RIVERTON RE-PURPOSING SEWER TRUNK LINE TO GROUND WATER SUB-DRAIN

Project ID: CEEn_2018CPST_011

by

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A Capstone Project Final Completion Report

Submitted to

Trace Robinson

Riverton City

Department of Civil and Environmental Engineering

Brigham Young University

Executive Summary

PROJECT TITLE: Riverton Re-purposing Sewer Trunk Line to Groundwater Sub-drain

PROJECT ID: CEEn_2018CPST_011

PROJECT SPONSOR: Riverton City

TEAM NAME: BKAT Engineering

Project Requirements

The scope of this project consists of formulating a recommendation to Riverton City regarding recent groundwater seepage and hillside movement adjacent to Lovers Lane within city limits. Currently, the hillside has been reported to have a low factor of safety, indicating that the hill is unstable. To make a final recommendation, several options were analyzed and compared. Decisions were based on costs, benefits, and safety improvements. In this report, we address the process that brought us to our final recommendation, as well as the details surrounding said recommendation.

Tasks

In order to complete this project several tasks are required. First, the final recommendation will need to be brought before the cities board in order to obtain the funding necessary for the project. The project contractors and details will then need to be finalized. Then the desired recommendation will need to be implemented. After the recommended adjustments to the hillside have been made the hill will need to be observed for the period of one year in order to examine the effects of implementing the project.

Project Objectives

The main objective of this project is to assist in producing a solution to stabilize the hillside for the city. To accomplish this the team focused on most efficient solutions to reduce excessive water content in the hillside.

Final Recommendation

There are two major sources of water in the hill, groundwater from the aquifer, and seepage water from the South Jordan Canal. Based on a thorough analysis, it is recommended that the City control the seepage from the South Jordan Canal. To do this it is recommended that the canal is lined with an impermeable layer/membrane. This will eliminate nearly all seepage water which has been percolating into the hillside from the Canal. This, in turn, will help stabilize the hillside by removing a portion of the excess water in the hill

It is recommended that Riverton City use a geosynthetic liner, such as the Husker Canal[3]. This is a flexible lining solution which creates a durable impermeable barrier between the irrigation water and surrounding soils. It has been used in a similar project in the area. It is also flexible enough to shotcrete over the top of the liner if necessary. For this application, the liner itself may be sufficient, but shotcrete may increase the lifetime of the lining.

It is also recommended before installing the liner for the Canal that the City install three wireless piezometer measuring stations in the hillside. These stations would act as a monitoring system for the hill. At these stations, the pore pressure and groundwater level of the hill would be reported. The center station would act as a data logger, as the two outside measuring stations report to it. The data logger would publish data that could be accessed through a computer or a smartphone. Readings would be taken before the installation of the canal liner, and at least a year after implementation. Based on the effect the liner has had on these readings, the hill should be reevaluated, and as necessary, further mitigation may be considered at that point.

In order to account for the excess groundwater that is in the hill, it is also recommended that City investigate the possibility of having at least a portion of the existing drainage pipes be cleaned out in order to help stabilize the hill while the canal is in the process of being lined.

Schedule

For this project to proceed and be implemented later this year and into next year, it must be selected to be funded by the City, before the new fiscal year. There are two major parts to these recommendations:

1. Installation of wireless measuring piezometers and data loggers
2. Site preparation and installation of the canal liner

Three measuring wireless piezometers are recommended to be installed prior to the installation of the canal liner. These piezometer stations may be installed before the end of the irrigation season for the canal, as they do not disrupt the canal in any way.

Construction and preparation work for installation of the liner should begin shortly after the end of the irrigation has closed for the season, which is October 15. This will help to decrease costs and inconveniences to the South Jordan Canal Company and the City. Grubbing, excavation, fill, and compaction work is required prior to the installation of the liner. This should be accomplished mid-December 2019. Once the canal shape and stability are finalized, the liner can be placed. The liner should be placed by March 2020. If a shotcrete layer is chosen to cover the liner, it should be placed following the liner. The shotcrete layer should be placed and given proper time to cure by the end of March. This will allow for no disruption in the irrigation water season and for the canal to open by April 15, 2020.

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Introduction

Overview

The scope of this project was to create a solution to minimize the amount of excessive groundwater seepage in the hillside adjacent to Lovers Lane in order to stabilize it from potential sliding and movement. In this project, three concepts which would decrease the water content in the hill were evalu:

1. Lining of the canal, which is located at the top of the hill in order to decrease water seepage.
2. Install an entirely new drainage system and install a new French drain system at the bottom of the hill.
3. Clean out the existing sewage line and connect it to the abandoned sewer line.

Each of these options has unique benefits and costs. Each option may help reduce excessive groundwater from the hillside. Because of this, each one was analyzed based on costs, benefits, and safety concerns.

Assumptions

- Roughness (n-values) assumed from visual interpretation of the canal.
- Canal's dimensions were assumed to be constant throughout.
- The flow rate is assumed to be a constant flow of the average flow rate as measured by the South Jordan Canal Company (60-65 CFS).
- Seepage from the canal was estimated based on previous soil reports and basic assumptions for the hill, using theatrical seepage equations such as Darcy's law. A more precise measured amount of seepage by ponding, or inflow-outflow may produce more accurate estimates of the quantity of seepage water entering the hill.
- Lengths, depths, and sizes were measured on site, but were only approximations and should be considered rough estimates.
- The water table levels were estimating based on previous geotechnical reports.
- Soil conditions in the hill were assumed to be similar to previous geotechnical reports.
- All costs were estimated at the simplest design cost, whereas actual projects may incur more costs.

Existing Conditions

The hillside for this project runs adjacent to Lovers Lane in Riverton, Utah. This hillside has previously been tested by geotechnical engineering firm AGEC. In the report by AGEC, dated June 21, 2015, it was reported that the steepest section of the hill is about 2.6:1 as indicated in Table 1. Furthermore, it was determined that the hill's stability was marginal. This indicates the hill has a high potential for movement, and possible mitigations should be investigated.

Table 1. AGEC Slope Report

Profile	Height of Slope (with respect to Lovers Lane			Slope (horizontal : vertical)	
	Above	Below	Total	Steepest	Overall
A	40	35	75	1.4:1	5.3:1
C	45	26	71	2.6:1	2.5:1
D	32	32	64	2.0:1	3.2:1

In addition to strength testing, AGEC tested the hill for depth to groundwater. It was found that the depth to groundwater was shorter than other nearby areas. This indicates the possible influence of seepage water from the adjacent canal. In addition, previous studies collected a soil sample from the hill and performed a sieve analysis. This analysis reported that the soil is mostly made up silty sand. Results are tabulated in Table 2 (next page).

Table 2. Sieve Analysis Gradation Results

Sieve Designation	Sieve Opening Size (mm)	Percent Passing (%)	Project Specifications (%)
5"	127	100	-
3"	76.2	100	-
1 1/2"	38.1	100	-
3/4"	19.1	89	-
3/8"	9.52	64	-
#4	4.76	46	-
#8	2.38	37	-
#16	1.19	29	-
#30	0.59	23	-
#50	0.297	18	-
#100	0.149	14	-
#200	0.074	10	-
GRAVEL	SAND	SILT & CLAY	
54%	36%	10%	

The hillside has an existing system of horizontal drains within the hill. Unfortunately, the system has become inefficient over the years due to corrosion and obstruction of the drains with soil, leaves, and other material. Some drain pipes show signs of drainage, while others seem to be clogged entirely. Due to rich vegetation, clayey soils, and the corrosion of drainage pipes, the current drainage system is inadequate to handle the excessive groundwater in the hill. Also, it is important to note the existing drainage system does not route the water to any facility but instead routes the water to the other side of Lovers Lane. This may present an issue for the city in the future.

Design, Analysis & Results

Previously, geotechnical analysis has determined that at the hillside at Lover's Lane stability is marginal. The slopes sampled along Lover's Lane approach unacceptable factors of safety indicating improvement or change is required. In the event of a seismic event, based on seismic slope analysis, the entire slope is at risk of failure.

Based on site visits, soil properties, and location, it was determined that the seepage from the canal is one of the major causes of instability of the hillside. Existing drains in the hill are continually draining water, but many of these pipes are clogged or deteriorated. The soil in the hillside consists mostly of silty sand and fill, which provides low stability strength. Altering the slope is not in the plans for the city at this time. Based on this information, the team's purpose was to propose a solution for the instability in the hill caused by the excess of groundwater. Three possible solutions were considered as proposed solutions. For this report, each scenario received a preliminary analysis of cost, benefits, and design, but only the option is chosen as a final recommendation received more in-depth design and cost analysis. A slope stability analysis was performed on options for the hill, as seen in Figure 1.

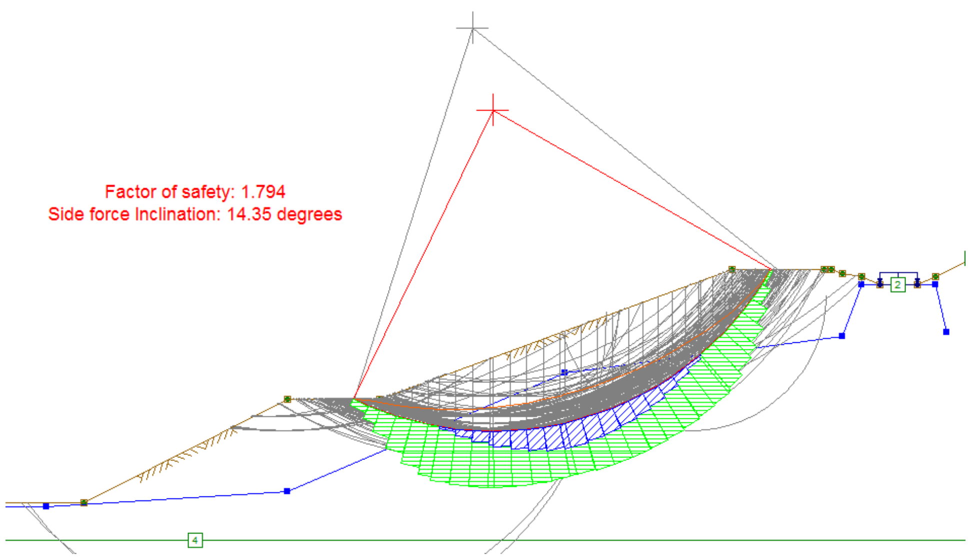

Figure 1. Slope Stability Analysis

Final Recommendation

It is recommended that Riverton City address the source of the water seepage, the South Jordan Canal. This includes lining the South Jordan Canal with an impermeable membrane to prevent water seepage during the irrigation season. This option may be complicated by the fact the Canal is not owned by the City of Riverton. The canal is owned by The South Jordan Canal Company. Therefore, any project involving lining the canal will only be possible depending on the coordination of Riverton City and South Jordan Canal Company, and the willingness to work together of each. In anticipation of this possible issue, the team has contacted the canal company, and they have communicated that they would be willing to work with the City to line the canal. Based on our analysis, this is the most effective means of stabilizing the hillside. Lowering the seepage rate from the canal will increase the stability of the hill significantly. It is recommended to use a synthetic lining, such as the Huesker Canal[3]. This lining has been used on other canals in the area and has proven to significantly decrease the seepage in those areas. This lining is also cost-effective, easy to maintain, and able to be custom made to fit the canal (see appendix for more detail on the product). The canal lining is flexible enough to allow shotcrete to be applied over the lining, if necessary. Based on the team's analysis, using shotcrete over the liner would not be necessary for this application, but may add several years to the lifetime of the lining.

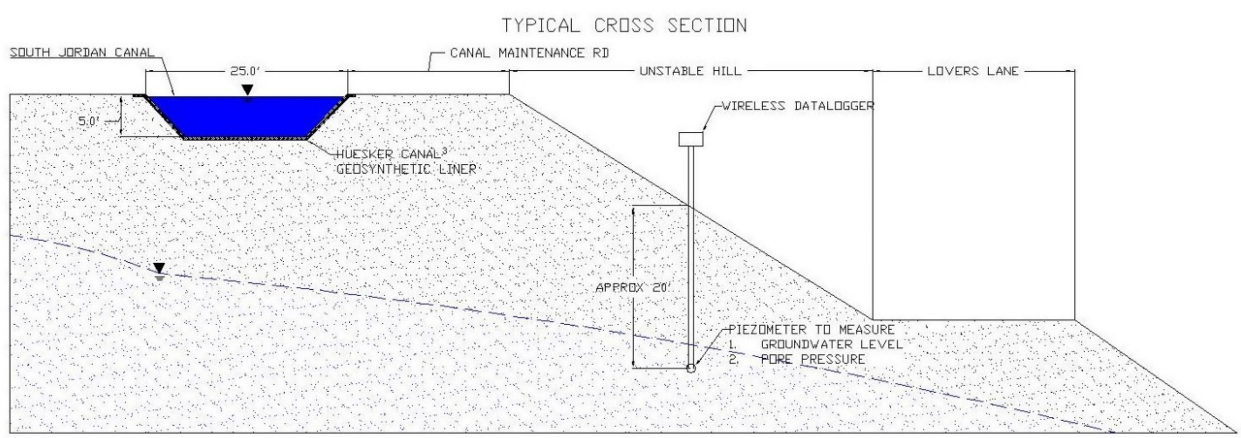

Figure 2. Typical Cross Section of Implemented Recommendations

It is also recommended before the installation of the liner for the Canal that the City install three wireless piezometer measuring stations in the hillside. These stations would act as a monitoring system for the hill. At these stations, the pore pressure and groundwater level of the hill would be reported. The center station would act as a data logger, as the two outside measuring stations report to it. The data logger would publish data that could be accessed through a computer or a smartphone. Readings would be taken before the installation of the canal liner, and at least a year after implementation. Based on the effect the liner has had on these readings, the hill should be reevaluated, and as necessary, further mitigation may be considered at that point. Figure 3 includes the locations for the piezometers.

Figure 3. Locations for Piezometer Stations

The team has reached out to Intermountain Environmental (IEI) who specializes in supplying this kind of equipment. This company is based in Logan, UT. It was confirmed that wireless piezometers could record groundwater level and pore pressure in the soil and report back the data wirelessly. It was suggested that the main station is installed in the middle of the hill with a data logger, while the outside stations report to it. These piezometers can be placed in the hill and left for any period of time. The measurements are sent directly to an app accessed by the client. This eliminates the need to go out to the hill regularly in order to measure the water levels by hand and can use in understanding the amount of water in the hill. The hill should then be observed for a period of at least one year in order to ensure the effects of lining the canal are fully understood. If the hill is still unstable, further mitigation measures (mentioned later) can then further decrease the water content in the hill. Figure 4 is an example from another wireless piezometer company, Specto Technology, of how the system would work.

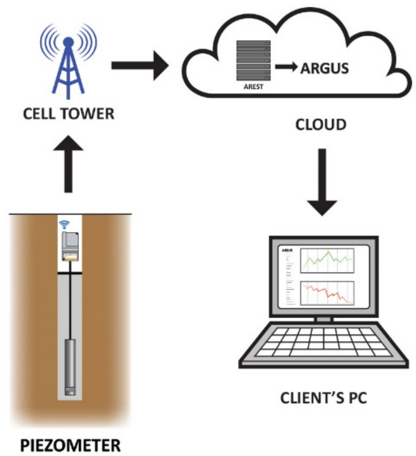

Figure 4. Wireless Piezometer Transmission Guide

Cost Analysis

The focus of our cost analysis was to look at the feasibility of lining the canal versus installing other drainage options within the hillside itself. Reinforcing the hillside by mechanical means was an option that was considered. However, with heavy water seepage within the hillside, and without a concrete design to pull from, it was determined that it may not be a viable option for the hill. Thus, a brief summary of the cost analysis is presented here, but the entire report can be found in the Appendix. Please note that costs associated with each design alternative are a rough estimate based on the most simplistic, hypothetic design. More specific design work will need to be done in order for a more accurate analysis for many of the options considered. However, these estimates should be adequate to give Riverton City an idea of the approximate costs of each alternative.

Cost of Main Recommendations

Costs were estimated based on similar past projects in the area. For this project, two options for lining the canal were analyzed. The first option would be to line the canal with a traditional concrete lining. The second was to line the canal with a synthetic, multi-layer material. Estimates for both options also included funds to acquire three monitoring devices to monitor the hillside before, during, and after the construction of the liner. Initial estimates indicate that the synthetic liner would cost at least $100,000 less than the concrete liner, and this is with a conservative estimate on a simple 6” concrete slab with no rebar reinforcement. Not only could a synthetic liner be a much more cost-effective solution, but also take less time to install, fewer materials, and potentially less maintenance. Based on this, the total estimated cost of installing the synthetic liner and install measuring piezometers would be approximately $150,000 for the section adjacent to the hillside.

Possible Additional Mitigation in the Future

Possible additional mitigation in the future, if necessary, may include the use of a perforated pipe to collect groundwater at the base of the hill. Based on previous geotechnical reports, the pipe would need to be buried approximately 8-10 feet under the ground to truly help drain some of the groundwater from the aquifer out of the hill. The cost of installing a simple French-style drain system at the base of the hillside is fairly inexpensive. The total cost of installing the drain system, along with resurfacing the road with recycled asphalt rototill, would be approximately $50,000. But to route the water up to the existing abandoned sewer pipe, a pump and low point would need to be designed for the hill. This in turn, due to design, pump, and maintenance costs would increase the amount needed to fund the project.

Other Options Considered

A secondary option considered was to install a completely new drainage system in the hillside and connect it to the existing abandoned sewer pipe. This may include removal of the old draining system, installing wet wells, perforated pipe, and horizontal drains to drain the moisture in the hill. This would cost significantly more than any other option. Furthermore, there is a major concern that digging into the hill may initiate movement in the hill and trigger. Because of this, it is not recommended to install a new drainage system into the hill.

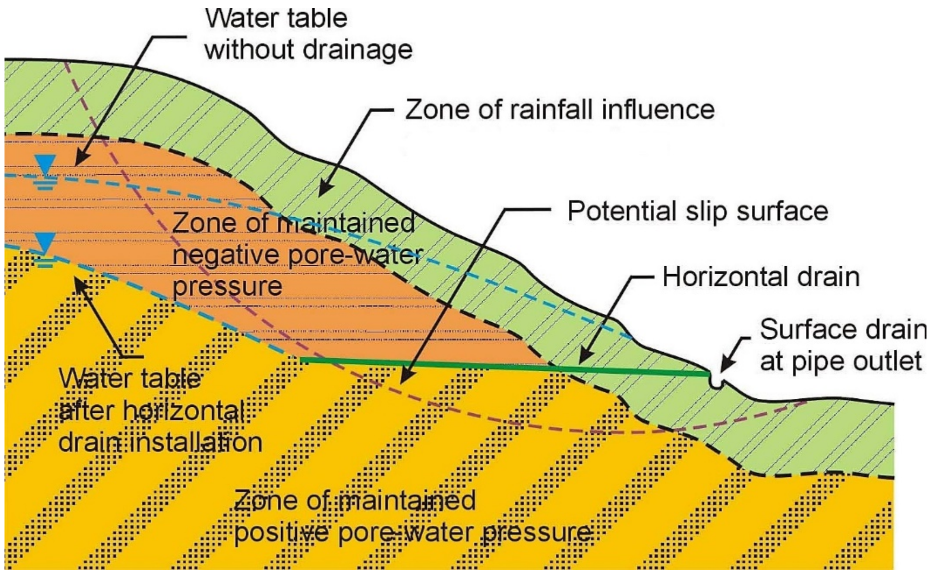

Figure 5. Theoretical Effect of Horizontal Drains

Another option considered was to clean out the existing drainage system and connect it to the abandoned sewer pipe in the hill. This takes advantage of the previously installed drainage system, optimizes it, and transports the moisture out of the area. Unfortunately, some issues prevent this option from being as efficient as it could be. These issues include the deterioration of the existing drainage pipes and wells, the ability to connect old deteriorated pipes to a reinforced concrete pipe (RCP), and future maintenance costs.

One of the biggest issues with this option is the fact that the abandoned sanitary sewer pipe is not positioned to capture the flow of the drainage pipes. Based on the limited information the team has on the sewer pipe, it seems it is set at a higher elevation than the existing drainage pipe system is currently. One way in which this line might still be utilized is to do install something similar to what was suggested before, using a pipe to collect all the water from the existing drainage pipes and pump it up to the abandoned sewer line. But with this, it must be remembered that the existing drainage pipes are in poor condition and may need to be replaced to make this work. Because of this, it is not recommended to connect to the old drainage system. Figure 4 depicts some of the standpipes and drainage systems in the hill currently.

Figure 6. Existing Standpipes in the Hill

Expectations

It is expected that by installing a liner in the section of the canal that is adjacent to the hill, it will create a barrier between the canal and the hillside. This eliminates the amount of seepage water entering the hill from the canal. It is expected that this will reduce the amount of water in the hill, and in turn, increase the stability of it. It is also expected that the wireless measuring piezometers will act as a monitoring system for the hillside. Furthermore, it is expected that the city will reexamine the hillside after a year of implementation to re-evaluate the hill and decide if any further mitigation is necessary.

Schedule & Implementation

The following schedule was made with the assumption as if the project had been funded for the 2019-2020 fiscal year. If the project is not funded for the next fiscal year, the schedule may still be used, and the years adjusted to match the year of funding. The irrigation season for the South Jordan Canal is April 15 – October 15, and the schedule is built around this fact. The schedule is separated into phases of the recommendation.

Installation of Wireless Piezometers

Three measuring piezometers are recommended to be installed prior to the installation of the canal liner. These piezometer stations may be installed before the end of the irrigation season for the canal, as they do not disrupt the canal in any way. Therefore, they should be installed at the near the end of the irrigation season, September 2019. After implementation, water levels and pore pressure should be obtained and recorded for future comparisons.

Site Work and Preparation for Lining the Canal

Site grading and preparation work for installation of the liner should begin shortly after the irrigation has closed for the season. This will help to decrease costs and inconveniences to the South Jordan Canal Company and the City. Grubbing, excavation, fill, and compaction work is all required prior to the installation of the liner. The South Jordan Canal is already graded in an appropriate manner, but the removal of trees and bushes along the canal is required. Based on this, it is estimated that this may take up to a maximum of two months and should be completed no later than mid-December 2019.

Installation of the Canal Liner

After the site has proper shape, stability, and has been cleared, the liner can then be placed. Generally, liner manufactures have the ability to make custom sizes of sections of the liner to optimize the process. The liner should be installed in sections, and then thermally bonded together. If a shotcrete layer is chosen to cover the liner, it should be placed following the liner. The shotcrete layer should be placed and given proper time to cure by the end of March 2020. Further details in for installing the liner can be found in Appendix A. Once the hillside has been given sufficient time to stabilize, additional slope improvements can be considered if needed.

