Year Peak Discharge (Q_{p100})

1. Project Name and Location: ______
2. Drainage Concentration Point: Start of wash
3. *Watershed Area (A) at Drainage Concentration Point: 2.4 acres.
4. Length of Hydraulically Longest Watercourse (L_c): 404 ft ft.
5. Length from center of Watershed Area (L_{ca}), along L_c: 202 ft.

For (Check One):
- ☐ Existing Conditions[†]
- ☐ Future Conditions[†]

6. Change in Length Factors - ft. / Change in Elevation Factors - ft.

a. ΔL_1: 238	$(\Delta L_1)^3$: 13481272	ΔH_1: 40	$(\Delta L_1)^3/\Delta H_1$: 337032
b. ΔL_2: 166	$(\Delta L_2)^3$: 4574296	ΔH_2: 3	$(\Delta L_2)^3/\Delta H_2$: 1524765
c. ΔL_3:	$(\Delta L_3)^3$:	ΔH_3:	$(\Delta L_3)^3/\Delta H_3$:
d. ΔL_4:	$(\Delta L_4)^3$:	ΔH_4:	$(\Delta L_4)^3/\Delta H_4$:

7. $$G = \left(\frac{\Delta L_1^3}{\Delta H_1}\right)^{1/2} + \left(\frac{\Delta L_2^3}{\Delta H_2}\right)^{1/2} + \left(\frac{\Delta L_3^3}{\Delta H_3}\right)^{1/2} + \left(\frac{\Delta L_4^3}{\Delta H_4}\right)^{1/2} = 580.5 + 1234.8 + \_\_\_ + \_\_\_ = 1815$$

8. Mean Slope (S_c) = $(L_c/G)^2$ = (0.223)^2 = 0.0495 ft./ft.
9. Areally reduced 100-year, one-hour rainfall depth ($P_{1,100}$): 3 inches.

	Subarea 1	Subarea 2	Subarea 3	Weighted Watershed Parameters
10. Watershed Type(s) (% of Total Area):	( )	( )	( )	
11. Basin Factor (n_{b100}):	0.055			n_{bw100} =
12. Soil Types, in %:				
13. Imperviousness (%):				I_w =
14. Runoff Coefficient (C_{w100}):	0.45			C_{w100} =
15. Contrib. Area Factor (F_{Ac}):	1.0			F_{Acw} =

16. **Time of Concentration (T_{c100}): 5 minutes, determined from:

$$T_{c100} = \left(\frac{0.23 n_{bw100}(L_c L_{ca})^{0.3}}{(S_c P_{1,100} C_{w100})^{0.4}} + 1.31\right)^{1.61}$$ When $5 \le T_{c100} \le 180$.

$T_{c100} = \left(\frac{0.23(0.055)(404 \times 202)^{0.3}}{(0.0495 \times 3 \times 0.45)^{0.4}} + 1.31\right)^{1.61} = 4.15$ min $= 5$ min

17. At T_{c100}, 100-Year Rainfall Intensity (i_{100}) = $(4P_{1,100})/(1+0.05T_{c100})$ = 9.6 inches/hour. $i_{100} = (4 \times 3)/(1+0.05(5)) = 9.6$
18. 100-Year Peak (Q_{p100}) = $(C_{w100})(i_{100})(F_{Acw})A$ = 0.45 x 9.6 x 1.0 x 2.4 = 10.4 cfs.
19. For Other Return Periods:

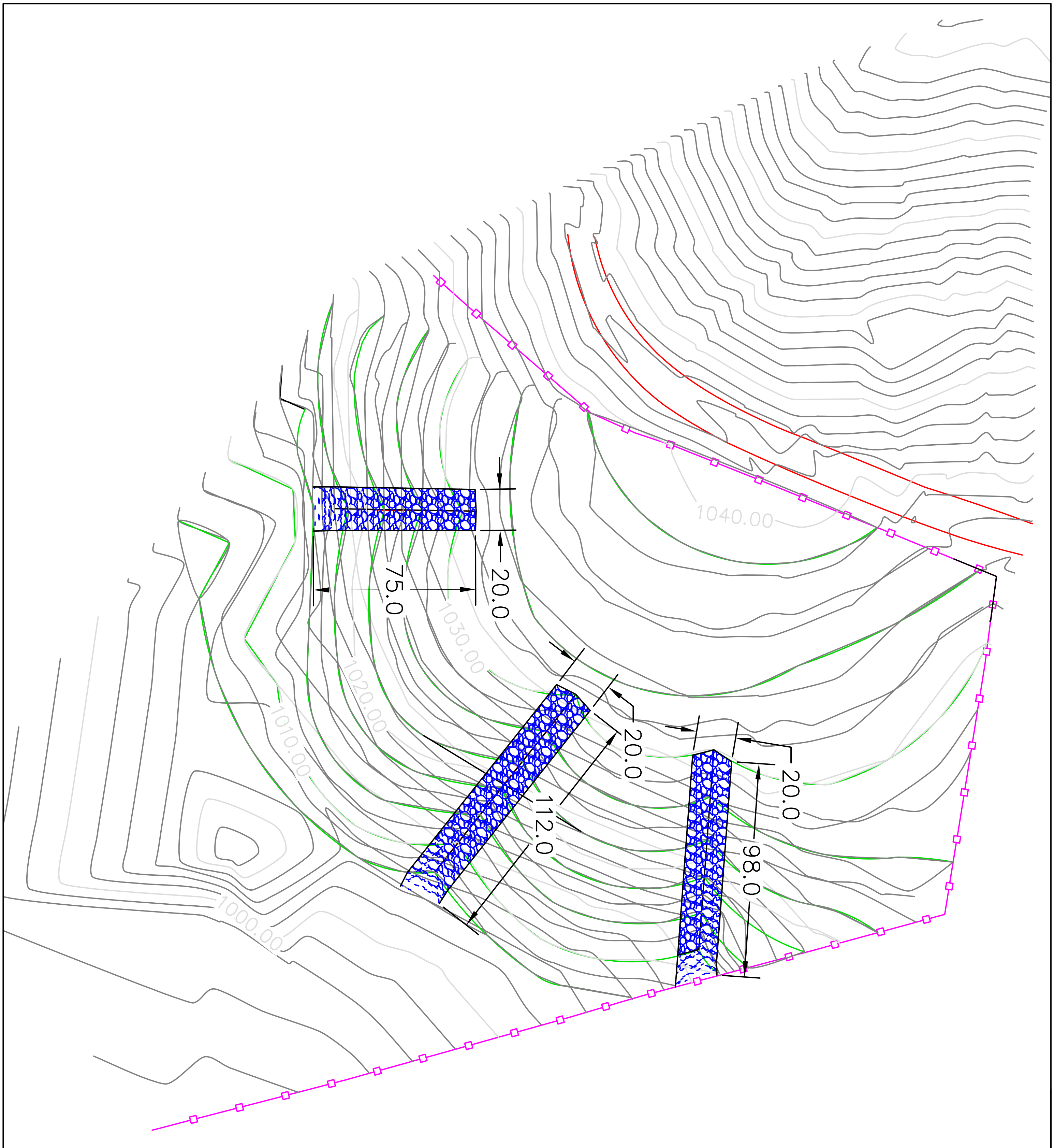
	2-Year	10-Year	25-Year	50-Year
Ratio to 100-Year Peak:	0.1	0.37	0.58	0.77
Q (cubic feet/second):	1.04	3.85	6.03	7.98
T_c (minutes [Eqn. 4.5]):				

*A may not exceed 6,400 acres (10 square miles) in size. **T_{c100} may not exceed 180 minutes. If $T_{c100} < 5$, set T_{c100} = 5 minutes.

[†]NOTE: Indicate whether hydrologic computations are for "Future Conditions" or "Existing Conditions" by checking the appropriate box above.

Prepared by: Alex Meisner Checked by: Brooke Rhodes Company: ______ Date: 4/5/2016