Post Evaluation of Hillside

After at least one year of installing the canal liner, and once the hillside has been given enough time to stabilize, the status of the hillside should be reviewed again. If the hillside has not reached a sufficient level of stability in the given time, additional drains or stability improvements may be installed if needed.

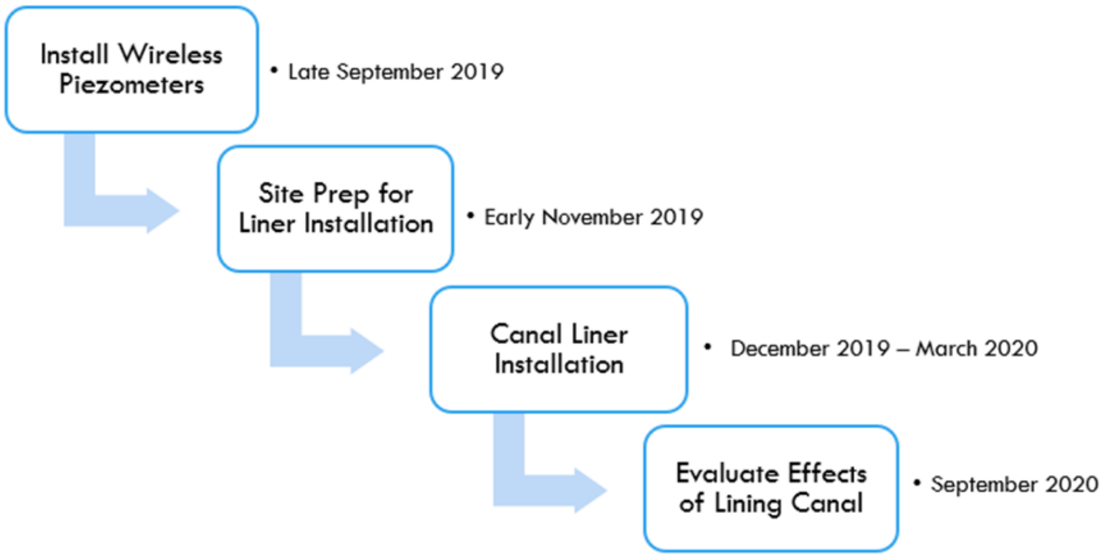

Figure 7. Implementation Schedule

Appendix A – Cost Analysis & Estimates

Further Mitigation Needed After One Year - Install French Drain

Category #	Item #	Description	Quantity	Unit	Unit Cost	Direct total Cost
1		**Site Preparation/Excavation**				
	1.1	Vegetation Removal	1	ea	$ 2,500.00	**$ 2,500.00**
	1.2	Excavate for drain pipe	1600	lf	$ 6.00	**$ 9,600.00**
	1.3	Import/Place Gravel	30	ton	$ 15.00	**$ 450.00**
	1.4	Place 10" perforated pipe	1600	lf	$ 4.00	**$ 6,400.00**
	1.5	Import/Place Bedding Sand	15	ton	$ 13.00	**$ 195.00**
	1.6	Backfill Drain Pipe	1600	lf	$ 2.50	**$ 4,000.00**
	1.7	Removal of Excess Material	45	ton	$ 10.00	**$ 450.00**
2		**Roadway**				
	2.1	Prepare Subgrade	19200	sf	$ 0.50	**$ 9,600.00**
	2.2	Place Recycled 4" Roadbase	250	ton	$ 13.00	**$ 3,250.00**
	2.3	Fine Grade Recycled Roadbase	19200	sf	$ 0.30	**$ 5,760.00**
3		**Miscellaneous**	1	ea	$ 5,000.00	**$ 5,000.00**
						$ 47,205.00

Concrete Lining of Canal

Category #	Item #	Description	Quantity	Unit		Unit Cost		Direct total Cost
1		**Site Preparation/Excacation**						
		Vegetation Removal	1	ea	$	5,000.00	**$**	**5,000.00**
		Excavation/Subgrade of Canal	41000	sf	$	0.25	**$**	**10,250.00**
		Removal of Excavated Soils	1000	ton	$	7.00	**$**	**7,000.00**
		Place 12" Engineered Fill	1600	ton	$	13.00	**$**	**20,800.00**
		Grade Engineered Fill	41000	sf	$	0.10	**$**	**4,100.00**
2		**Concrete Work**						
		Form 6" Concrete Canal Lining	41000	sf	$	0.50	**$**	**20,500.00**
		Pour 6" Concrete Canal Lining *	775	cy	$	200.00	**$**	**155,000.00**
		Strip 6" Concrete Canal Lining	41000	sf	$	0.35	**$**	**14,350.00**
3		**Miscellaneous**						
		Install Monitoring Sensors	3	ea	$	4,333.33	**$**	**13,000.00**
		Misc. Cleanup/Finish Work	1	ea	$	15,000.00	**$**	**15,000.00**
							$	**265,000.00**

Synthetic Lining of Canal

Category #	Item #	Description	Quantity	Unit	Unit Cost	Direct total Cost
1		**Site Preparation/Excavation**				
		Vegetation Removal	1	ea	$ 5,000.00	**$ 5,000.00**
		Excavation of Canal	41000	sf	$ 0.07	**$ 2,870.00**
		Removal of Excavated Soils	500	ton	$ 7.00	**$ 3,500.00**
		Place Engineered Fill	750	ton	$ 13.00	**$ 9,750.00**
		Grade Engineered Fill	41000	sf	$ 0.10	**$ 4,100.00**
						$ -
2		**Synthetic Canal Lining**				**$ -**
		Installation	41000	sf	$ 1.10	**$ 45,100.00**
		Material	41000	sf	$ 1.10	**$ 45,100.00**
3		**Miscellaneous**				
		Install Monitoring Sensors	3	ea	$ 4,333.33	**$ 13,000.00**
		Misc. Cleanup/Finish Work	1	ea	$ 10,000.00	**$ 10,000.00**
						$ 138,420.00

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Phone: 435-755-0774 Fax: 435-755-0794
Fed ID: 87-0502649 DUNS: 80-936-8012

Web Site: www.inmtn.com

QUOTATION

Date	Quote #
03/19/19	IEIQ12224

To: Brigham Young University
Bryce Terry
Provo, UT

Phone:
e-Mail: bryce.terry1995@gmail.com

Ship To: Brigham Young University
Bryce Terry
Provo, UT

Phone :
e-Mail : bryce.terry1995@gmail.com

Quoted By	Terms	Ship Via	FOB
Josh Hanks	Upon Approval	UPS-Gnd	Lgn,Ppd & Add

Model #	Description	Qty	Unit Price	Ext. Price
	CENTRAL STATION			
CR850-ST-SW-NC	Measurement & Control Datalogger with Keypad & Display -ST Tested -25 to 50C -SW Standard 3 Yr Warranty -NC No Calibration Certificate	1	$1,382.40	$1,382.40
ENC16/18-SC-SB-MM	16" x 18" Weather-Resistant Enclosure Series -SC 1 Conduit for Cables -SB Standard Backplate -MM Tripod Mast Mounting	1	$456.00	$456.00
AVW200-ST	2-Channel Vibrating Wire Interface -ST Tested -25 to +50C	1	$494.40	$494.40
18663	Data Cable Null Modem DB9 Male to Male, 1ft	1	$4.61	$4.61
RF401A-ST	Radio, 900 Mhz 250 mW Spread Spectrum - ST Tested -25 to +50 C	1	$460.80	$460.80
CELL205-AT	CELL205 4G LTE Cat1 Cellular Module for AT&T (-40 to +80C) - AT AT&T North America	1	$472.00	$472.00
CELLDATA-V-A25	CELLDATA Campbell Scientific Cellular Data Service Subscription - V Verizon US - A25 25MB/Mon for 1 Yr Additional charges will be billed if usage limits are exceeded. NON CANCELABLE OR RETURNABLE PRODUCT	1	$144.00	$144.00
31128	Wideband 8dBd Yagi Antenna w/Type N Female & Mounting Hardware	1	$83.52	$83.52
COAXSMA-L10	Antenna Cable LMR195 w/SMA & Type N Male Connector [no restocks] -L10 10 ft cable length	1	$81.86	$81.86
14221	900MHz 3dBd Omni Antenna w/Type N Female & Mounting Hardware (use COAX RPSMA-L or COAXNTN-L)	1	$158.40	$158.40
COAXSMA-L10	Antenna Cable LMR195 w/SMA & Type N Male Connector [no restocks] -L10 10 ft cable length	1	$81.86	$81.86
BP12	12 Ahr, 12 V Sealed Rechargeable Battery, w/ Mounting Hardware	1	$126.72	$126.72
SS-6-12V	Battery Charging Regulator (12 Vdc, 6.5 Amp) 3ft cable with tinned wires and spade connectors	1	$61.60	$61.60
SPM020P-BP	Solar Panel, 20-Watt, 15ft Cable	1	$153.85	$153.85
SLB-0112	Pole Mount, Side of Pole, for Solarland 20-40 Watt	1	$50.00	$50.00
SPC-SEN	4500ALV VW Piezometer, 1" OD, vented, 70 kPa (10 psi)	1	$743.75	$743.75

Model #	Description	Qty	Unit Price	Ext. Price
	*Specify 70 or 170 kPa when ordering			
SPC-SEN	4500AL VW Piezometer, 1" OD, unvented, 70 kPa (10 psi) *Specify 70 or 170 kPa when ordering.	1	$662.50	$662.50
SPC-OTH	Yellow Vented Sensor Cable	25	$1.42	$35.50
SPC-OTH	Blue Non-Vented Sensor Cable	25	$0.93	$23.25
	OTHER TWO STATIONS			
AVW206-ST	900MHz Wireless 2-Channel Vibrating Wire Interface -ST Tested -25 to +50C	2	$720.00	$1,440.00
ENC12/14-SC-MM	12" x 14" Weather-Resistant Enclosure - SC 1 Conduit for Cables - MM Tripod Mast Mounting	2	$316.80	$633.60
14201	900MHz 9dBd Yagi Antenna w/Type N Female & Mounting Hardware (use COAX RPSMA-L or COAXNTN-L)	2	$148.80	$297.60
BP7	12 Vdc, 7 Ahr Sealed Rechargeable Battery & Mounting Bracket & Pigtail	2	$71.04	$142.08
COAXSMA-L10	Antenna Cable LMR195 w/SMA & Type N Male Connector [no restocks] -L10 10 ft cable length	2	$81.86	$163.72
SS-6-12V	Battery Charging Regulator (12 Vdc, 6.5 Amp) 3ft cable with tinned wires and spade connectors	2	$61.60	$123.20
SPM010P-BP	Solar Panel, 10-Watt, 15ft Cable	2	$118.46	$236.92
HPM 5/10H	Mounting Bracket, Hinged Universal, for 5 - 10 Watt	2	$42.86	$85.72
SPC-SEN	4500ALV VW Piezometer, 1" OD, vented, 70 kPa (10 psi) *Specify 70 or 170 kPa when ordering	2	$743.75	$1,487.50
SPC-SEN	4500AL VW Piezometer, 1" OD, unvented, 70 kPa (10 psi) *Specify 70 or 170 kPa when ordering.	2	$662.50	$1,325.00
SPC-OTH	Yellow Vented Sensor Cable (25 feet per sensor)	50	$1.42	$71.00
SPC-OTH	Blue Non-Vented Sensor Cable (25 feet per sensor)	50	$0.93	$46.50
	Programming and Data Access Software			
LoggerNet-D	Datalogger Support Software [no restocks] [90 day warranty] -D Download Only	1	$724.80	$724.80

SubTotal	$12,454.66
Sales Tax	$0.00
Est. Shipping & Insur.	$0.00
Total	**$12,454.66**

We appreciate the opportunity to provide this quotation. Please feel free to contact us with any questions or comments.

Quoted PRICES are good for 30 days. DELIVERY times will vary, 25 - 30 business days is typical. * SHIPPING CHARGES are estimated, actual shipping charges will be F.O.B. Logan, UT, with freight and insurance prepaid and added to the invoice as a seperate item unless noted otherwise. Items listed with a item code starting with SPC- are not returnable. All products are covered by the manufacturers WARRANTY which is typically 12 months unless otherwise noted. All returned products are subject to a minimum 15% RESTOCKING FEE for products returned within 60 days, with original packaging ($50 minimum). PAYMENT TERMS: Net 30 for approved Purchase Orders. VISA, MasterCard, American Express are accepted however invoices over $3000 will incur a 2.5% surcharge. We also accept payments by US Check, ACH, or Wire Transfer. Our banking information is available upon request. A finance fee of 1.5% (18% annual) per month will be charge on past due accounts.

Appendix B – Huesker Liner Brochure & Installation Guide

Canal$^{3®}$

Geocomposite for Canals & Water Containment Applications

HUESKER
Ideas. Engineers. Innovations.

Why Is Canal^3 The Preferred Choice?

Canal^3 Geocomposite. When Every Drop Counts.

Canal$^{3®}$

Geocomposite for canals and water containment applications

Canal^3 is a multi-layer geosynthetic composite membrane designed for water containment applications offering an easy, reliable and cost-effective canal lining solution. Canal^3 provides superior puncture resistance and increased interface friction properties that allows the liner to be deployed directly in contact with most existing soils and steepened side slopes.

Puncture Resistance

Canal^3 is comprised of a polyethylene membrane laminated between two nonwoven protection layers. The nonwovens can be designed for increased puncture protection if deemed necessary by site conditions, allowing onsite soils to be used as the subgrade material without the cost of placing an expensive bedding material or placement of separate nonwoven layers.

Interface Friction

Lining an existing earthen canal typically requires reshaping the bottom and side slopes prior to installing the **Canal^3** geocomposite. The side slopes can range from relatively flat to very steep depending on site conditions and property boundaries. The bottom nonwoven on **Canal^3** provides a superior interface friction response with onsite soils which prevents **Canal^3** from sliding. The top nonwoven layer also allows for soil or shotcrete to be used as cover material even for 1.5 H: 1 V slopes.

your partner worldwide: HUESKER.com

BEFORE RESHAPING

PREPARED CANAL

CANAL^3 INSTALLATION

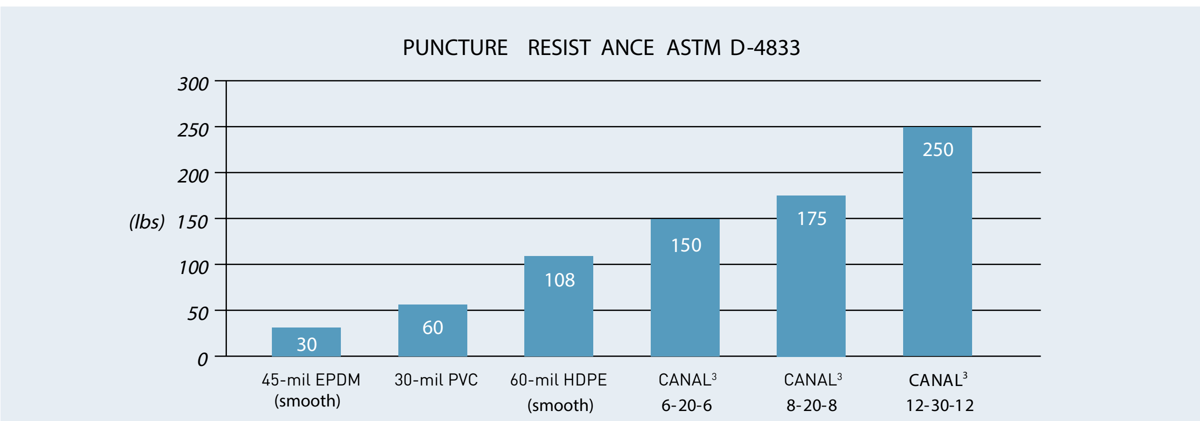
The demand for water and the high costs of delivery requires implementation of proven conservation practices. Lining canals with HUESKER's **Canal^3** geocomposite is the most effective step towards water conservation. With high seepage rates greater than 40% in unlined canals, lining with **Canal^3** reduces seepage losses and increases available water for delivery.

HUESKER's **Canal^3** may be comprised of polyester or polypropylene nonwovens depending upon project specific design parameters. Manufactured to a standard width of 17 feet (5.18 m) and a custom width up to 25 feet (7.6 m), **Canal^3** can be installed parallel or perpendicular to the centerline of the canal in order to minimize excess material in exposed, buried, or shotcreted applications.

Canal³
Proven Performance.

Canal lining installations require cleaning and reshaping of the canal prior to the liner installation. Typically, other liners call for a sand bedding layer or a nonwoven cushion above the reshaped canal to provide puncture protection for the liner. **Canal³** is designed with a high puncture protective layer beneath and above the membrane liner, and can be placed directly on the existing reshaped soils eliminating the costs of placing a sand layer.

The following chart includes published ASTM D-4833 puncture index test values for typical canal liners. Recently, a thorough field assessment of various types of canals concluded, "Without question, liners with a protective barrier performed the best and have required no maintenance, while the performance on the liners without a protective barrier has varied significantly," (Evaluation of Canal Lining Projects in the Lower Rio Grande Valley of Texas, Karimov, Leigh, Fipps, P.E., 2009.)



Canal³ provides superior puncture properties for various site conditions from smooth to rough subgrades and is available in several styles. Irrigation districts and contractors agree that the ease of installing **Canal³** over other liners is not only cost effective but also reduces installation time by using our wider width materials. Installations of **Canal³** can be performed by a subcontractor or by irrigation personnel with minimal instructions from a HUESKER technical representative. The following are recommendations for the proper selection of the **Canal³** products for various site conditions.

Material	Subgrade			Application		
	Smooth	Moderate	Rough	Buried	Exposed	Shotcreted
Canal³ 6-20-6	✓			✓		
Canal³ 8-20-8	✓	✓		✓	✓	✓
Canal³ 12-30-12	✓	✓	✓	✓	✓	✓

Installation

In order to achieve a successful installation, the first step is to deliver materials safely to the site. Each roll of **Canal³** is wrapped with heavy duty plastic for protection during shipment along with two lifting straps for ease of unloading at the jobsite. **Canal³** is typically shipped to the customer on flatbed trucks which allows easy unloading with slings or a lifting bar.

To aid in the deployment process, HUESKER supplies an installation guide which provides a detailed overview for installing **Canal³**. **Canal³** can be installed perpendicular or parallel to the centerline depending on the size of the canal and its alignment. Details of the typical anchoring methods are included in the Installation Manual for specific configurations of side slopes.

Recommended seaming methods include using a hot melt adhesive, standard wedge welding, or a combination of both. Laboratory test results are available for each of these methods of seaming.

When mechanical fastening is required, **Canal³** is easily attached to concrete structures by using batten strips which are anchored into the concrete using expansion anchors.

HUESKER's **Canal³** composite has been installed worldwide in various applications with successful results, and continues to be the designers first choice for canal lining applications. In today's water conservation environment, eliminating costly seepage is a priority to ensure that every drop counts today and for future generations.

For more information on **Canal³**, call HUESKER at (800) 942-9418 or visit our website at www.HUESKER.com.

Case Study

In 2007, the Porter Canal owned by the New Sweden Irrigation District located in Idaho Falls, Idaho was reshaped and lined with **Canal^3** 12-30-12 by a commercial developer due to seepage onto a proposed commercial subdivision. The project consisted of reshaping 1,400 linear feet of the Porter Canal and installing 157,500 ft^2 of **Canal^3** geocomposite liner by HK Contractors, Inc. The custom roll size of 25 feet wide x 300 feet long reduced the number of seams and expedited the installation process. The entire project took approximately 2 weeks; 1 week to reshape the existing canal, 4 days to install the **Canal^3**, and another 3 days to seam and attach to a bridge structure. After construction, the Developer built on the now dry parcel adjacent to the canal.

Project: Lining of Porter Canal
Location: Idaho Falls, Idaho
Owner: New Sweden Irrigation District
Contractor: HK Contractors, Inc.
Material: Canal^3 12-30-12

Case Study

In 2004, after years of concrete repairs, and high seepage rates, Hidalgo County Irrigation District No. 2 located in San Juan, Texas decided to rehabilitate their Lateral "A" canal. The 7.26-mile lateral was drained, and cleaned of loose debris, as well as cracks filled prior to the installation of **Canal^3** 8-20-8 geocomposite above the existing concrete canal. Approximately 850,000 ft^2 of **Canal^3** were supplied in standard and custom roll widths to reduce waste along the entire reach of the canal. The Contractor employed a modified shotcreting method for placing the 3-inches of shotcrete above the **Canal^3** which resulted in placing over 125 yd^3/day. Incorporating the **Canal^3** above the existing concrete canal with the shotcrete above provides a "secondary" containment layer beneath the shotcrete layer extending the life of the canal beyond 50 years, according to the 10-year Study written by the Bureau of Reclamation.

Project: Rehabilitation of Lateral "A" Canal
Location: San Juan, Texas
Owner: Hidalgo County Irrigation District No.2
Contractor: McAllen Construction
Material: Canal^3 8-20-8

Basetrac®

Engineered polypropylene biaxial geogrids provide tensile reinforcement, confinement and separation to the base and subbase aggregate layers for both paved and unpaved roads that are used to access canals for periodic maintenance. Basetrac® geogrids increase the bearing capacity of underlying soils by introducing a uniform tensile element into the roadway system that distributes the applied loads over a greater area. Lateral displacement of the aggregate is reduced with Basetrac® geogrids, thereby maintaining the base course thickness.

Fortrac®3D

Fortrac® 3D is a further development of the renowned Fortrac® geogrid and is used for slope stabilization, veneer stability and turf reinforcement to control soil erosion. Fortrac® 3D is a flexible, three-dimensional reinforcement grid manufactured from high tensile strength, creep resistant yarns with a three-dimensional structure that enhances its interaction with soil. The geogrid is given a special polymer coating to protect it from UV exposure and installation damaged. It is well understood long-term properties allow Fortrac® 3D to be designed for the specific period of use required for each project.

Ultimat®

Ultimat® needle-punched nonwovens are manufactured using polypropylene or polyester staple fibers to produce the widest widths and heaviest weights available in many colors. Ultimat® heavyweight nonwovens provide excellent puncture protection when placed above and below membrane liners in reservoirs and landfill applications. The wide width greatly reduces the installation costs when compared with typical nonwoven widths. Ultimat® also provides superior separation between finer subgrade soils and typical base course extending the life of roadways. Using various denier staple fibers, Ultimat® can be designed for capping application where filtration of specific particle sizes are required.

Canal^3® is a lining solution for irrigation canals and other water containment applications. The top and bottom layers of the nonwovens not only provide increased puncture protection, but also increased interface friction. **Canal^3®** is neither affected by changing temperatures or frost which typically cause cracks in concrete lining solutions or by animals which often cause damage to membrane liners. This innovative canal liner can be installed in exposed or buried applications. Shotcrete can also be applied onto **Canal^3®** for additional protection from vandalism and ultraviolet light.

For more information about the application of **Canal^3®**, please contact us.

Canal3® is a registered trademark of HUESKER, Inc.

HUESKER Synthetic is certified to ISO 9001, ISO 14001 and ISO 50001.

HUESKER, Inc.

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Further Information:

HUESKER
Ideas. Engineers. Innovations.

HUESKER

CANAL^3

INSTALLATION MANUAL

FIRST EDITION 3/2005
REVISED REPRINT V2.0 9/2005
REVISED REPRINT V3.0 2/2006

SECOND EDITION 9/2009

TABLE OF CONTENTS

HUESKER'S CANAL^3 INSTALLATION MANUAL

1.0 SPECIFICATIONS

The following is general specification data. For more specific installation information, contact one of our field representatives or call our technical department at the number below for prompt service.

1.1 MANUFACTURER

Huesker inc.
10701-W South Commerce Blvd.
P. O. Box 411529
Charlotte, NC 28241-1529

Tel - (800) 942-9418
Tel - (704) 588-5500
Fax - (704) 588-5988

2.0 PRODUCT

2.1 PRODUCT DESCRIPTION

The Huesker geocomposite "Canal^3" is a high performance puncture-resistant geocomposite and is typically manufactured in two types:

Canal^3 8208
HUESKER'S CANAL^3 8208 IS A GEOCOMPOSITE GEOTEXTILE THAT CONSISTS OF TWO (TOP AND BOTTOM) 8 OZ/YD^2 POLYESTER NONWOVENS BONDED TO 20 MILS OF A AN EVA GEOMEMBRANE. THE CANAL^3 8208 GEOCOMPOSITE IS INERT TO BIOLOGICAL DEGRADATION AND NATURALLY ENCOUNTERED CHEMICALS, ALKALIES, AND ACIDS.

Canal^3 123012
HUESKER'S CANAL^3 123012 IS A GEOCOMPOSITE GEOTEXTILE THAT CONSISTS OF TWO (TOP AND BOTTOM) 12 OZ/YD^2 POLYESTER NONWOVENS BONDED TO 30 MILS OF A AN EVA GEOMEMBRANE. THE CANAL^3 123012 GEOCOMPOSITE IS INERT TO BIOLOGICAL DEGRADATION AND NATURALLY ENCOUNTERED CHEMICALS, ALKALIES, AND ACIDS.

Canal^3 can be custom made to accommodate any type of subgrade condition, i.e., CANAL^3 82012 used in an area where the subgrade may be rough and extra protection is required.

Product marking/overlap line if required

2.2 PRODUCT SUPPLY SPECIFICATIONS

The following table describes the typical roll dimensions for Huesker's Canal^3. Custom lengths are available upon request.

PRODUCT	MEMBRANE THICKNESS		WIDTH		LENGTH		AREA		ROLL WEIGHT	
Canal^3	mils	mm	ft	M	ft	m	ft^2	m^2	lb	kg
CANAL^3 8208	20	0.5	17	5.2	360	110	6,120	572	1,580	720
CANAL^3 8208	20	0.5	25	7.6	300	91.4	7,500	695	1,930	870
CANAL^3 123012	30	0.75	17	5.2	300	91.4	5,100	475	1,820	830
CANAL^3 123012	30	0.75	25	7.6	300	91.4	7,500	695	2,660	1,200

CANAL^3 8208 and CANAL^3 123012 are rolled on six-inch inside diameter composition cores. Dimensions and weights are approximate. Special length rolls may be produced to meet specific job requirements.

2.3 MATERIAL PROPERTIES

PHYSICAL PROPERTIES OF CANAL³ 8208 GEOCOMPOSITE

PROPERTY	TEST METHOD	VALUES
Mass Per Unit Area	ASTM D-5261	36 oz/yd^2
Membrane Thickness	ASTM D-5199	20 mils
Grab Tensile Strength (MD)	ASTM D-4632	300 lbs
Grab Elongation (MD)	ASTM D-4632	>50 %
Trapezoid Tear Strength (MD)	ASTM D-4533	100 lbs
Puncture Strength, (5/16)	ASTM D-4833	175 lbs
Permeability	ASTM D-4491	Non-measurable

Roll Sizes – Width 17 feet x Length 360 feet
Width 25 feet x Length 300 feet

PHYSICAL PROPERTIES OF CANAL³ 123012 GEOCOMPOSITE

PROPERTY	TEST METHOD	VALUES
Mass Per Unit Area	ASTM D-5261	50 oz/yd^2
Membrane Thickness	ASTM D-5199	30 mils
Grab Tensile Strength (MD)	ASTM D-4632	500 lbs
Grab Elongation (MD)	ASTM D-4632	>50 %
Trapezoid Tear Strength (MD)	ASTM D-4533	150 lbs
Puncture Strength, (5/16)	ASTM D-4833	250 lbs
Permeability	ASTM D-4491	Non-measurable

Roll Size – Width 17 feet x Length 300 feet
Width 25 feet x Length 300 feet

Each roll of CANAL³ 8208 and CANAL³ 123012 geocomposite delivered to the project site is labeled by HUESKER® with a roll label that indicates manufacturer's name, product identification, lot number, roll number and roll dimensions. All rolls of Canal³ are encased in a sturdy polyethylene wrap to shield the product from rain, dirt, dust and ultraviolet light. Contact HUESKER for information on our material warranty.

These specifications are offered as a guide for consideration to assist engineers with their specifications; however, Huesker inc. assumes no liability in connection with the use of this information. The specifications on this data sheet are subject to change without notice.

3.0 GENERAL SPECIFICATIONS

3.1 SCOPE OF APPLICATION

Canal^3 is designed for use as an impervious barrier in water containment and conveyance structures. The following are a few examples where Canal^3 can be utilize:

- Irrigation: concrete and earthen canals, ditches, laterals
- Dams: upstream facing (exposed or protected)
- Lakes, ponds, reservoirs, fountains
- Retention and storm water basins
- Waste water: storage and purification
- Embankments: positive cutoff
- Landfill Caps

Canal^3 can be used in most geotechnical applications. Please consult Huesker's Geocomposite Division for specific applications not listed above.

Ponds

Canals with Shotcrete cover

Fish Ladder Bays

Exposed Canal applications

Diversion Dams

Canals with earth or rock cover

3.2 GENERAL REQUIREMENTS

Excavation, backfilling and all engineered surfaces on which Canal³ will be applied must be prepared in accordance with the most current practice of soil mechanics to ensure that they remain stable under all conditions of use.

3.3 SHIPPING AND STORAGE

Canal³ rolls are wrapped in plastic and may be stored on the ground. A tarp should be placed over the material in order to protect it from the elements if stored for a long period of time. Full truck load orders are shipped using flat bed trailers. Care should be taken when off loading the material.

Canal³ ready to be off loaded at a jobsite.

3.4 HANDLING

Handle all materials in such a manner as to preclude damage and contamination from moisture or foreign matter. Handle rolled goods to prevent damage to edges or ends.

3.5 DAMAGED MATERIAL

Any materials that are found to be damaged or stored in any manner other than stated above will be automatically rejected, removed and replaced at the Contractor's expense.

4.0 SITE PREPARATION

4.1 GENERAL

Design of the subgrade falls within the field of civil/geotechnical engineering. A qualified professional engineer should review all subgrade designs. The $Canal^3$ installation shall not begin until a proper base has been prepared to accept the geocomposite material.

4.2 VEGETATION

All vegetation and traces of organic vegetable substances must be removed in order to prevent direct contact of large roots with the geocomposite material and rotting of organic substances such as roots, etc., which would make the soil compressible and would release gas.

4.3 SLOPE OF EMBANKMENTS/STABILITY

Design of the slopes must comply with current practices of soil mechanics. The slopes must be stable. $Canal^3$ serves as waterproofing material only. The excavation shall be well contoured with a maximum slope of 1.5:1. $Canal^3$ can be used on steeper side slopes in some installations. Please contact Huesker, inc. for specific subgrade acceptance.

4.4 SUBGRADE PREPARATION - SOIL

The subgrade should be smoothed so no protrusions or sharp rocks on the surface exceed 4-inches in diameter. The areas near the seams should be free of large stones so seaming can performed.

The subgrade should be smooth and free of debris, soft spots and should not have abrupt transitions. Sloped subgrades consisting of loose material (sand, gravel or rubble) should be stabilized.

If there is a risk of vegetation growing under the geomembrane, the soil must be treated with chemicals compatible with $Canal^3$. Contact Huesker, inc. for compatible soil sterilants.

4.5 SURFACE PREPARATION – CONCRETE, ASPHALT

Concrete/asphalt surface should be clean and dry prior to installation. Canal^3 can be placed over concrete and asphalt substrates provided that all cracks and voids over 4-inches are filled, and the surface is made level or uniformly sloped. Canal^3 can be loose laid or glue applied to these substrates.

4.6 GAS AND GROUNDWATER

Any organic substances in the soil may deteriorate and release gases that can inflate the Canal^3 material. If Canal^3 is ballasted, a gas drainage system is not necessary. If Canal^3 is not ballasted, a drainage system may be necessary. Gas drainage vents must be fitted with a valve to prevent excessive pressure under the geocomposite.

If ground water under Canal^3 is likely to cause damage due to hydrostatic back pressure, a drainage system must be provided. This can be achieved by installing a layer of drainage sand or a synthetic drainage layer prior to installing the geocomposite.

A filter must be provided between the surrounding soil and the drainage layer, depending on the soil gradation, to prevent infiltration of soil into the drainage system. Drainage water is collected in drain pipes and a sump located at the lower end of the structure. A complete drain system should be placed under the geocomposite if required. When possible, the drainage system should be designed to detect any leakage through the geocomposite.

A gas drainage system should always be installed along with a water drainage system.

5.0 HUESKER GEOCOMPOSITE INSTALLATION

5.1 GENERAL

Canal^3 shall be placed over the prepared subgrade in such a manner to ensure minimum handling. Anchor trench excavation should be completed before the lining installation begins. The rolls shall be of maximum design size and shall be placed in such a manner as to minimize seaming. Only those rolls of material, which can be anchored and seamed together that same day, shall be unrolled and placed in position.

In areas where wind is prevalent, lining installation should be started at the upwind side of the project and proceed downwind. The leading edge of the membrane shall be secured at all times by means of ballast (i.e. sandbags) spaced every 3 feet to hold it down during high winds.

Canal^3 shall be closely fitted and sealed around inlets, outlets and other projections through the liner.

5.2 HANDLING

Special mechanical equipment is necessary to handle Huesker's Canal^3 which has a roll width of 25 feet as shown in the pictures on the next page.

Simple lifting bars built by the irrigation districts. Minimum pipe diameter is 3 inches


One lifting bar built by an irrigation district (left) and one built by a contractor (right)

5.3 UNROLLING HUESKER CANAL[3] 25 FEET WIDE ROLLS

Twenty-five feet wide rolls are packaged with the black polyester textile on the inside so that it is on top when unrolled from a mobile gantry, crane or backhoe.

Canal[3] being unrolled across the canal

5.4 PLACEMENT OF ROLLS

Due to the weight and length of the wide rolls, mechanical placement of the rolls is necessary by one of the following methods; a crane, backhoe, or mobile gantry suspended from an excavator. Construction equipment shall not be allowed to operate directly on the liner except for all terrain vehicles that produce ground pressure less than 5 pounds per square inch.

The only case when a mobile gantry is not required is when the roll length does not exceed 80 feet. The use of a light crane or backhoe is still necessary for handling the shorter rolls. The contractor for specific application requirements can design unrolling devices.

5.5 SEAMING HUESKER CANAL^3 GEOCOMPOSITE

Canal^3 geocomposite rolls cannot be thermally bonded at the overlap while unrolling the roll. The material should be unrolled and overlapped a minimum of six (6) inches. Seams may be joined using hot melt adhesive, epoxy glue or wedge welded. All seams shall extend to the outside edge of the liner. Seamed surfaces shall be free of moisture, dust, dirt, standing water, or soft prepared surface material. Seaming shall not be performed when the ambient sheet temperature is below 32 degrees Fahrenheit.

Horizontal seaming on side slopes is not recommended. If the geomembrane is not ballasted with cover material and is subject to flowing water, i.e. canals, seams must be laid in a shingle fashion downstream. Overlaps must be increased by two (2) inches when covering an irregular substrate.

Canal^3 being seamed with a hot melt adhesive

Seaming to ensure water tightness should be only done with a hot melt adhesive. The following are recommended methods of installation:

1. Exposed Canal[3] –
   A. Used in a Canal: overlaps should be shingled in the downstream direction and glued.
   B. Used in a Pond: overlapped and glued.

Note: Methods A and B are the only two approved/tested methods for watertight seams.

2. Buried Canal[3] (earth or concrete) –
   C. Same as A above.
   D. Same as B above.
   E. Overlap one (1) foot and tack to hold in place and cover.

   Note: All buried applications may be adhesively glued, wedge welded, Leistered (using hot air), or some other method, which will hold the geocomposite together while applying the cover material.

5.6 SEAM INSPECTION

Upon completion of the Canal[3] installation, the installation contractor shall visually inspect all seamed areas for obvious defects. Any suspect areas shall be further tested and repaired as necessary.

5.7 PATCHING/REPAIRING

Repairs/patching of the Canal[3] shall be made with the material on a cleaned surface. The patch shall extend a minimum of six (6) inches in each direction beyond the damaged area. Completely bond the patch material to the prepared surface, smoothing out any wrinkles.

6.0 ANCHORING

6.1 ANCHOR TRENCH

Canal[3] shall be anchored at the top of the slope to prevent the geomembrane from slipping down the embankment and to allow the geomembrane to resist wind uplift. During installation the membrane must be held in place at the top of the side slopes before anchoring. Temporary ballasting in trenches can be accomplished with sandbags or soil. Mechanical anchors (18" rebar with a 4-inch bend at the top) can also be used to secure the membrane temporarily until the trench can be filled.

As a general guideline, the width and depth of the trench to be excavated at the top of the slope is indicated in the table below in relation to the length of the side slope. A V-Notch type trench may be used in lieu of the standard type. The length of the run out in relation to the length of the side slope is given in the table below.

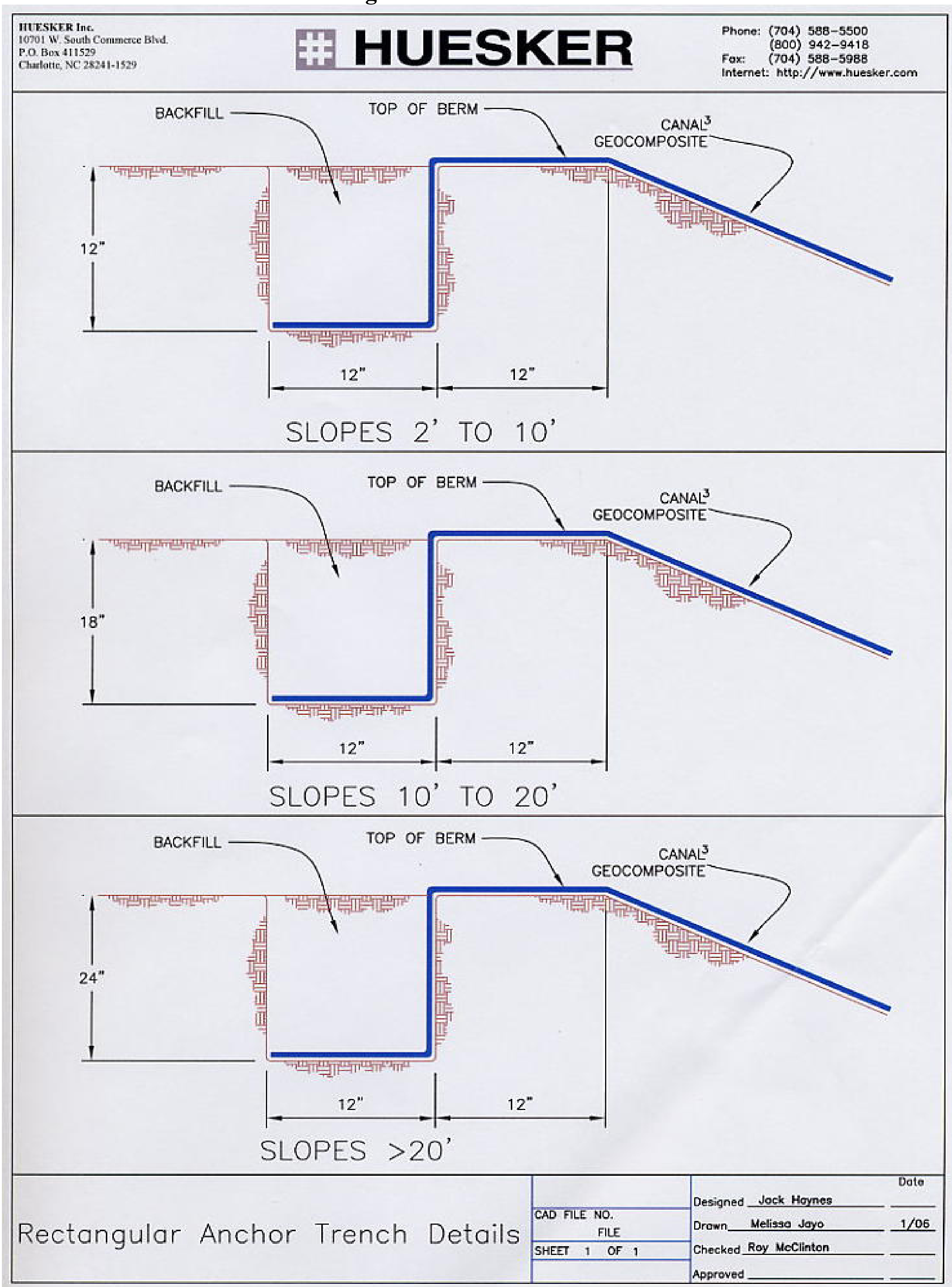
Rectangular Anchor Trench (see details)

Length of Slope (Feet)	Trench Area Cross Section		
	Bank Length (in)	Trench Width (in)	Trench Depth (in)
2-10	12	12	12
10-20	12	12	18
20 and greater	12	12	24

Note: THE ABOVE TABLE IS ONLY A GENERAL GUIDELINE

Rectangular Anchor Trench (10 – 20 ft slope)

Rectangular Anchor Trench Details



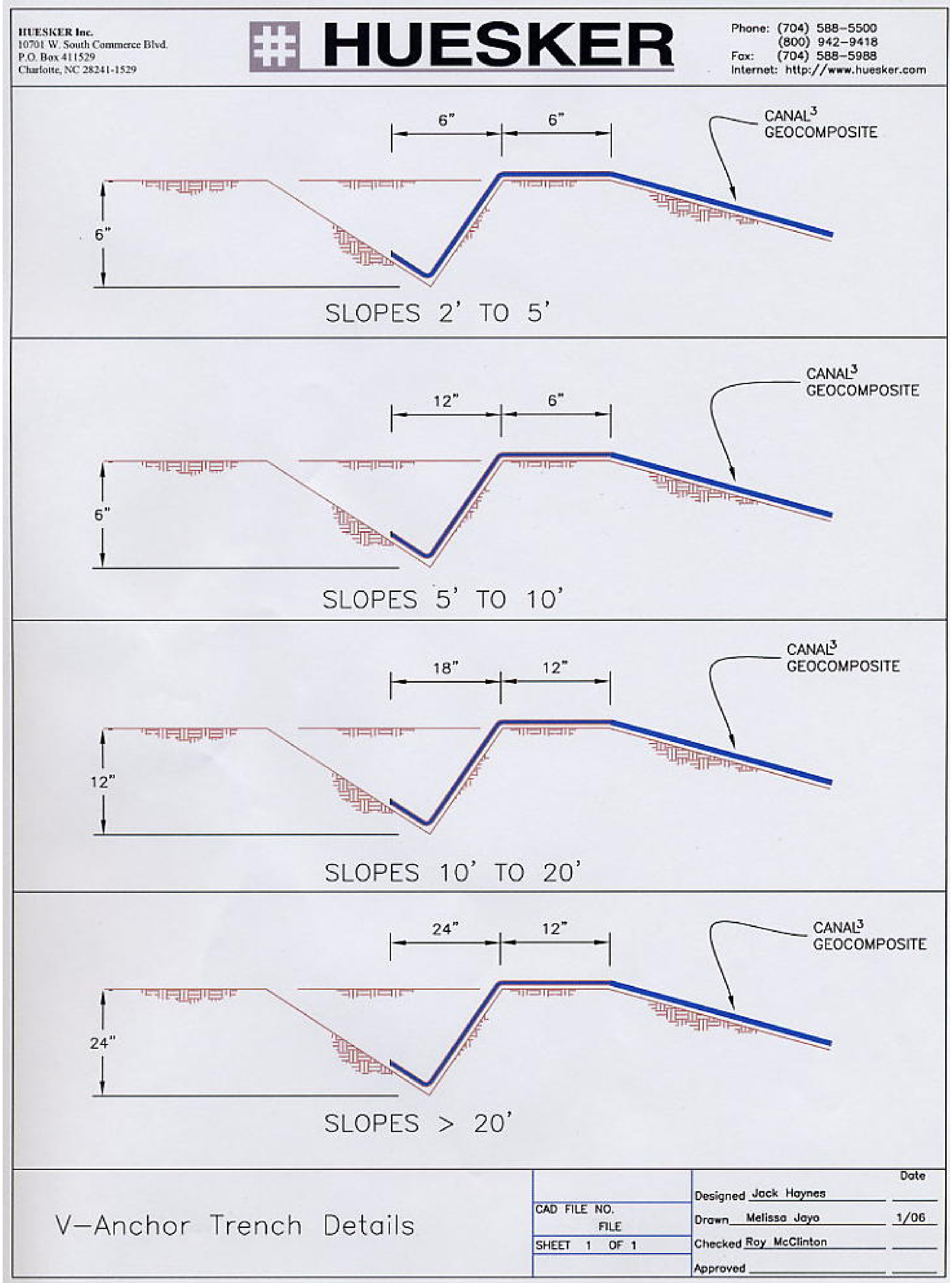
V-Anchor Trench (see details)

Length of Slope (Feet)	Trench Area Cross Section		
	Bank Length (in)	Material Width (in)	Trench Depth (in)
2-5	6	6	6
5-10	6	12	6
10-20	12	18	12
20 and greater	12	24	24

Note: THE ABOVE TABLE IS ONLY A GENERAL GUIDELINE

V-Anchor Trench (2 – 5 ft side slope)

V-Anchor Trench Details



6.2 CUT-OFF TRENCH

A cut-off trench is used when starting a lining job in the middle of a canal section. The anchor trench should be excavated across the width of the canal. The trench should be deep enough to prevent water from getting under the liner, usually between one to two feet deep and 18 inches wide in an earth canal.