FIGURE 4.1: HYDROLOGIC DATA SHEET



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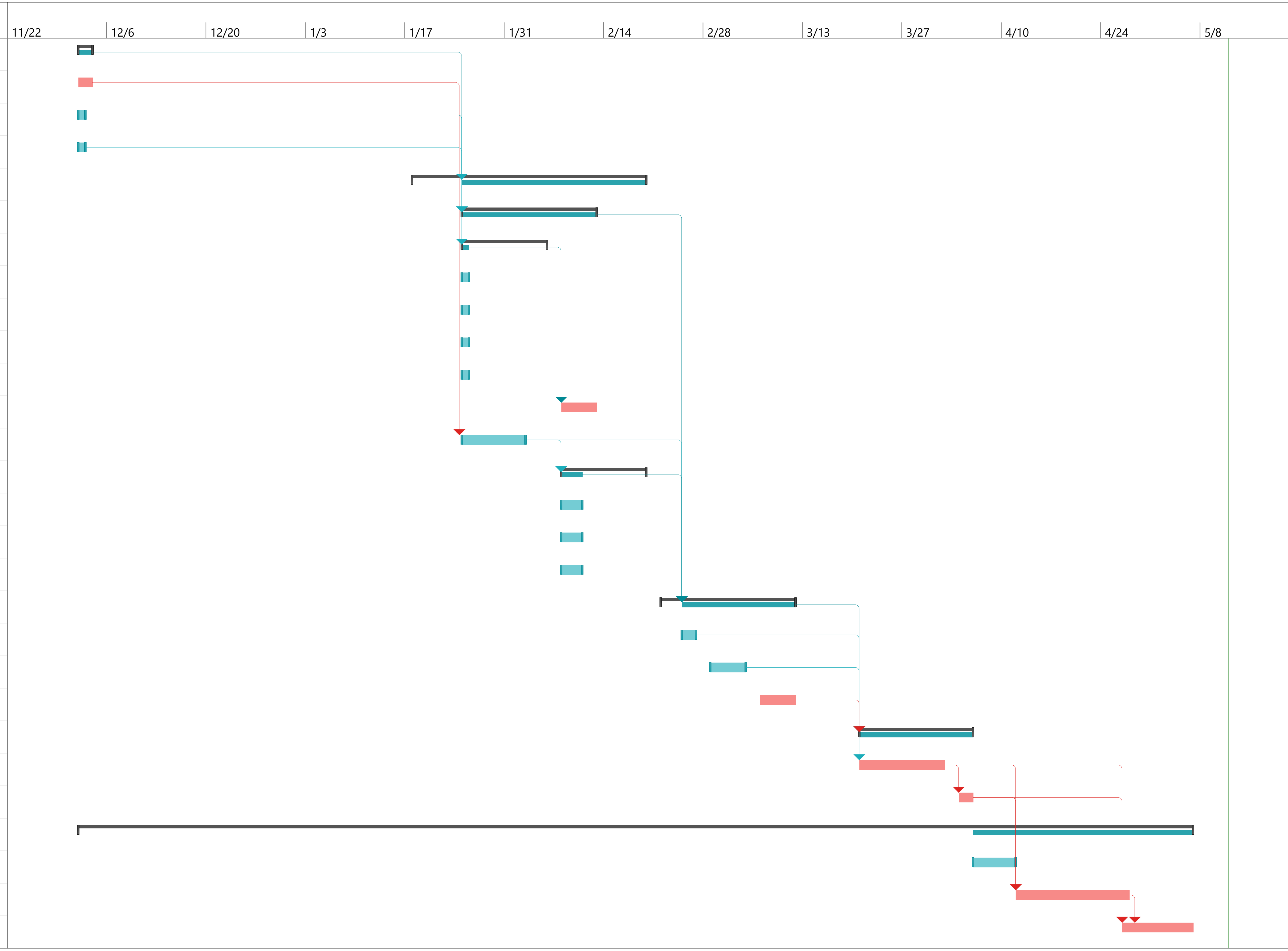
NORTHERN ARIZONA UNIVERSITY

DATE: 04/21/16
DRAWN BY: AWM
SCALE: 1"=60'

FINAL DESIGN
GRADING PLAN

APPENDIX I

ID	Task Number	Task Name
1	1	**Site Investigation**
2	1.1	Surveying
3	1.2	Collect Soil Samples from Site
4	1.3	Physical Site Analysis
5	2	**Identify Problem Area of Cap**
6	2.1	**Soil Analysis**
7	2.1.1	**Geotech Lab Work**
8	2.1.1.1	Sieve Test
9	2.1.1.2	Hydrometer Test
10	2.1.1.3	Shear Strength Test
11	2.1.1.4	Compressive Strength Test
12	2.1.2	Analyze Soil Test Results
13	2.2	Tophographic Analysis
14	2.3	**Hydrologic Analysis**
15	2.3.1	Define Channels
16	2.3.2	HEC-RAS HEC-HMS
17	2.3.3	Determine Runoff Flows
18	3	**Design Alternatives and Qualifications**
19	3.1	Define Criteria
20	3.2	Determine Design Alternitives
21	3.3	Cost Estimates
22	4	**Design Work**
23	4.1	Choose and Create Design
24	4.2	Draft Design
25	5	**Project Management**
26	5.1	Website
27	5.2	Final Design Report
28	5.3	Final Presentation



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9	2.1.1.2	Hydrometer Test
10	2.1.1.3	Permeability Testing
11	2.1.1.4	Compressive Strength Test
12	2.1.2	Analyze Soil Test Results
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