In a concrete canal this trench may be smaller as long as the water is not permitted to get under the liner.

Cut-off trench excavated across the canal bottom (Earth)

Cut-off trench excavated across the canal bottom (Concrete)

6.3 BOTTOM OF SLOPE (DAM APPLICATIONS)

Canal^3 shall be anchored at the bottom (toe) of the slope to ensure the stability of the geomembrane under wind suction/pressure effect and to ensure the continuity of the waterproofing between the geomembrane and the substrate.

6.4 BALLASTING

Ponds or basins that do not have permanently stored liquids in them may require ballasting or attachment with soil anchors to resist wind uplift pressures. Contact Huesker's Geocomposite Division for specific ballasting requirements based on expected wind forces.

6.5 ATTACHMENT TO CONCRETE (Vertical and Horizontal Walls)

Where Huesker's Canal^3 is to be attached by a mechanical attachment to concrete, the concrete shall be thoroughly cleaned of all scum and scale. The area where the attachment is made shall be six (6) inches in width unless noted otherwise and fastened according to the detail below. Canal^3 can also be glued and mechanically fastened to any structure to avoid leaks. However, to avoid the high cost of this method, premixed concrete bags or sand bags may be placed on the liner next to the structure as tight as possible to stop the large leaks.

Canal^3 glued to the side of the wall

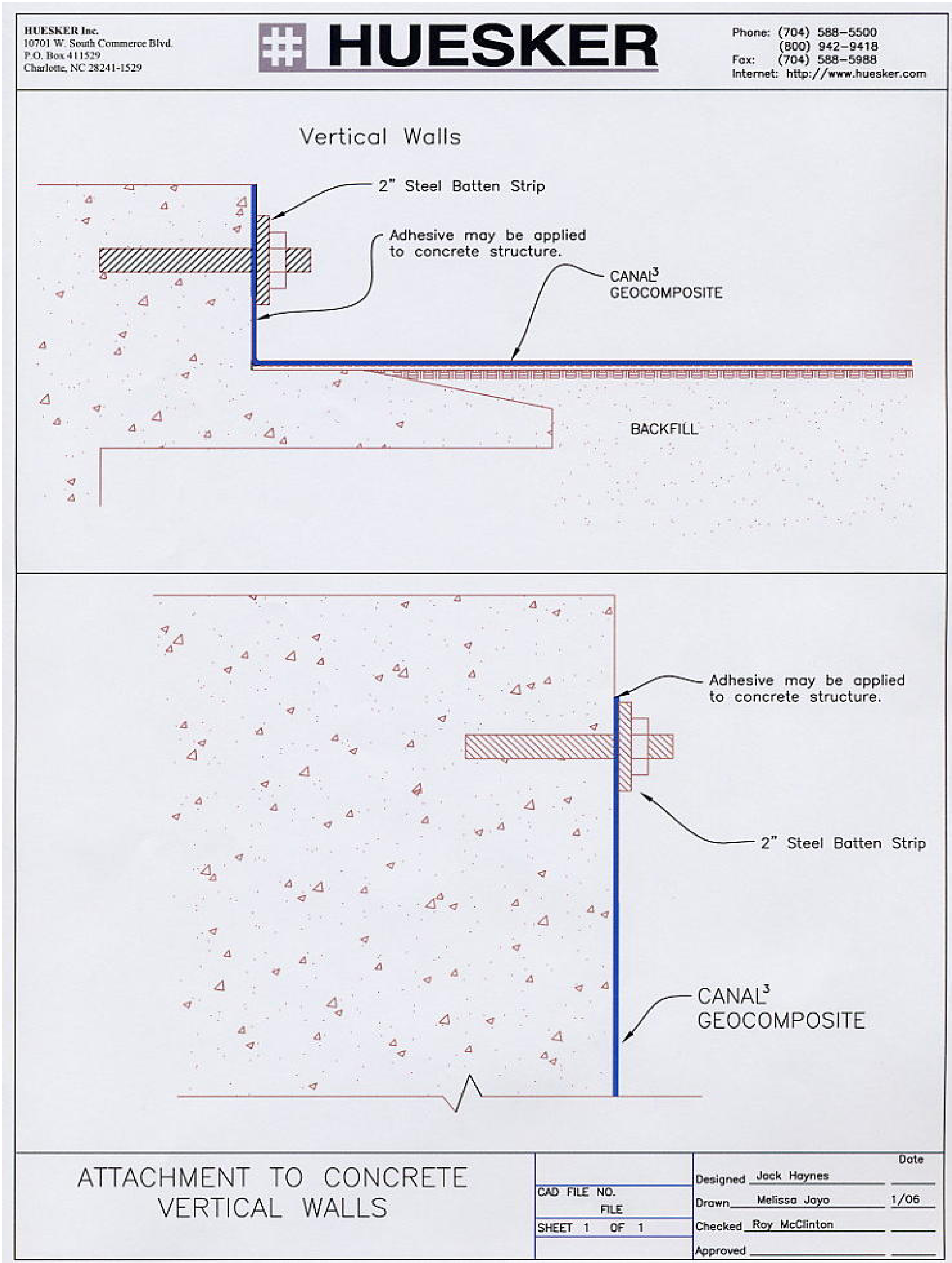
Concrete bags used to hold material down

ATTACHMENT TO CONCRETE (Vertical and Horizontal Walls continued)

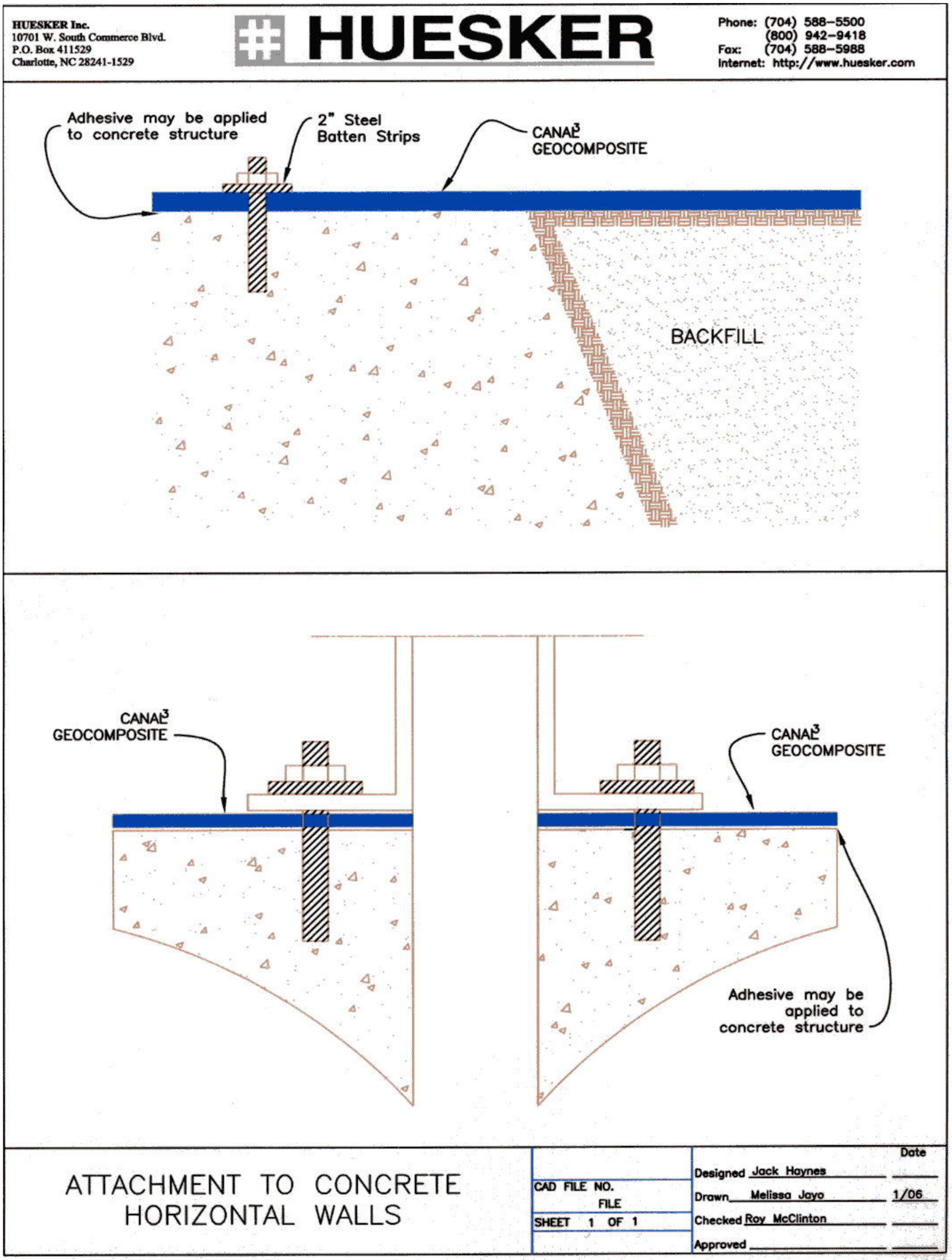
Two inch steel batten strips anchored to wall with expansion anchors on one foot spacing

Steel batten strips anchored to wall with two expansion anchor bolts on each end

ATTACHMENT TO CONCRETE (Vertical and Horizontal Walls continued)



ATTACHMENT TO CONCRETE (Vertical and Horizontal Walls continued)

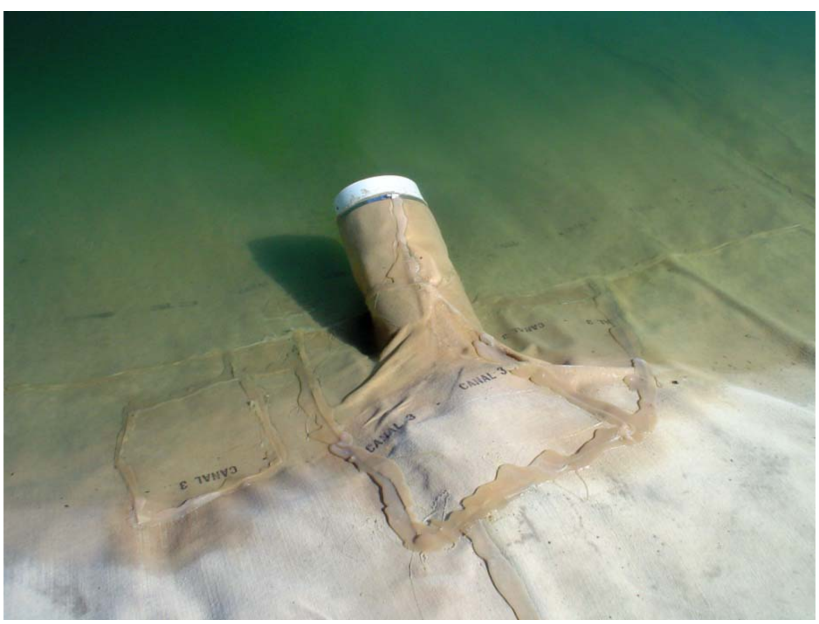


6.6 TYPICAL BOOT DETAILS

Where Huesker's Canal^{3} is to be attached to a pipe, small pieces are cut to fit snugly around the pipe and glued in place. The area where the attachment is made shall be one foot in width unless noted otherwise and fastened according to the detail below. A strip of Canal^{3} should be cut so a mechanically fastened clamping collar can be attached to the pipe to avoid leaks.

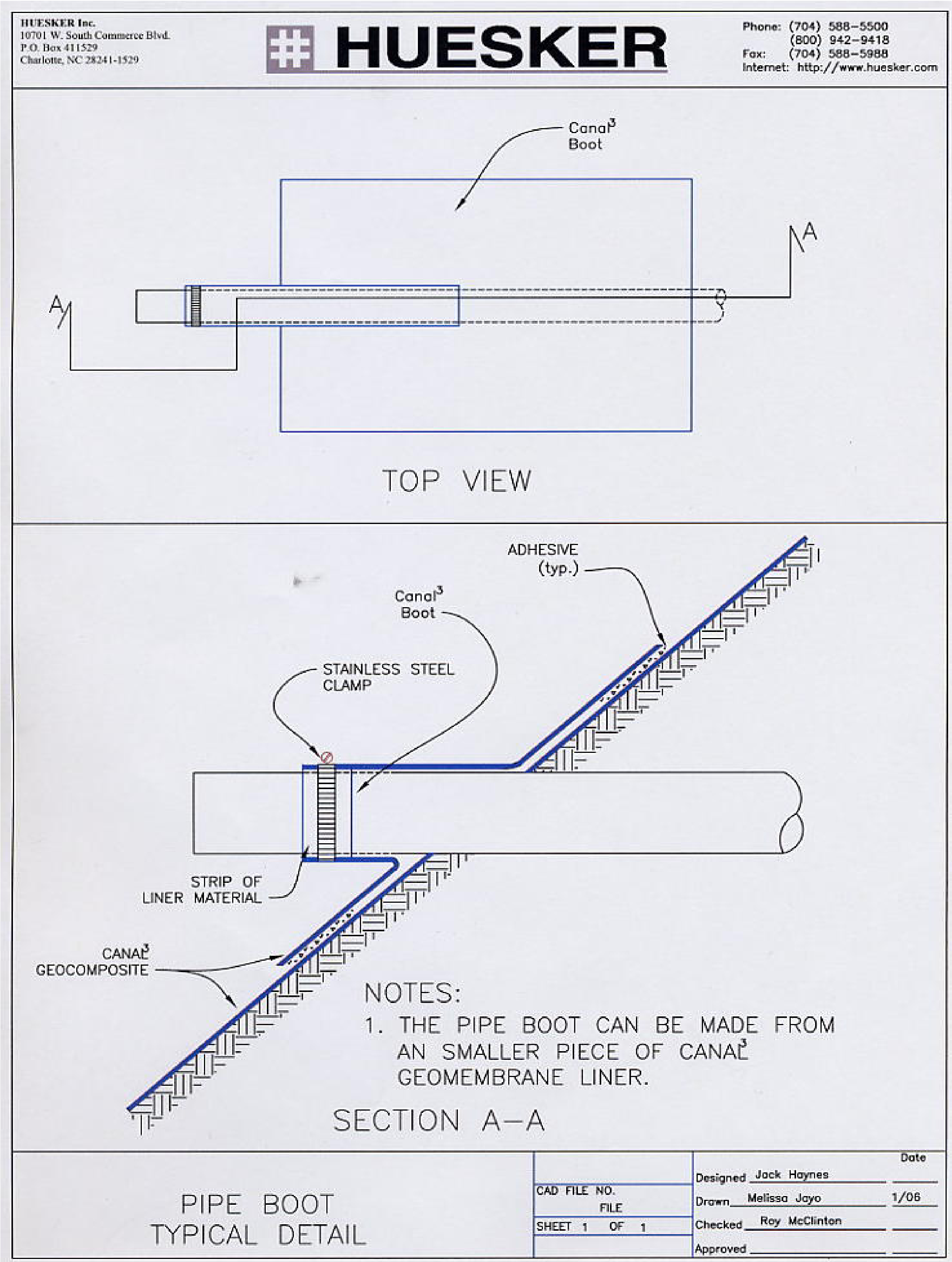
However, to avoid the high cost of this method, a premixed concrete collar may be used if the job was to be under concrete/shotcrete. Sand bags may be placed on the liner next to the pipe as tight as possible to stop the large leaks if the job was to be buried under earth.

Finished boot around 12 inch PVC emergency outlet pipe



Finished boot around 10 inch PVC fill pipe

CANAL[3] PIPE PENETRATION (BOOT) TYPICAL DETAIL



7.0 MEMBRANE PROTECTION

Canal^3 can withstand normal foot and light vehicle traffic without additional protection. However, Canal^3 is susceptible to damage from tracked machinery, tired vehicles when the tires are inflated at a higher pressure than the ground resistance, vandalism, gun shots and excessive traffic. Canal^3 can withstand occasional animal traffic.

7.1 PROTECTION LAYER

For protection on the upstream face of dams, it is important that the design allow for the drainage of water between the protection layer and the geomembrane. Protection layers can be soil, sand, rubble or concrete pavers.

7.2 WATER FLOW PROTECTION

Protection may be required when Canal^3 is used in a fast flowing canal. Special design features may be required when the velocity exceeds 4 ft/sec. Contact Huesker's Geocomposite Division for specific project requirements.

HUESKER inc.

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P.O. Box 411529
Charlotte, NC 28241-1529

Tel. (704) 588-5500 (800) 942-9418
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Fax (208) 853-1610
Email jahaynes@hueskerinc.com

Canal^3
When Every Drop Counts

Our strength lies just beneath the surface

HUESKER

Appendix C – Contact Information

Project Contact List

Name	Company Name	Contact Title	Phone Number	E-Mail Address	Notes
Seth Briggs	North Jordan Canal	Engineer for North Jordan Canal	801-243-9029	seth@edmllc.net	He is the engineer that recommended and oversaw the installation of Huesker Liner for the North Jordan Canal
Robert (Bob) Wirthlin	North Jordan Irrigation Company	President	801-450-1523	aztecsteel@comcast.net	He is president over the NorthJordan Canal, he says the liner has been durable and he recommended it to us
-	South Jordan Canal Company	Office	801-859-4248		
Louis Chadwick	South Jordan Canal Company	Maintenance Manager	435-243-3111		We talked to him concerning the possibility of the City working with him to line the canal, he said they would be open to the option. He may be the best contact to get things moving for the canal.
Josh Hanks	Intermountain Environmental (IEI)	Salesmen / Cost Estimator	435-755-0774 (Ext 223)	jhanks@inmtn.com	Josh is who we talked with for estimating the cost of the 3 wireless piezometers, see attached cost estimate in the appendix from IEI. IEI is based out of Logan Utah and he would be the man to speak to concerning installing the piezometers
Brett Borup	Brigham Young University	Professor	801-422-6311	borupb@byu.edu	Dr. Borup was the adviser to the students for this project.

Appendix D – AGEC Geotechnical Report

AGEC
Applied GeoTech

GEOTECHNICAL INVESTIGATION

LOVERS LANE SLOPE STABILITY

APPROXIMATELY 1100 WEST BETWEEN
13000 SOUTH AND 13800 SOUTH

RIVERTON, UTAH
PROJECT 176-15

PREPARED FOR:

RIVERTON CITY CORPORATION
12830 SOUTH REDWOOD ROAD
RIVERTON, UTAH 84065

ATTENTION: ENGINEERING DEPARTMENT

PROJECT NO. 1150135 JUNE 19, 2015

600 West Sandy Parkway • Sandy, Utah 84070 • (801) 566-6399 • FAX (801) 566-6493

TABLE OF CONTENTS

EXECUTIVE SUMMARY

A. PROBLEM (as presented by Riverton City)

Historically, Lovers Lane has served as a single-lane roadway that has provided access to local agricultural properties. Pressure to develop these properties has been a cause of concern for Riverton City. These concerns have been triggered by the presence of constant water seepages along the face of the east and west slope of the roadway.

The South Jordan canal sits at the top of the west slope and a South Valley Sewer District trunk line parallels Lovers Lane in said slope.

The west slope is also dotted with corrugated drainage standpipes connected to drain lines that discharge groundwater to the east slope of Lovers Lane. Many of these pipes are plugged or collapsed. The east slope is heavily vegetated and saturated with discharges from drain lines and springs. There are also existing culinary and secondary water lines in Lovers Lane.

Developers have proposed that Lovers Lane be widened to a two-lane facility with construction of single-family residential homes on the downhill side of the roadway. Riverton City is concerned with the stability of the canal, roadway side slopes and the drainage of groundwater along Lovers Lane.

B. CONCLUSIONS

The study area was separated between what is considered the "S" Turn portion of the project and also the Lovers Lane project.

The subsurface conditions, the existing ground surface profile along with the evidence of water seepage from the hill slope has been used along with laboratory test results, engineering analysis and our professional engineering judgement in order to provide our opinion on the relative stability of the slopes in question.

> <u>"S" Turn</u> - The "S" Turn area was found to have an appropriate factor of safety against slope instability under static conditions of 1.6. Analysis indicates that a significant seismic event could result in down slope movement the order of 1 foot.
>
> There are also deposits of potentially liquefiable soil in this slope which would increase the likelihood of slope instability and the potential for significantly larger lateral movements during a major seismic event.

Lovers Lane Section - It is our professional opinion that the stability of a majority of the slope above Lovers Lane is marginal (safety factor near 1).

We anticipate that the installation of drainage pipes has helped maintain the stability of the slope.

Any improvement of the stability of the slope would require placement of a buttress fill on the lower portions of the slope by flattening the slope from the crest of the hill to the toe.

With the static stability being marginal a seismic event could result in significant lateral movement and damage to the canal, roadway and utilities.

Improvements along Lovers Lane, with a wider traffic right-of-way, could help improve the stability due to the placement of fill that would act as a buttress to support the hillside.

It will be important during conceptual design to include the stability of the overall slope and also the potential for liquefaction. This may necessitate the inclusion of some type of ground improvement in the potential liquefiable zones or sufficient soil to buttress the toe of the slope.

SCOPE OF WORK

Applied Geotechnical Engineering Consultants, Inc. was requested to conduct an investigation into the stability of the slope which supports the South Jordan Canal, a South Valley Sewer Line, Lovers Lane and utilities by investigating the subsurface conditions, testing soil samples obtained, measuring the groundwater level and measuring the relative profile of the existing ground surface.

The information obtained was evaluated to develop our professional opinion on the relative stability of the hillside and also allowing us to estimate the likelihood of future instability. This report summarizes the information developed and our opinions that relate to the stability of the slope.

PREVIOUS STUDIES

AGEC has conducted geotechnical investigations in the general area near Lovers Lane over the past many years. The subsurface information from these studies have been considered in our analysis. Of particular interest were borings drilled at four specific locations listed below:

1. Liquefaction Hazard Evaluation; 1113 West 13749 South
2. Geotechnical Investigation; 13270 South 1192 West
3. Geotechnical Investigation; 950 West 13500 South
4. Geotechnical Investigation; 13895 South Redwood Road

Each of these reports provide subsurface soil and groundwater information. These studies indicate the groundwater level west of the slope is typically 15 to 20 feet below grade. The water level is within a few feet of the ground surface on the down slope side.

HISTORY

Based on our conversation with personnel from the canal company, we understand that seepage occurs year around. The canal company is not aware of movement of the hillside and that the canal has performed well for many years.

FIELD INVESTIGATION

The field investigation included documenting the location and elevation of seeps, drain pipes and stand pipes that were observed along the hillside. The ground surface profile was also measured at three locations.

The subsurface investigation consisted of drilling three or four borings along three profiles along with one additional boring. The borings were advanced to depths ranging from 20 to 40 feet and soil samples were obtained at frequent intervals in the upper soil where fill was encountered and then typically every 5 feet thereafter.

Slotted PVC pipe was installed in each of the borings to facilitate measurement of the groundwater level.

At the time of report writing, the PVC pipes remain in the borings with the anticipation that there may be a desire to leave them in place for future measurements of the water level.

GENERAL SLOPE CONDITIONS

Indicated on Figure 1 are the locations of the slope profiles that were evaluated during this study. Listed below is a table summarizing the basic characteristics of each of these slopes.

Slope Characteristics

Profile	Height of Slope (with respect to Lovers Lane			Slope (horizontal : vertical)	
	Above	Below	Total	Steepest	Overall
A	40	35	75	1.4:1	5.3:1
C	45	26	71	2.6:1	2.5:1
D	32	32	64	2.0:1	3.2:1

At the time of our field investigation, there were numerous areas where the soil was visibly wet on the up slope side of Lovers Lane. Water actually seeping from the hillside was also observed at numerous locations. The location of the visibly wet and the seeps correspond to those as indicated on Figure 1.

SUBSURFACE CONDITIONS

AGEC drilled twelve borings at the locations shown on Figure 1. The borings were drilled on May 19 through 22 and June 1, 2015. A representative of AGEC visited the site on May 29, 2015 to measure the water levels in the borings.

The subsurface profile as encountered in the borings generally consisted of fill extending from 2 to 6 feet below grade. The fill was predominantly sand with some areas where it was predominantly gravel.

The natural soil consisted predominantly of sand with varying amounts of silt. Clay and interlayered clay and silty sand was encountered at greater depth. Logs presenting the subsurface profile encountered are shown on Figures 2 through 4 with a legend on Figure 5.

Specific descriptions of each of the material types is included below.

Fill

There were two predominant types of fill material encountered in our borings. Description of each is below.

Silty Sand - The silty sand was occasionally gravelly and occasionally clayey. The density of the fill was found to be rather loose and occasionally medium dense. The sand was predominantly moist and brown.

Gravel - The gravel fill also contains silty sand. It was found to be predominantly medium dense. The gravel was moist and brown to black.

The natural soils were typically found to consist of the following;

Silty Sand and Slightly Silty Sand - The sand deposits were found to have varying amounts of silt. The silt content was as low as 2 percent. The sand was found to be predominantly loose and occasionally medium dense. Occasional gravels were also encountered. The sand was slightly moist to wet and brown.

Interlayered Lean Clay and Silty Sand - Interlayered lean clay and silty sand was encountered deeper in the soil profile. The cohesive portion of this deposit was found to be soft to stiff with the granular portion being medium dense. The soil was moist to wet and brow to gray in color with gray being at greater depth.

Silty Clay and Lean Clay - These deposits were found to occasionally contain sand lenses or layers. Consistency was soft to medium stiff, wet and brown to gray.

Gravel - The gravel was sandy with varying amounts of silt. It was medium dense to dense, moist to wet and brown to gray.

Water Level

The water level is described below based on the location of where the borings was drilled.

Measured Water Level

Location	Depth(ft)	Elevation (ft)
Top of Slope	10½ to 27½	4411.5 to 4424.5
Canal Maintenance Road	8 to 19	4410 to 4424
Lovers Lane	7 to 17	4378 to 4392
Lower Slope	12½ to 18	4356.5 to 4378

Of interest also is the range in elevation of most of the seeps along the hillside. These measurements were taken where water was exiting the slope and also the exit elevation of the drain pipes that have been installed. The elevation varies from 4401 to 4402 on the South to 4389 to 4396 on the North. Water seeps were measured to be at an elevation as high as 4405 (located between B-1 and C-3).

LABORATORY TESTING

A few of the samples obtained from the field investigation were tested for their index properties and strength characteristics. Listed below is a summary of the test results for the index properties for each of the general soil types.

Index Properties

	Moisture		Dry Density		-200	
	Range	Average	Range	Average	Range	Average
Fill	4-9	6	98-105	103	3-13	8
Sand	3-25	9	92-103	97	2-30	10
Clay	14-51	34	72-95	84	59-99	87

The soil strength was measured by conducting pocket penetrometer and torvane shear tests on the clay samples obtained and also by conducting an unconfined compressive strength test, a direct shear and a triaxial shear test on samples of the clay. Listed below is a table summarizing the findings for the direct shear and the triaxial shear.

Strength Test Results

				Direct Shear		Triaxial Shear	
Boring	Depth (ft)	Moisture Content	Dry Density	ϕ(degrees)	c(psf)	ϕ′(degrees)	c′(pcf)
A-2	39	51	70	28	520		
A-2a	16	43	79			26.5	135

Note: Boring B-2a was drilled adjacent to A-2 to obtain this sample.

ANALYSIS

The surface profile along with the subsurface information were evaluated and subsurface profiles developed. A presentation of each of these profiles is included on Figures 14, 16 and 20.

The strength characteristics of each of the soil types was modeled in our analysis by using the values listed below.

Soil	Density (pcf)	Friction (degrees)	Cohesion (psf)
Existing Fill	100	28	0
Sand	100	28	0
Clay and Clay Silt	110	26.5	135
Interlayered Clay and Silty Sand	110	27.5	100

Our analysis also includes evaluation of placing a buttress fill. The properties of the buttress fill was assumed to include a unit weight of 125 pounds per cubic foot (pcf), a friction angle of 36 degrees and cohesion of 0.

STABILITY RESULTS

Each profile was evaluated to determine the factor of safety under static conditions under a seismic event resulting in a horizontal acceleration of 0.25g. We also estimated the potential deformation should a major seismic event occur.

Listed below is a table summarizing the findings for the existing slopes.

Profile	Static Factor of Safety	Seismic Factor of Safety	Yield Acceleration	Deformation (ft)
A	1.6	0.8	0.17g	1
C	1.0	0.6	0.16g	1
D	1.0	0.6	0.16g	1

Assuming that the existing profile and water conditions do not change, we also evaluated the distance down slope that would potentially be impacted in order to develop a setback line for potential future development.

Indicated on Figure 1 is an approximated line indicating the toe where a slip surface having a factor safety of 1.5 would exit the ground surface. It must be understood that the line between the actual profiles has been estimated along with the fact that even though the section for Profile A indicates a safety factor of 1.6, we have continued the setback line in order to accommodate some potential uncertainties that may exist in that location.

FINDINGS

Based on this analysis, the existing slopes are marginal with respect to stability. The stability is most critical above Lovers Lane. If the slope above Lovers Lane is modified to improve it's stability then the overall hillside becomes of concern.

These studies have all been conducted assuming that the natural soils do not liquify under a seismic event. The hillside has layers of material that would be susceptible to liquefaction during a major seismic event. If these soils were to liquify the ability of the soil to support the slope and soil above it would be significantly compromised and the magnitude of movement would potentially would be more than indicated in our analysis.

The collection and removal of water from the hillside is important to maintain the stability. As part of our analysis we assumed that many of the existing drains were not functioning and the water was allowed to seep out onto the face of the slope. If this were to occur, we anticipate that the surficial portion of the slope would slump and potentially cause continued erosion and failure of the slope.

MITIGATION

It is our professional opinion that efforts should be taken to improve the stability of the hillside. Three options of mitigation are presented below that would provide an increased amount of improvement.

1. At the least, the existing seepage areas should be maintained and in many cases put back in order. Ideally, this would consist of excavating at each spring location and by placing a filter fabric, gravel and a pipe so that water could be collected before approaching the surface of the slope. Once collected the water could be directed away from the slope.

2. Improving the stability of the slope could be accomplished by buttressing the slope. The buttress would include placing fill at the toe of the slope extending up to the crest. We have analyzed this option by including a new 28-foot right-of-way for Lovers Lane. The slope would need to be 3:1 (horizontal to vertical) for Section"C" and a lower slope of 3:1 and an upper slope of 3.5:1 along Section D. This slope modification would result in factors of safety of greater than 1.5 under static conditions and would result in potential movement of 1 foot under a major seismic event. Figures 17-19 and 21-22 present the profiles analyzed.

   If the buttressing and flattening of the slope is conducted, it will be important to install a collection drain for each and every seep encountered. This could be accomplished with a french drain that is enveloped by a filter fabric, filled with gravel with sufficient sized pipe to accumulate and discharge the water.

3. All of the above mentioned modifications do not address the potential for liquefaction of the natural soil deposit. Improvement of this condition could

be accomplished by installing stone columns within the liquefiable zone. The method of stone columns should not incorporate a method that could result in excessive settlement of the existing materials due to the potential problem of settlement of existing utilities and of the canal.

We recommend that the City Planning and Engineering Departments evaluate the relative impact of various slope configurations in order to accomplish the desired of improvement. The key issues that should be considered is that the slope needs to be 3 to 3.5 to1 horizontal or flatter. Ground improvement would likely allow more flexibility on the final profile.

COST ESTIMATE

Listed below is an estimate of the potential costs for each of the steps indicated above.

Method	Estimated Cost
Drainage Maintenance and Improvement	$200,000
Buttress Fill and Flattening the Slope	$1.5 Million
Installation of Stone Columns	$2 Million

FURTHER STUDY

Based on the conditions encountered during the study, it is apparent that the soil conditions vary significantly across the site. We recommend that additional investigation and evaluation be conducted once a direction has been established to verify that the process will accomplish the benefit that is desired. These studies could potentially include the following.

1. Cone penetration tests and borings to further define the liquefiable zones.
2. Additional borings to increase confidence of the subsurface profiles.

LIMITATIONS

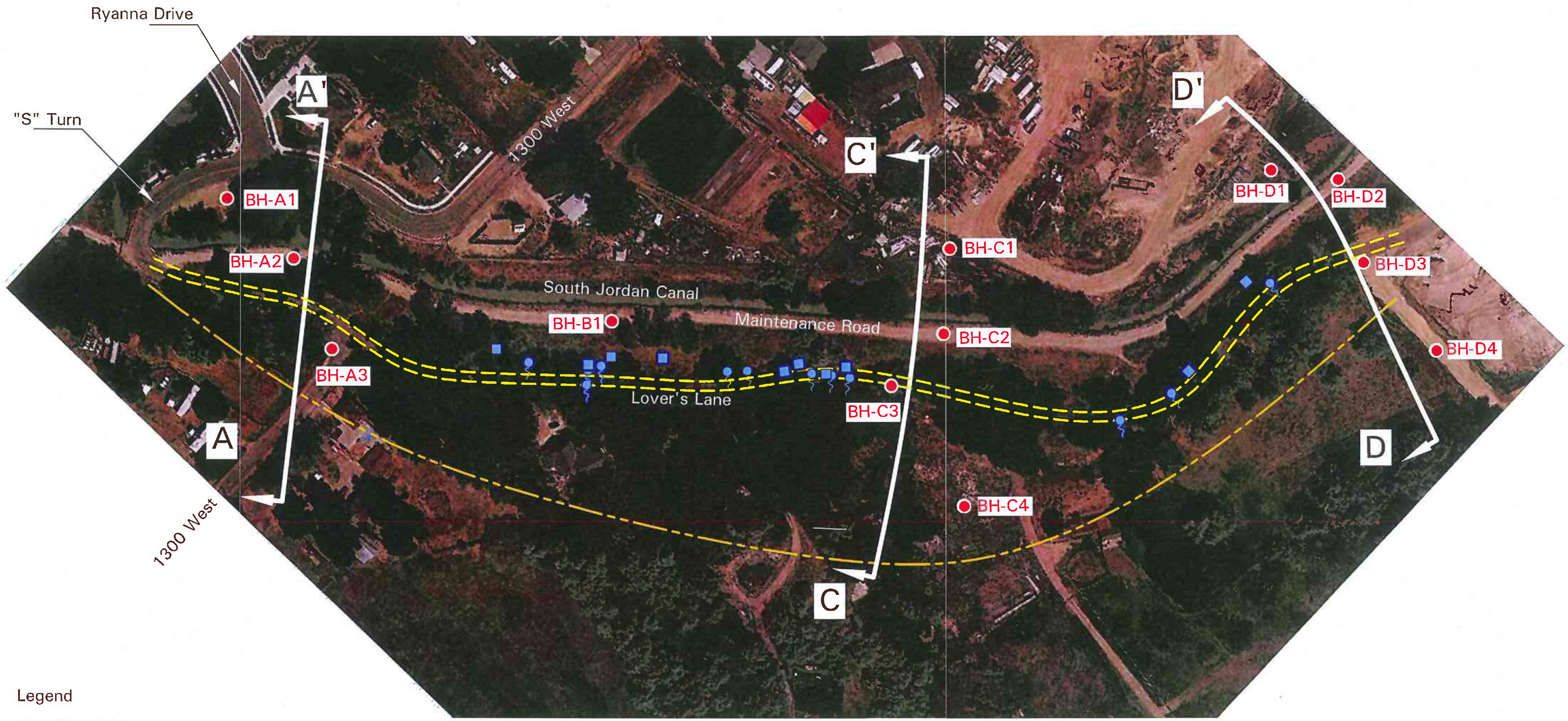
This report has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client. The conclusions and recommendations included within the report are based on the information obtained from earlier studies and the data obtained from the borings drilled and the laboratory test conducted. Variations in the subsurface conditions may not become evident until additional excavation is conducted. If new information becomes available, we should be notified to reevaluate our recommendations.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

REGISTERED PROFESSIONAL ENGINEER
No. 143916
JAMES E.
NORDQUIST
6/19/18
STATE OF UTAH

James E. Nordquist, P.E.

JEN/rs



Legend

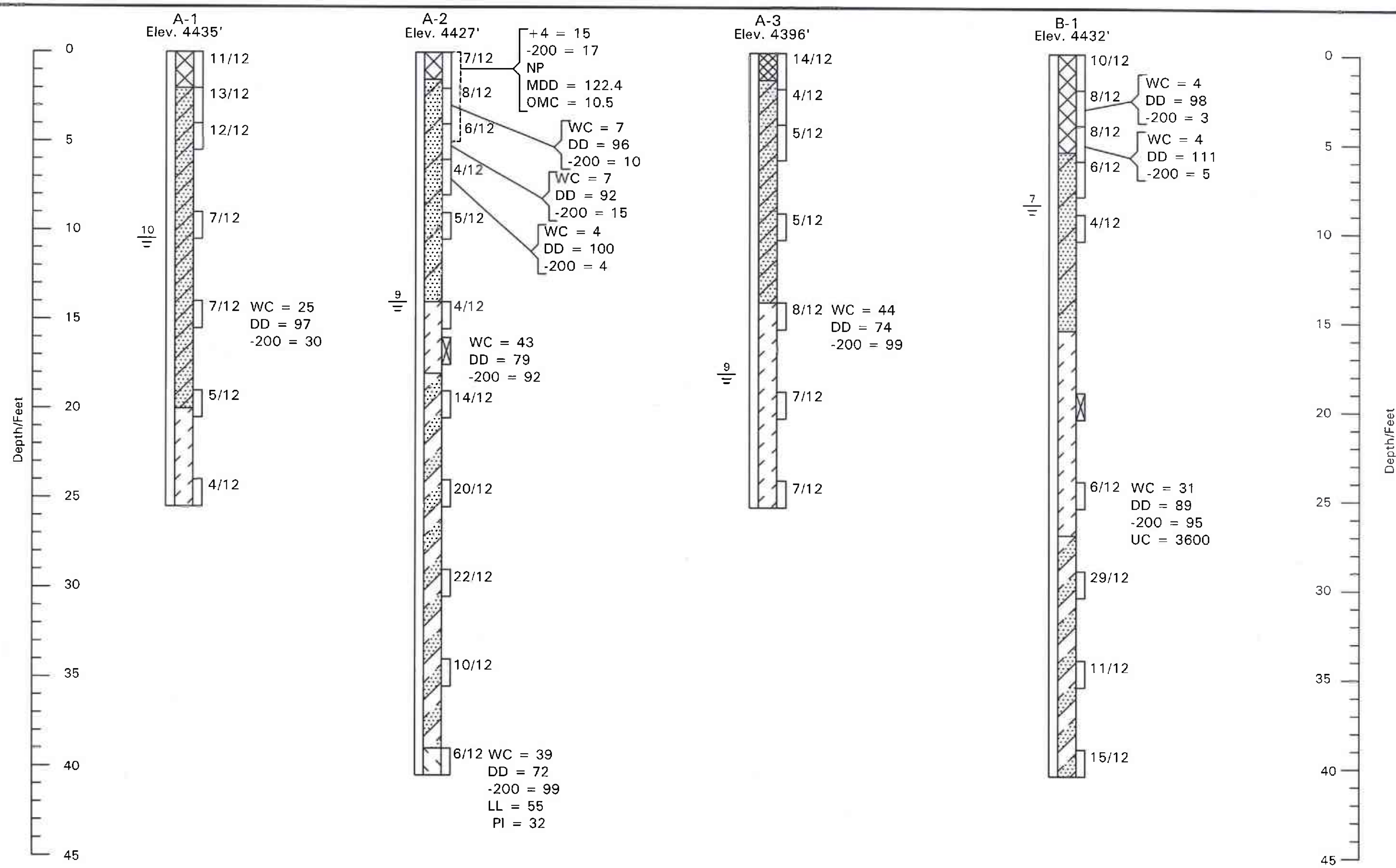
- BH-A1 Boring Locations
- Cross Section
- Lover's Lane
- Set Back
- Seepage
- Drainage Stand Pipes

N

0 150 300 feet
Approximate Scale

LOVERS LANE STABILITY INVESTIGATION AND ANALYSIS
RIVERTON CITY CORPORATION
12830 SOUTH 1700 WEST
RIVERTON, UTAH

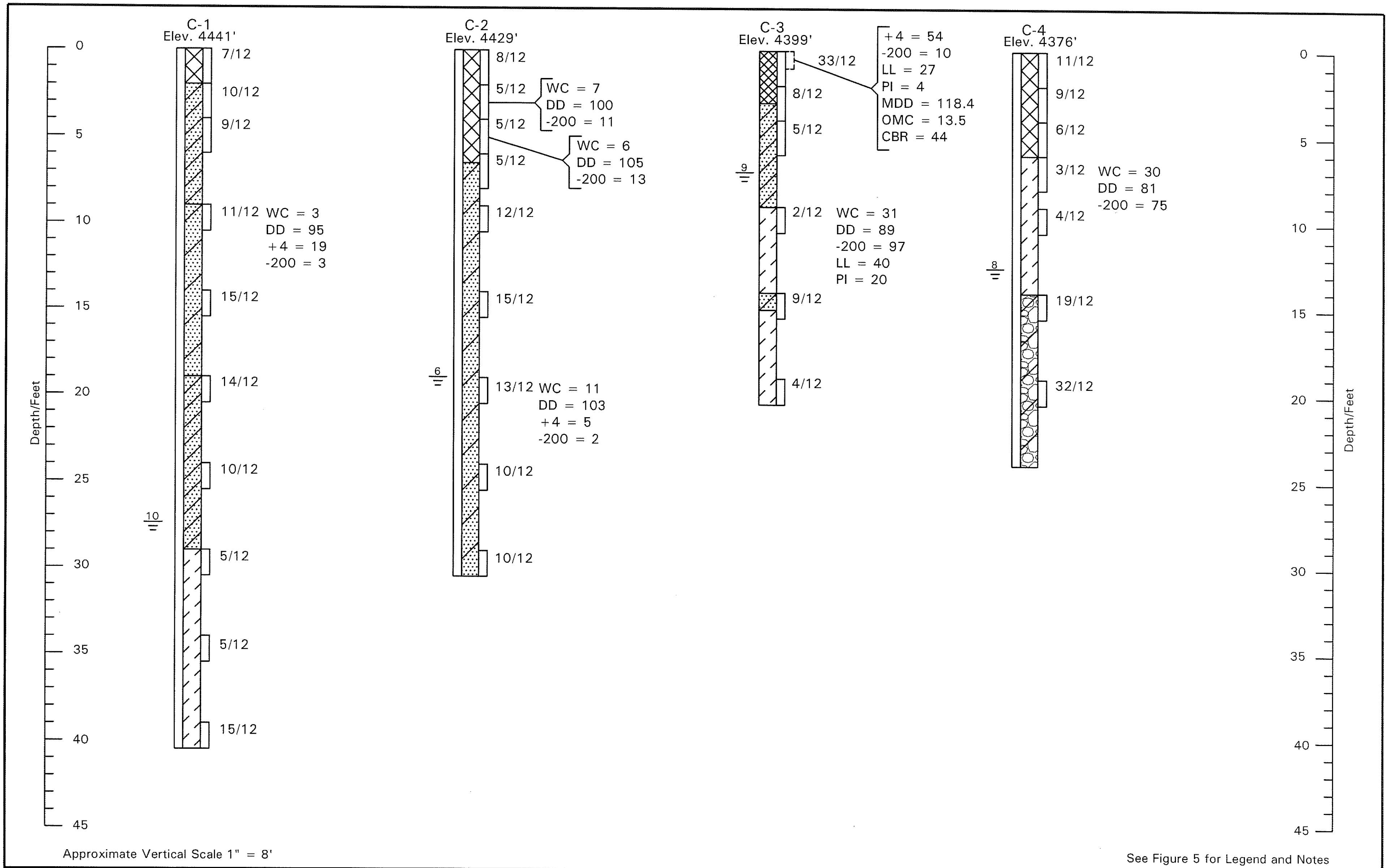
1150135	AGEC	Locations of Exploratory Borings	Figure 1



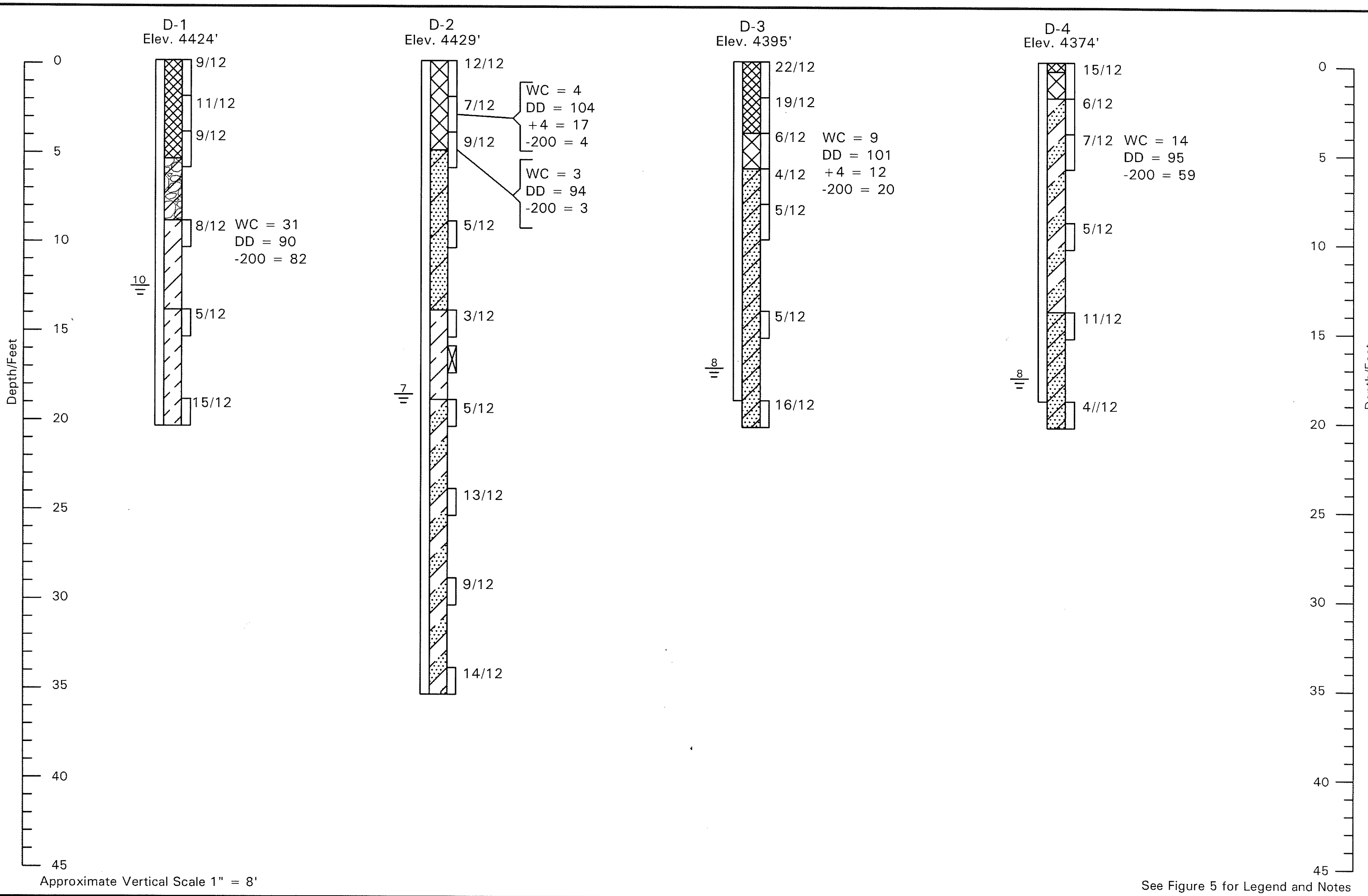
Approximate Vertical Scale 1" = 8'

See Figure 5 for Legend and Notes

1150135	AGEC	Logs of Exploratory Borings A-1, A-2, A-3 and B-1	Figure 2



1150135	AGEC	Logs of Exploratory Borings C-1, C-2. C-3 and C-4.	Figure 3



1150135	AGEC	Logs of Exploratory Borings D-1, D-2, D3 and D-4.	Figure 4

LEGEND:

Fill; Silty Sand and Gravel, medium dense, moist, brown to black.

Fill; Silty Sand, occasional gravel, occasionally clayey, loose to medium dense, moist brown.

Silty Gravel with Sand to poorly-graded Gravel with Silt and Sand (GP-GM); medium dense to dense, wet, gray.

Poorly-graded Gravel with Silt and Sand (GP-GM); medium dense, moist, brown.

Poorly-graded Sand with Silt (SP-SM); occasional gravel, loose to medium dense, slightly moist to wet, brown.

Silty Sand (SM); loose to medium dense, moist to wet, brown.

Inter-layered Lean Clay and Silty Sand (CL/SM); soft to stiff or meium dense, very moist to wet, brown to gray.

Silty Clay (CL-ML); slightly sandy, medium stiff, wet, gray.

Lean Clay (CL); occasional sand layers, soft to medium stiff, wet, brown to gray.

Fat Clay (CH); medium stiff, wet, dark gray.

10/12 California Drive sample taken. The symbol 10/12 indicates that 10 blows from a 140 pound automatic hammer falling 30 inches were required to drive the sampler 12 inches.

LEGEND (cont.):

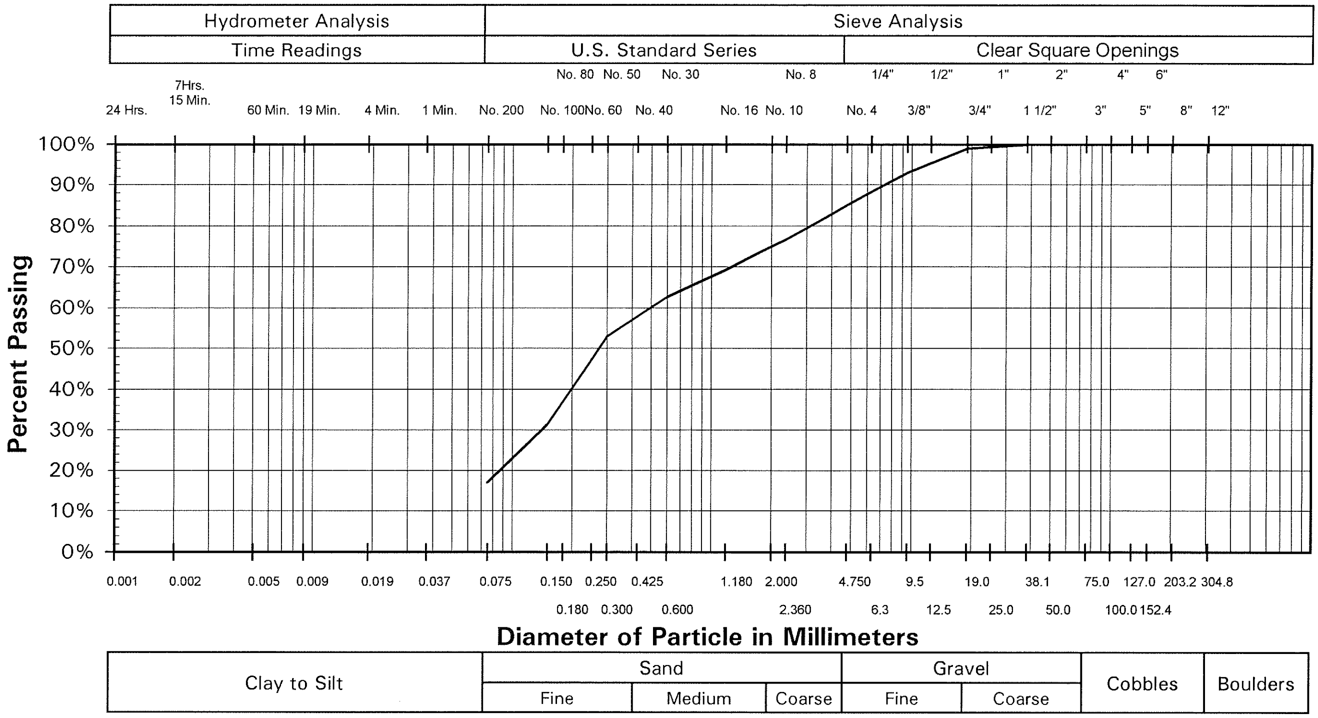
Indicates slotted 1½ inch PVC pipe installed in the boring to the depth shown.

5 Depth at which water was measured and the number of days after drilling that the measurement was taken.

NOTES:

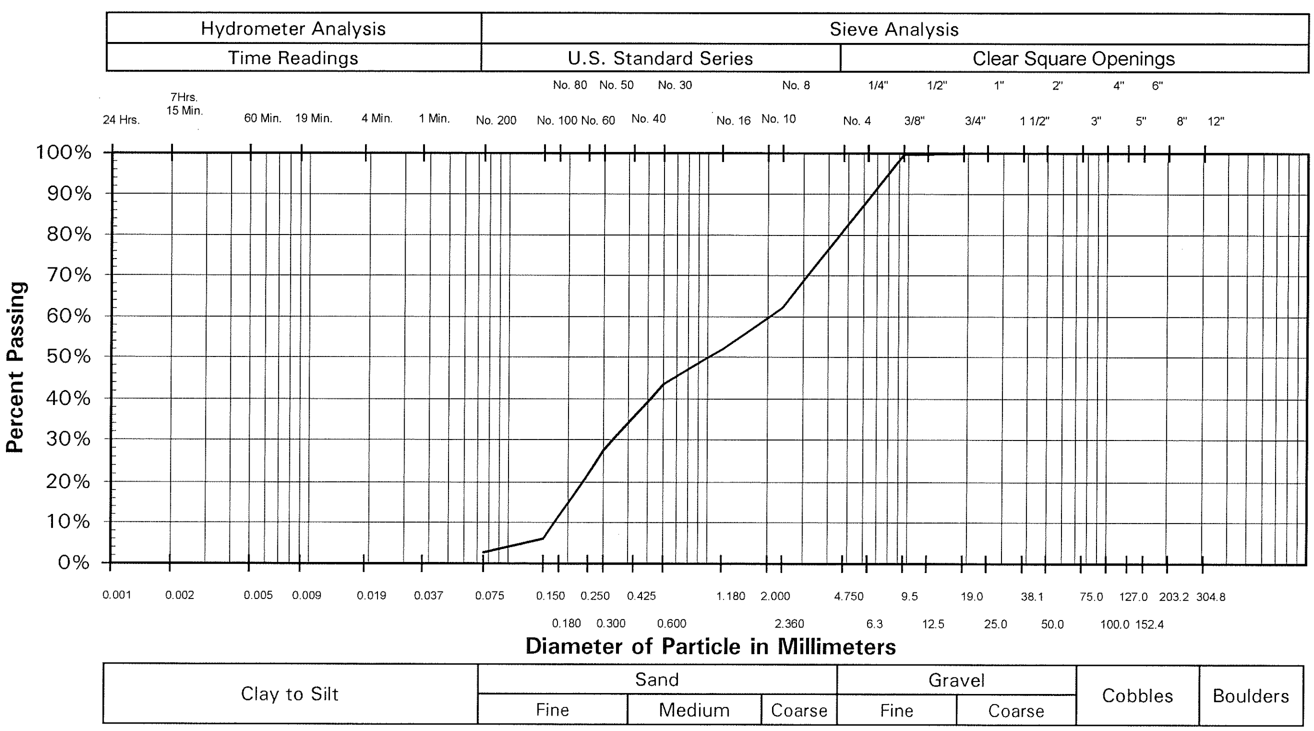
1. Borings were drilled on May 19 - 22 and June 1, 2015 with 8-inch diameter hollowstem auger.
2. Locations and elevations of borings were measured by survey.
3. The boring locations and elevations should be considered accurate only to the degree implied by the method used.
4. The lines between the materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.
5. WC = Water Content (%);
   DD = Dry Density (pcf);
   +4 = Percent Retained on No. 4 Sieve;
   -200 = Percent Passing No. 200 Sieve;
   LL = Liquid Limit (%);
   PI = Plasticity Index (%);
   NP = Non-Plastic (%);
   UC = Unconfined Compressive Strength (psf);
   MDD = Maximum Dry Density (pof);
   OMC = Optimum Moisture Content (%);
   CBR = California Bearing Ratio (%).

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.



Gravel 15%
Sand 68%
Silt and Clay 17%
Sample Description Silty Sand with Gravel

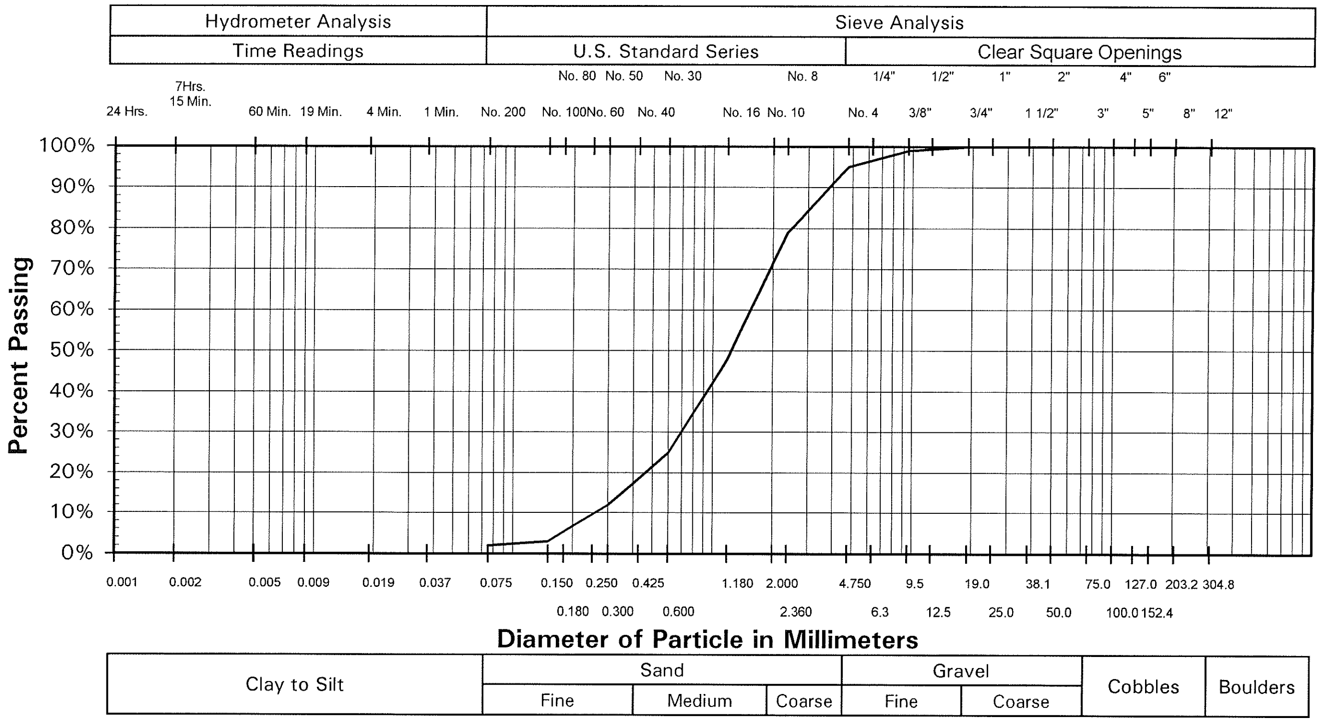
Liquid Limit -
Plasticity Index -
Sample Location A-2 @ 1 - 5 feet



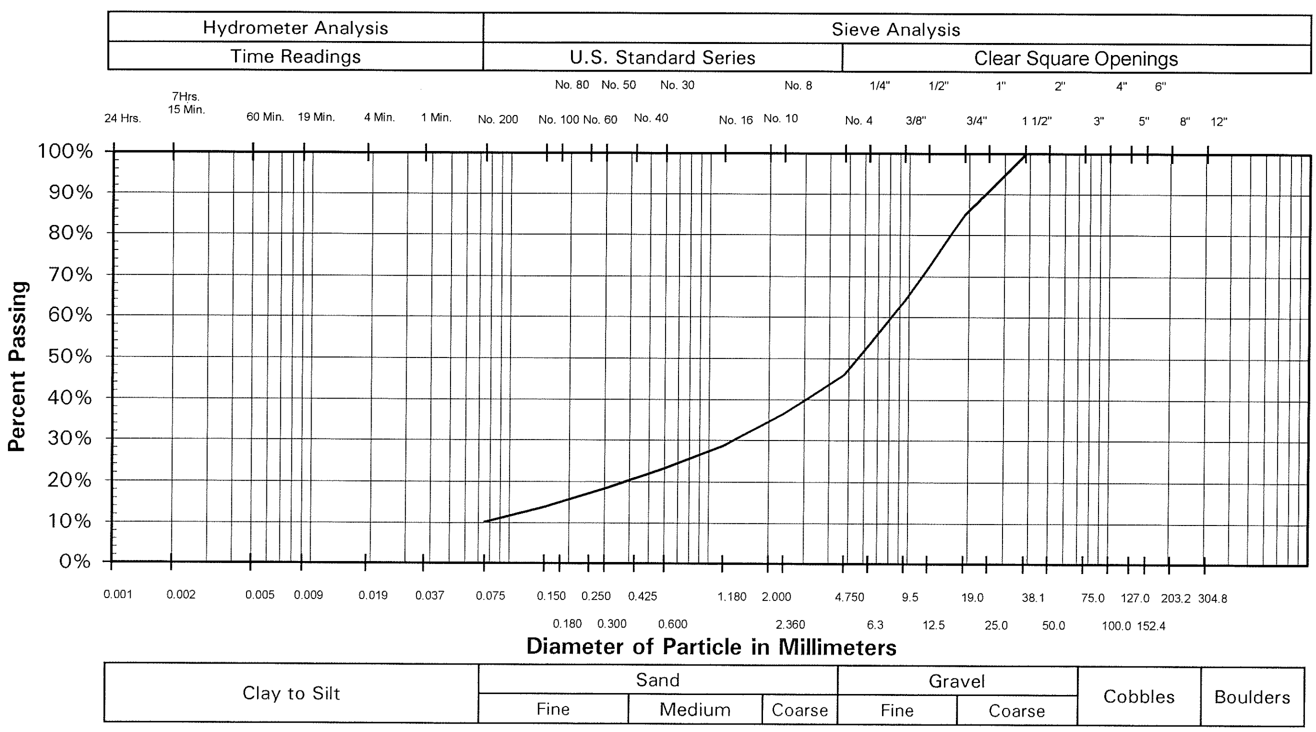
Gravel 19%
Sand 78%
Silt and Clay 3%
Sample Description Silty Sand with Gravel

Liquid Limit -
Plasticity Index -
Sample Location C-1 @ 9 feet

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.



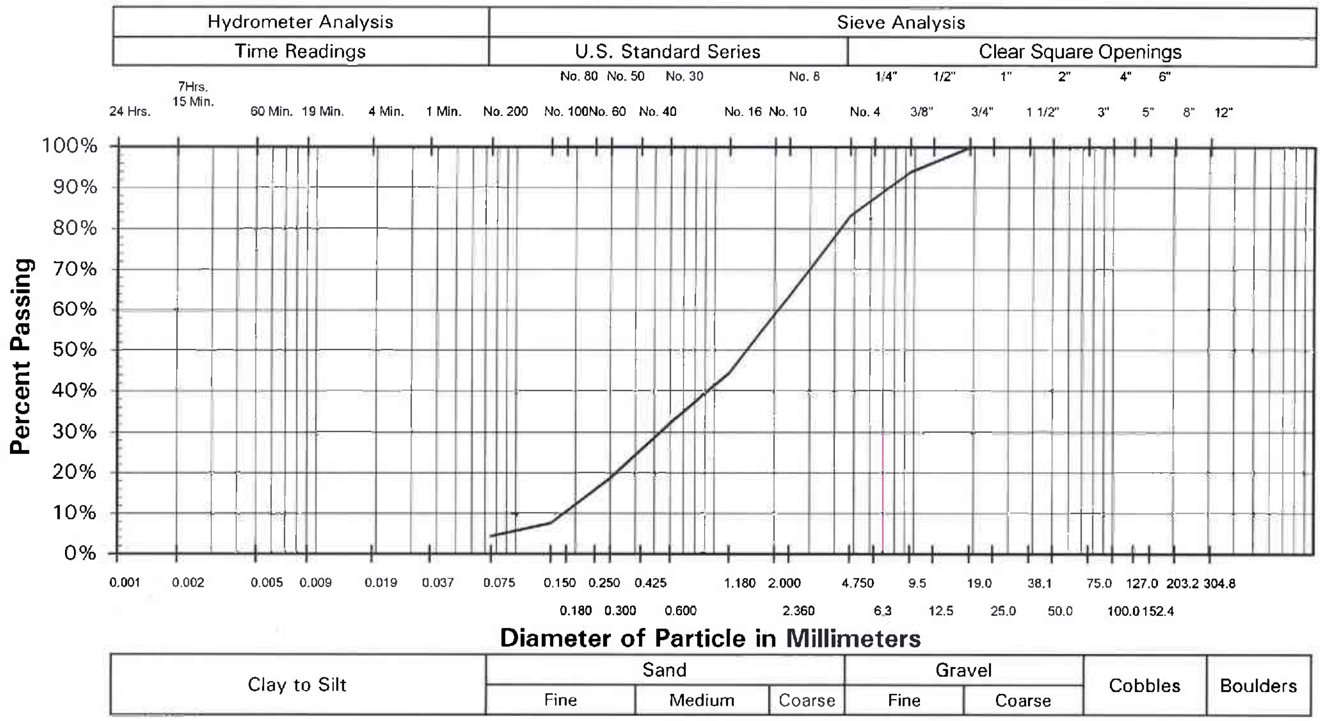
Gravel	5%		Liquid Limit	-
Sand	93%		Plasticity Index	-
Silt and Clay	2%		Sample Location	C-2@ 19 feet
Sample Description	Poorly Graded Sand			



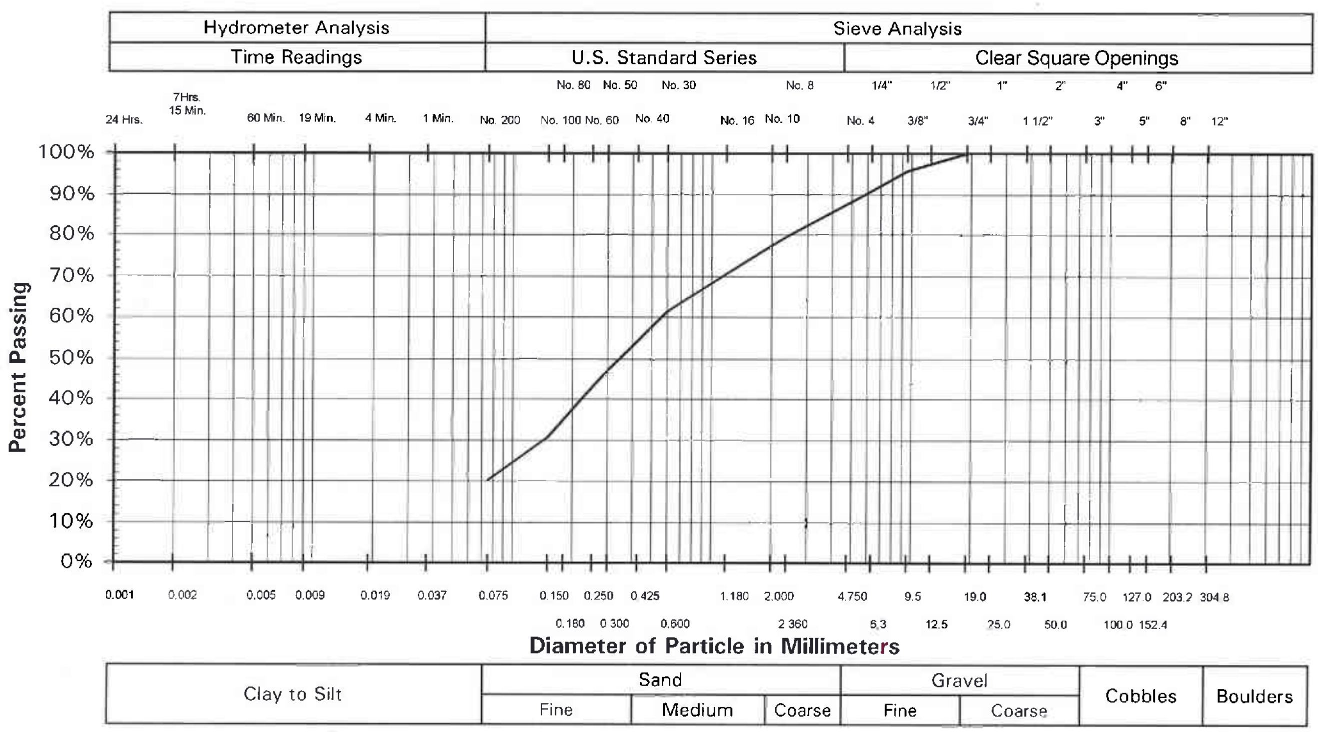
Gravel	54%		Liquid Limit	27%
Sand	36%		Plasticity Index	4%
Silt and Clay	10%		Sample Location	C-3 @ 0 - 14 inches
Sample Description	Silty Sand			

GRADATION TEST RESULTS

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.



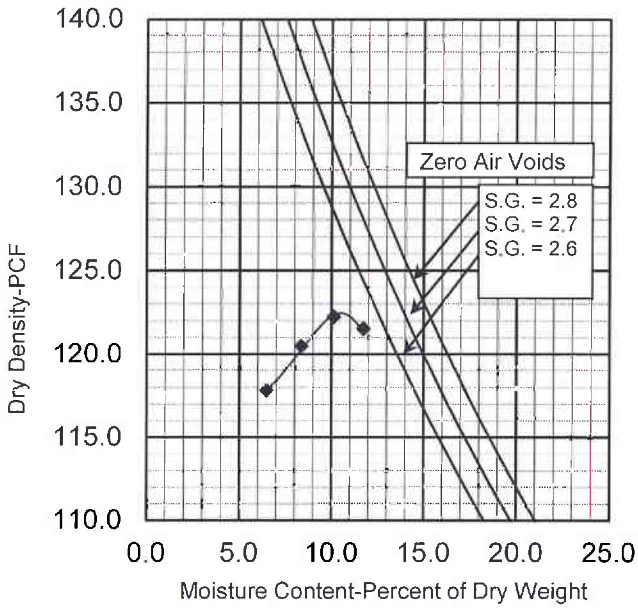
Gravel	17%		Liquid Limit	-
Sand	79%		Plasticity Index	-
Silt and Clay	4%		Sample Location	D-1 @ 2 feet
Sample Description	Poorly Graded Sand with Gravel			



Gravel	12%		Liquid Limit	-
Sand	68%		Plasticity Index	-
Silt and Clay	20%		Sample Location	D-3 @ 4 feet
Sample Description	Silty Sand			

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, Inc.

Moisture - Density Relationship, Gradation, & Classification Results



SAMPLE IDENTIFICATION

Project Name: Lover's Lane

Project No. 1150135
Sample No. 13580
Sample Location: A-2 at 1' to 5'

Date Sampled: 06/01/15
Sampled By: -

TESTING INFORMATION

Date Tested: 06/01/15
Tested By: RN
Reviewed By: KBB
Test Procedure: ASTM D698 A
Specific Gravity: Assumed 2.6
Moisture Curing: Not Used

ATTERBERG DATA

Liquid Limit (LL)
Plastic Index (PI)
Non-Plastic

Test Procedure ASTM D4318

PROCTOR RESULTS

Maximum Dry Density 122.4 pcf
Optimum Moisture 10.5%

Final Based On Microwave Oven Moisture Contents

UNIFIED SOIL CLASSIFICATION (ASTM D2487)

Silty Sand with Gravel (SM)

GRADATION RESULTS

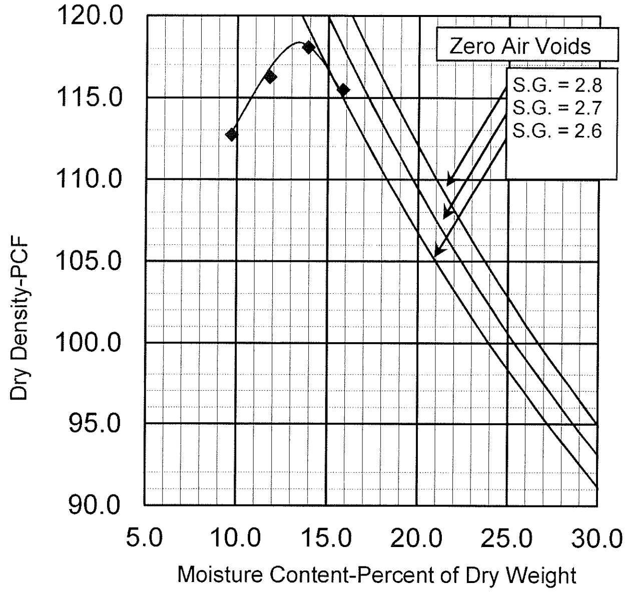
Sieve Designation	Sieve Opening Size (mm)	Percent Passing (%)	Project Specification (%)
5"	127	-	-
3"	76.2	-	-
1 1/2"	38.1	100	-
3/4"	19.1	99	-
3/8"	9.52	93	-
#4	4.76	85	-
#8	2.38	77	-
#16	1.19	69	-
#30	0.59	63	-
#50	0.297	53	-
#100	0.149	31	-
#200	0.074	17	-

GRAVEL	SAND	SILT & CLAY
15%	68%	17%

Figure 9

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, Inc.

Moisture - Density Relationship, Gradation, & Classification Results



SAMPLE IDENTIFICATION

Project Name:	Lover's Lane
Project No.	1150135
Sample No.	13579
Sample Location:	C-3 at 0' to 1.5'
Date Sampled:	-
Sampled By:	BOC

TESTING INFORMATION

Date Tested:	06/02/15
Tested By:	RN
Reviewed By:	KBB
Test Procedure:	AASHTO T-99D, Scalp&Replace
Specific Gravity:	Not Used
Moisture Curing:	Not Used

ATTERBERG DATA

Liquid Limit (LL)	27
Plastic Index (PI)	4

Test Procedure ASTM D4318

PROCTOR RESULTS

Maximum Dry Density	118.4 pcf
Optimum Moisture	13.5%

Final Based On Microwave Oven Moisture Contents

UNIFIED SOIL CLASSIFICATION (ASTM D2487)

Poorly Graded Gravel with Silt and Sand (GP-GM)

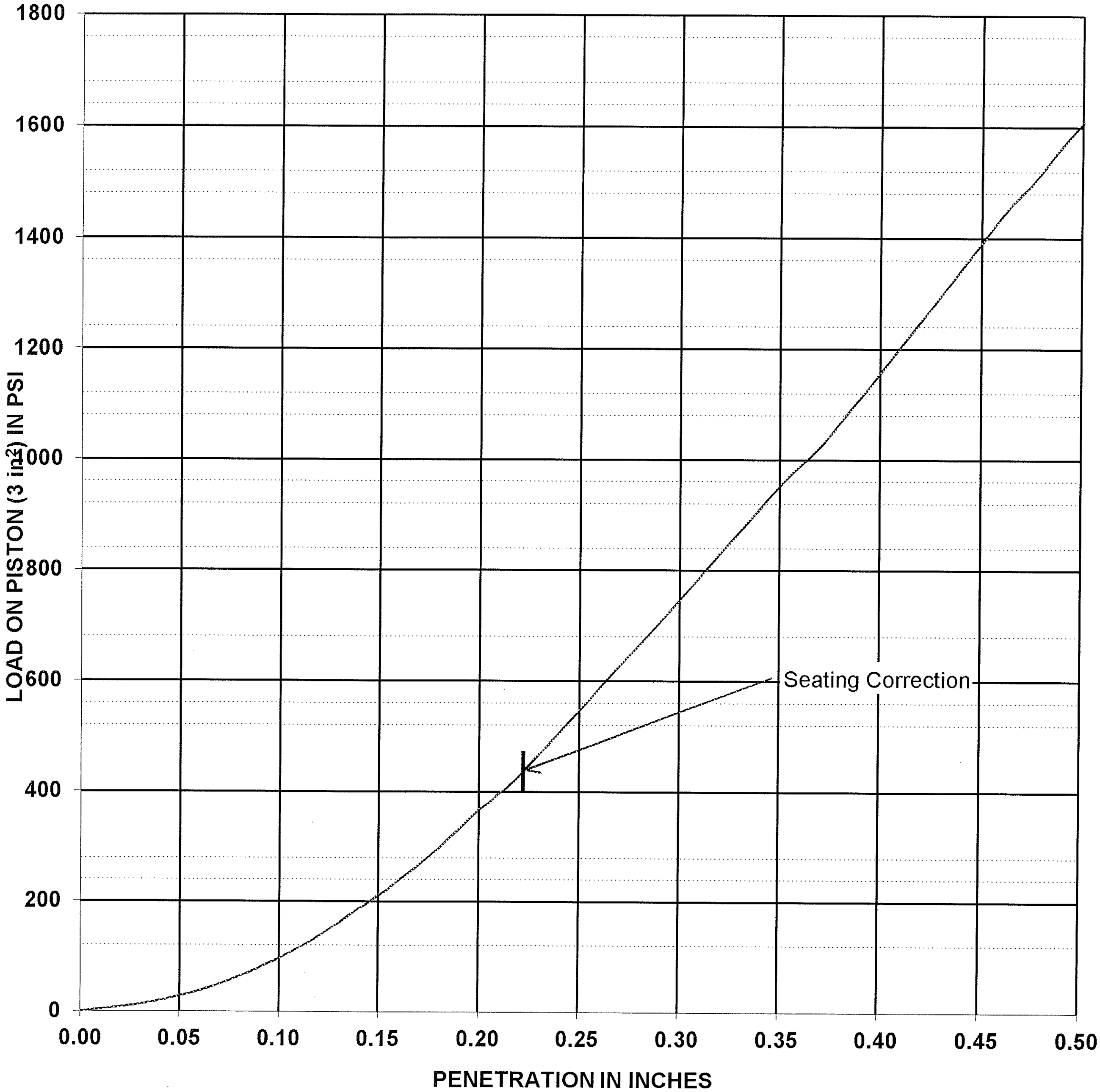
GRADATION RESULTS

Sieve Designation	Sieve Opening Size (mm)	Percent Passing (%)	Project Specification (%)
5"	127	100	-
3"	76.2	100	-
1 1/2"	38.1	100	-
3/4"	19.1	89	-
3/8"	9.52	64	-
#4	4.76	46	-
#8	2.38	37	-
#16	1.19	29	-
#30	0.59	23	-
#50	0.297	18	-
#100	0.149	14	-
#200	0.074	10	-

GRAVEL	SAND	SILT & CLAY
54%	36%	10%

Figure 10

Applied Geotechnical Engineering Consultants, Inc.



Sample of Poorly Graded Gravel with Silt and Sand (GP-GM)

Location: C-3 at 0' to 1.5' CS#: 13579

Method of sample preparation: Remolded to approx 100 % Maximum Dry Density at Optimum Moisture Content per AASHTO T-99D, Scalp &Replace

Sample penetration after soaking for 87 hours

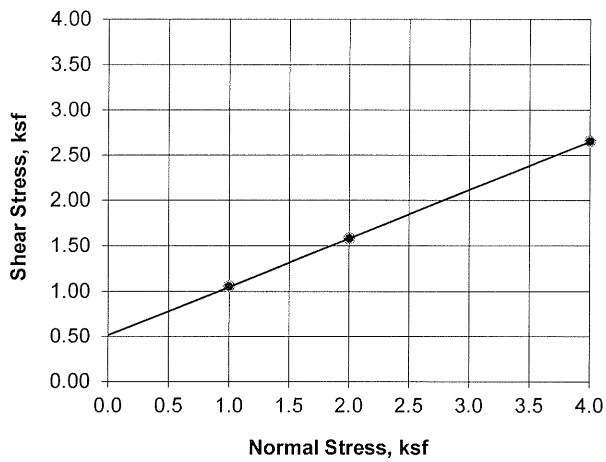
Dry Density:	as molded	117 pcf	Moisture Content:	as molded	14	percent
	after soaking	120 pcf		top 1-inch after soaking	12	percent
Swell:	after soaking	-0.2 percent		average after soaking	12	percent

(Swell Expressed as Positive Value, Compression Expressed as Negative Value)

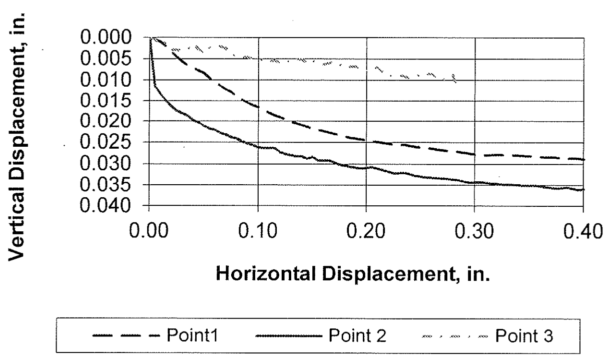
Bearing Ratio of Sample, **CBR = 44.0** percent with a surcharge of 10 lb

Proj. No. 1150135 **CALIFORNIA BEARING RATIO TEST RESULTS** Figure 11

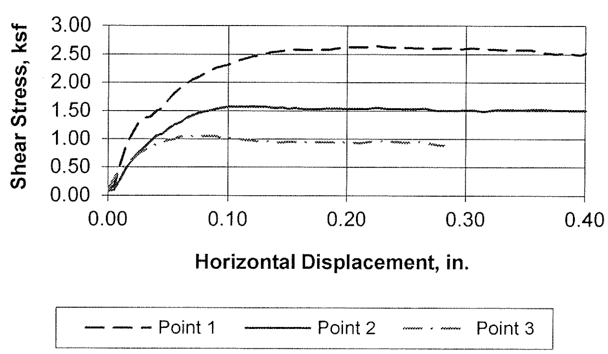
Applied Geotechnical Engineering Consultants, Inc.



c = 520 psf ϕ = 28 °	
Strength Parameters were determined from linear regression of the PEAK shear stress values	
Project and Sample Information	
Project Number	1150135
Project Name	Lover's Lane
Sample Identification	A-2 @ 39'
Sample Description	Fat Clay (CH)

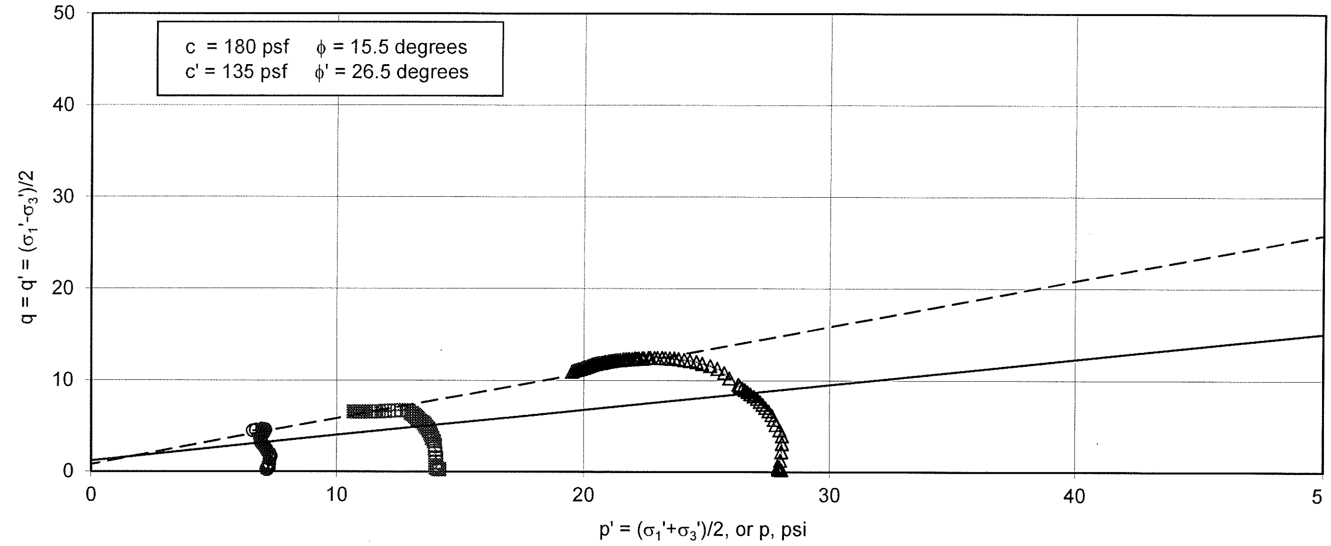


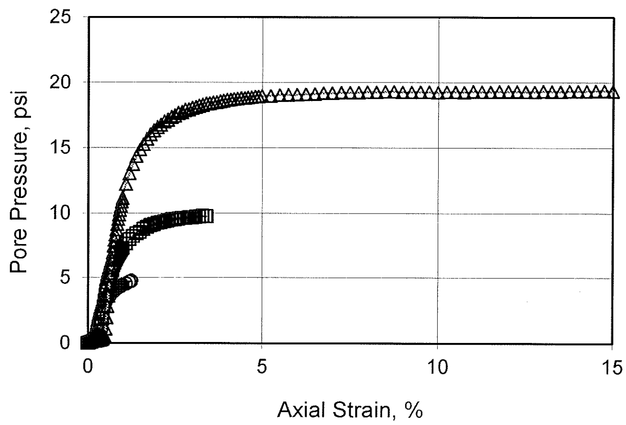
Test No. (Symbol)	1 (▲)	2 (■)	3 (●)
Test Type	Consolidated Drained Wetted		
Sample Type	Undisturbed		
Length, in.	1.00	1.00	1.00
Diameter, in.	1.93	1.93	1.93
Dry Density, pcf	71.9	71.2	69.9
Moisture Content, %	51.1	51.1	51.1
Consol. Load, ksf	4.0	2.0	1.0
Normal Load, ksf	4.0	2.0	1.0
Shear Stress, ksf	2.66	1.58	1.06
Rate of Strain	.001 in/min		
Each sample point was wetted when loaded and the sample point was allowed to consolidate. After consolidation, each sample point was sheared.			

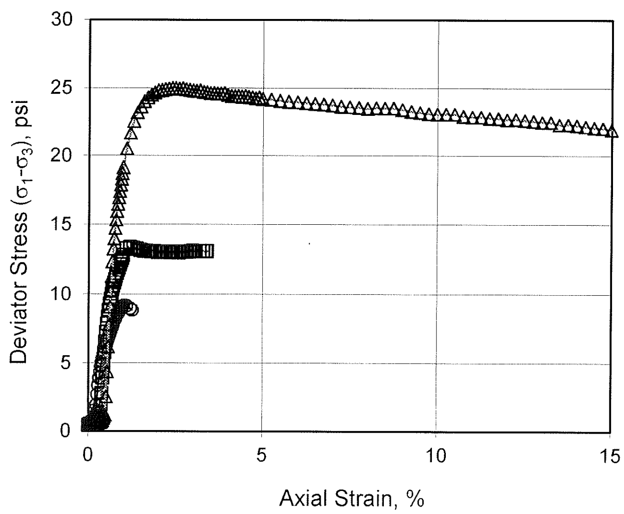


Sample Properties	
Dry Density, pcf	See Above
Moisture Content, %	51.1
Liquid Limit, %	55
Plasticity Index, %	32
Percent Gravel	0
Percent Sand	2
Percent passing No. 200 Sieve	98

Applied Geotechnical Engineering Consultants, Inc.







Test No. (Symbol)	O	□	Δ
Sample Type	Undisturbed		
Length, in.	5.20	5.14	4.92
Diameter, in.	2.84	NM	NM
Dry Density, pcf	79	NM	NM
Moisture Content, %	43	NM	NM
Consolidation Pressure, psi	6.9	13.9	27.8
"B" Parameter	95	NA	NA
Total Confining Stress (σ_3), psi	6.9	13.9	27.8
Total Axial Stress (σ_1), psi	16.1	27.3	52.8
Deviator Stress (σ_1-σ_3), psi	9.2	13.4	25.0
Effective Lateral Stress (σ_3'), psi	2.4	5.9	10.5
Effective Axial Stress (σ_1'), psi	11.6	19.3	35.5
Pore Pressure (μ), psi	4.6	8.0	17.3
Strain, %	1.1	1.2	2.4

Remarks: Multistage Test (CU) Consolidated
Undrained with pore pressure measurements.
Sample saturated with back pressure saturation.
Strength envelopes based on condtions at peak load.

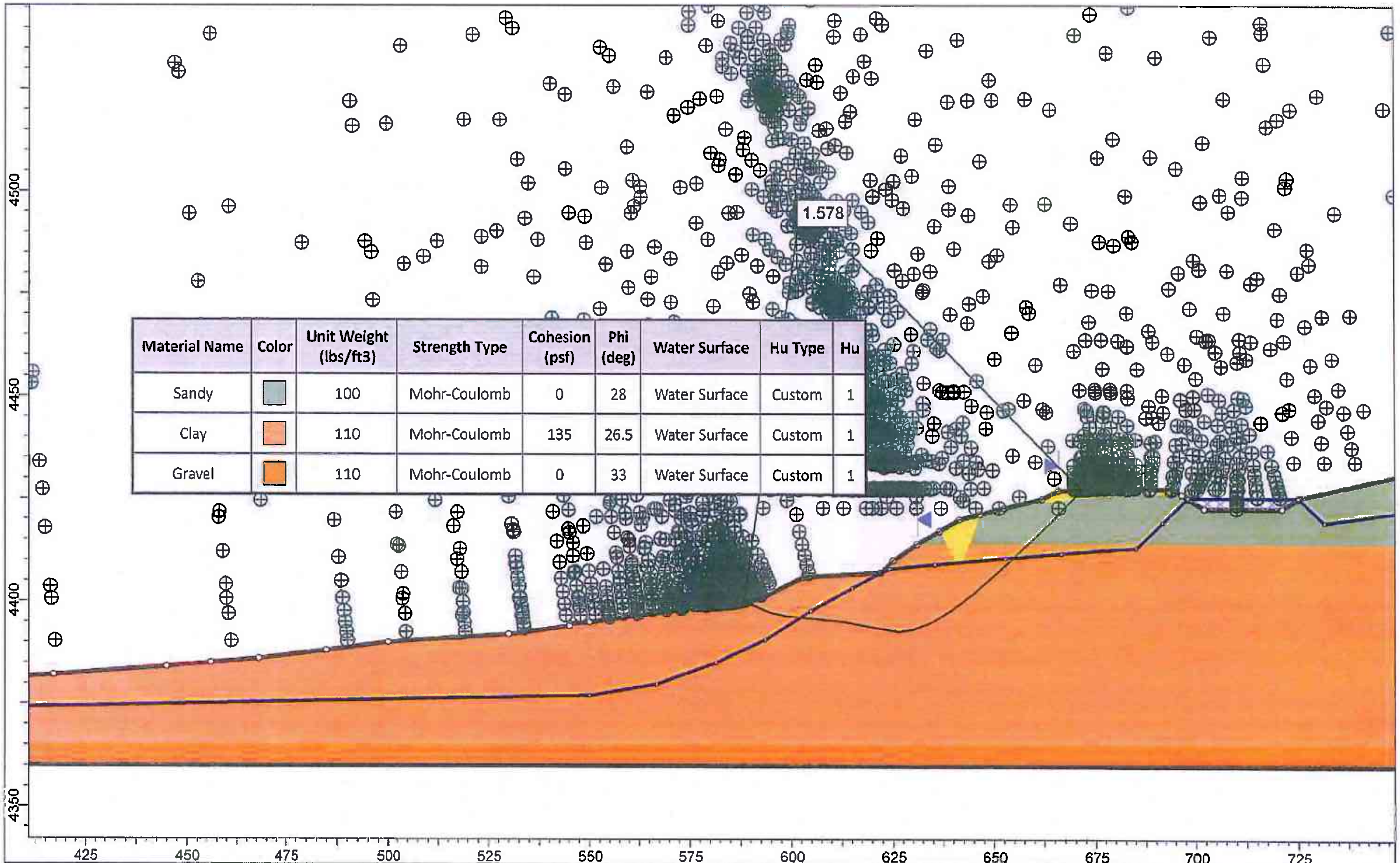
Sample Index Properties	
Ave. Natural Dry Density, pcf	79
Ave. Natural Moisture Content, %	43
Liquid Limit, %	38
Plasticity Index, %	19
Percent Gravel	0
Percent Sand	8
Percent Passing No. 200 Sieve	92

USCS Classification
Lean Clay (CL)

Test Description: Multi-Stage Triaxial Compression Test
Test Sample Location: A2a-16'to17.5'
Project Name: Loever's Lane
AGEC Project No.: 1150135

Triaxial Compression Test

Figure 13



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Sandy		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1

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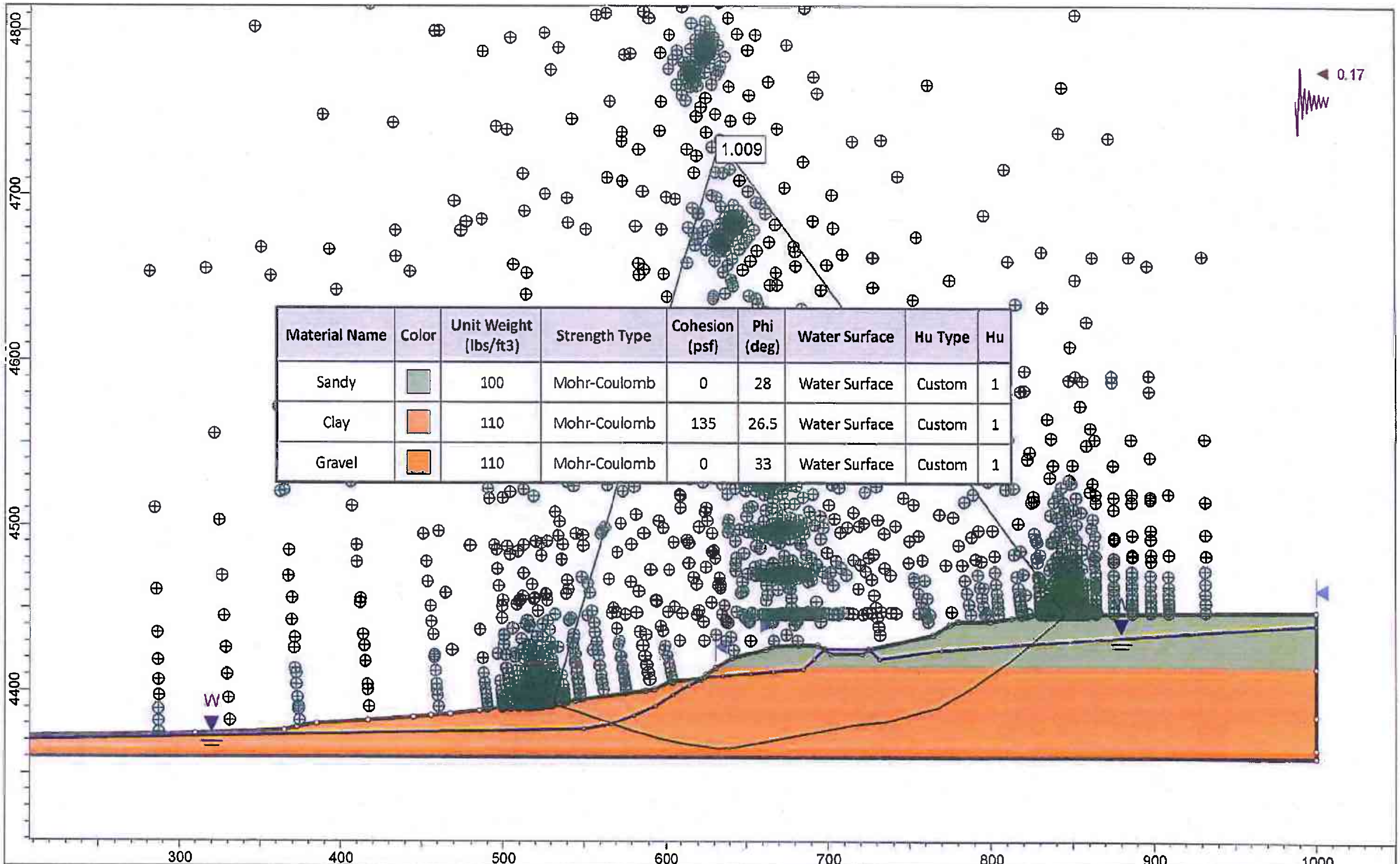
SLIDEINTERPRET 6.035

Project			
SLIDE - An Interactive Slope Stability Program			
Profile A - A' - Current Condition - Static Analysis			
Drawn By	Scale 1:393	Company	
Date 6/13/2015, 10:41:50 AM		File Name	LoversLane a1.slim

Figure 14



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Sandy		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1

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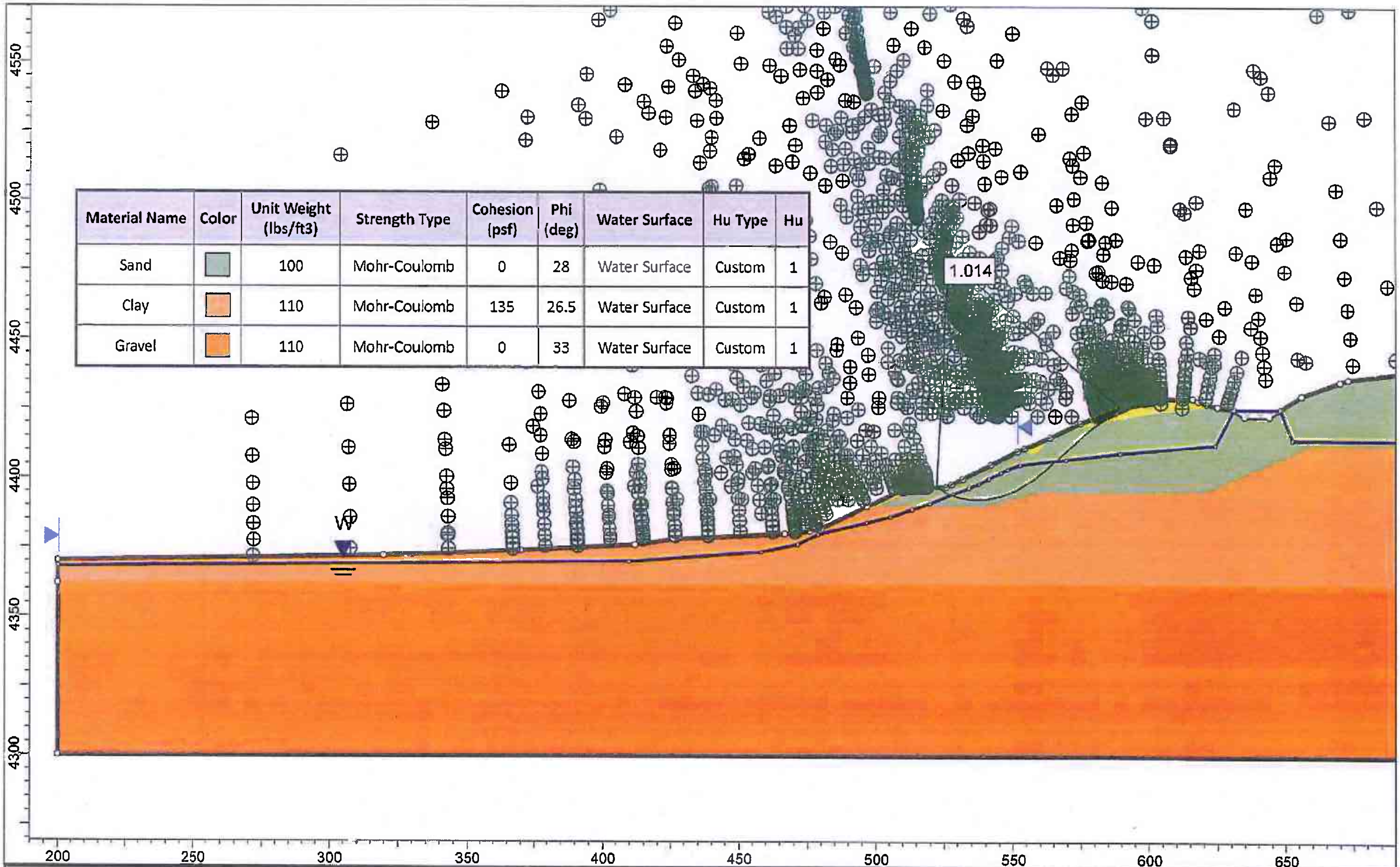
SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program
	Profile A - A' - Current Condition - Seismic Analysis - Yield Acceleration
Drawn By	
Scale	1:979
Company	
Date	6/13/2015, 10:41:50 AM
File Name	LoversLane a1ey.slim

Figure 15



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1

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SLIDEINTERPRET 6.035

Project

SLIDE - An Interactive Slope Stability Program

Profile C - C' - Current Conditions - Static Analysis

Drawn By

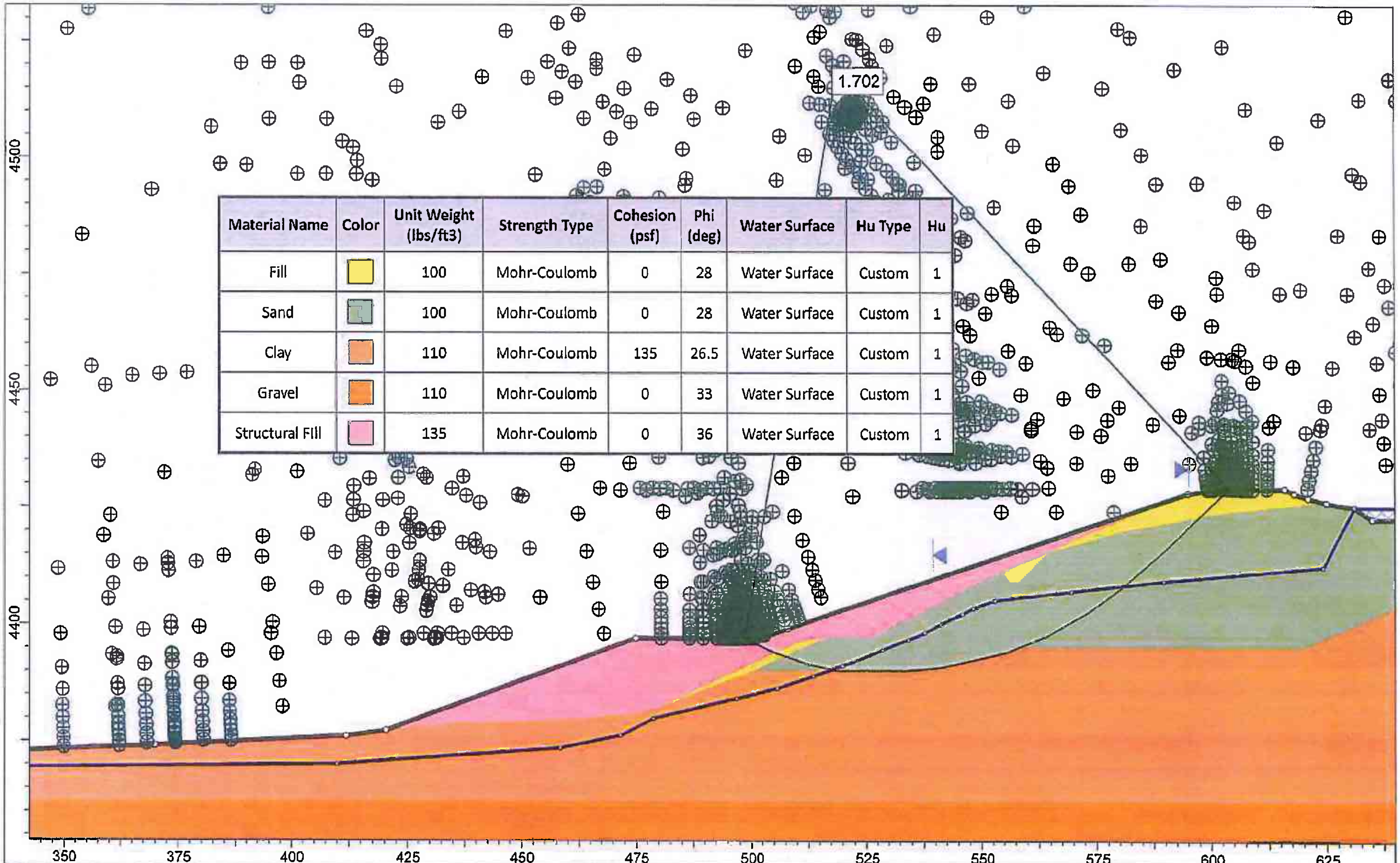
Scale 1:582

Company

Date 6/13/2015, 9:36:52 AM

File Name LoversLane c1.slim

Figure 16



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1
Structural Fill		135	Mohr-Coulomb	0	36	Water Surface	Custom	1

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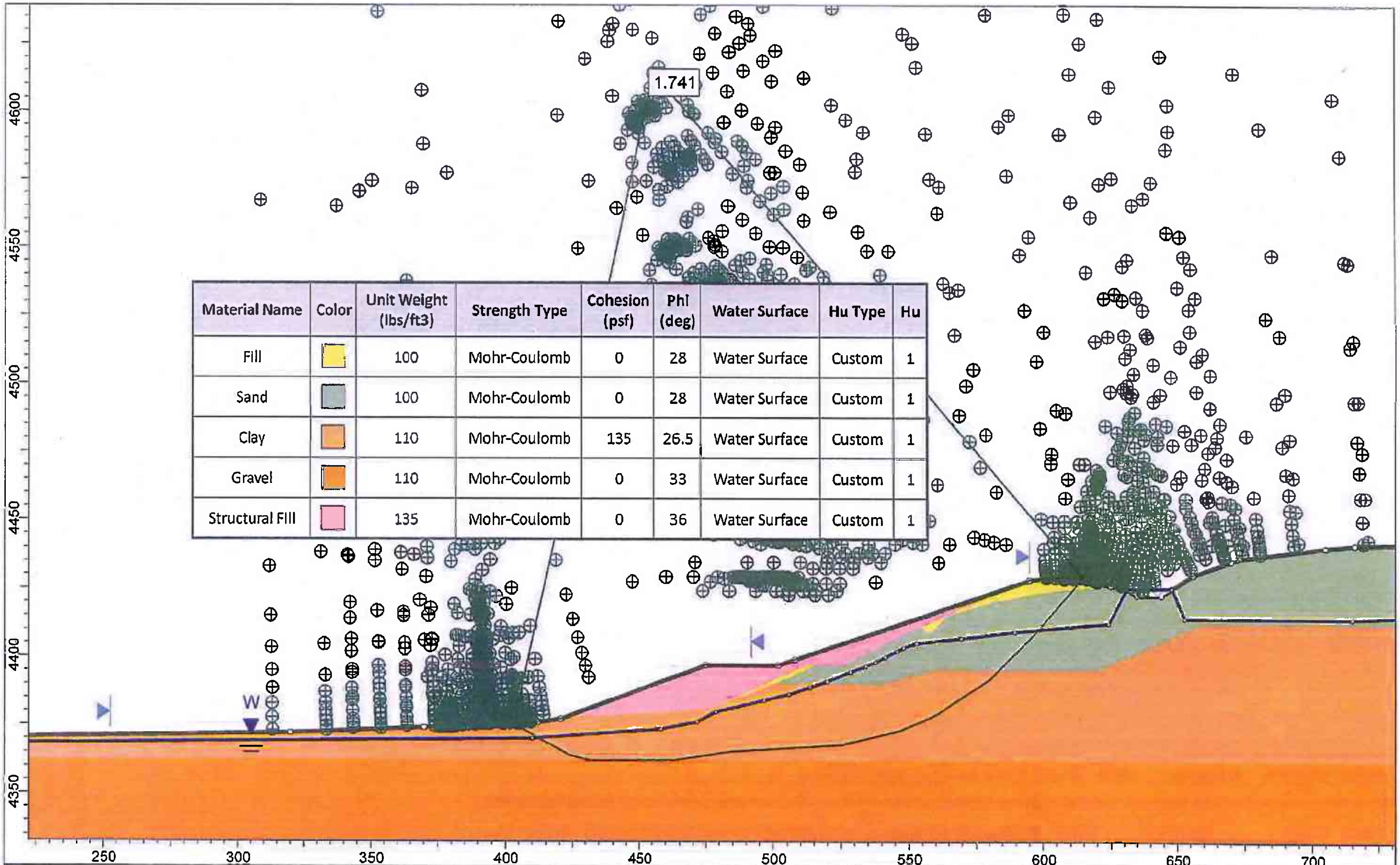
SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program
	Profile C - C' - 3 to 1 buttress and road - Static Analysis
Drawn By	*Scale* 1:346
Company	
Date 6/13/2015, 9:36:52 AM	*File Name* LoversLane c 3 to 1 with road.slim

Figure 17



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1
Structural Fill		135	Mohr-Coulomb	0	36	Water Surface	Custom	1

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SLIDEINTERPRET 6.035

Project

SLIDE - An Interactive Slope Stability Program

Profile C - C' - 3 to 1 buttress and road - Static Analysis

Drawn By

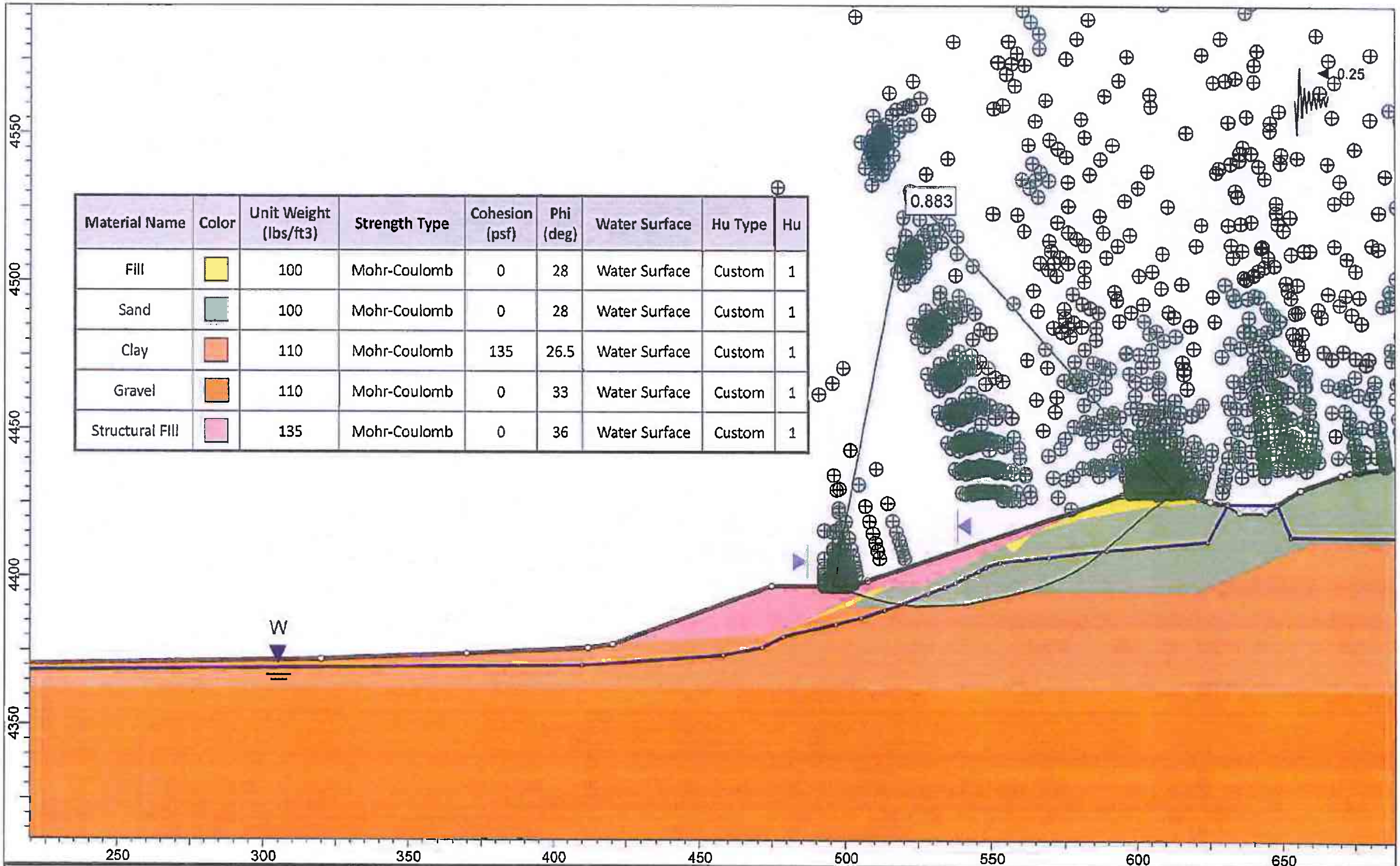
Scale 1:593

Company

Date 6/13/2015, 9:36:52 AM

File Name LoversLane c 3 to 1 with road.slim

Figure 18

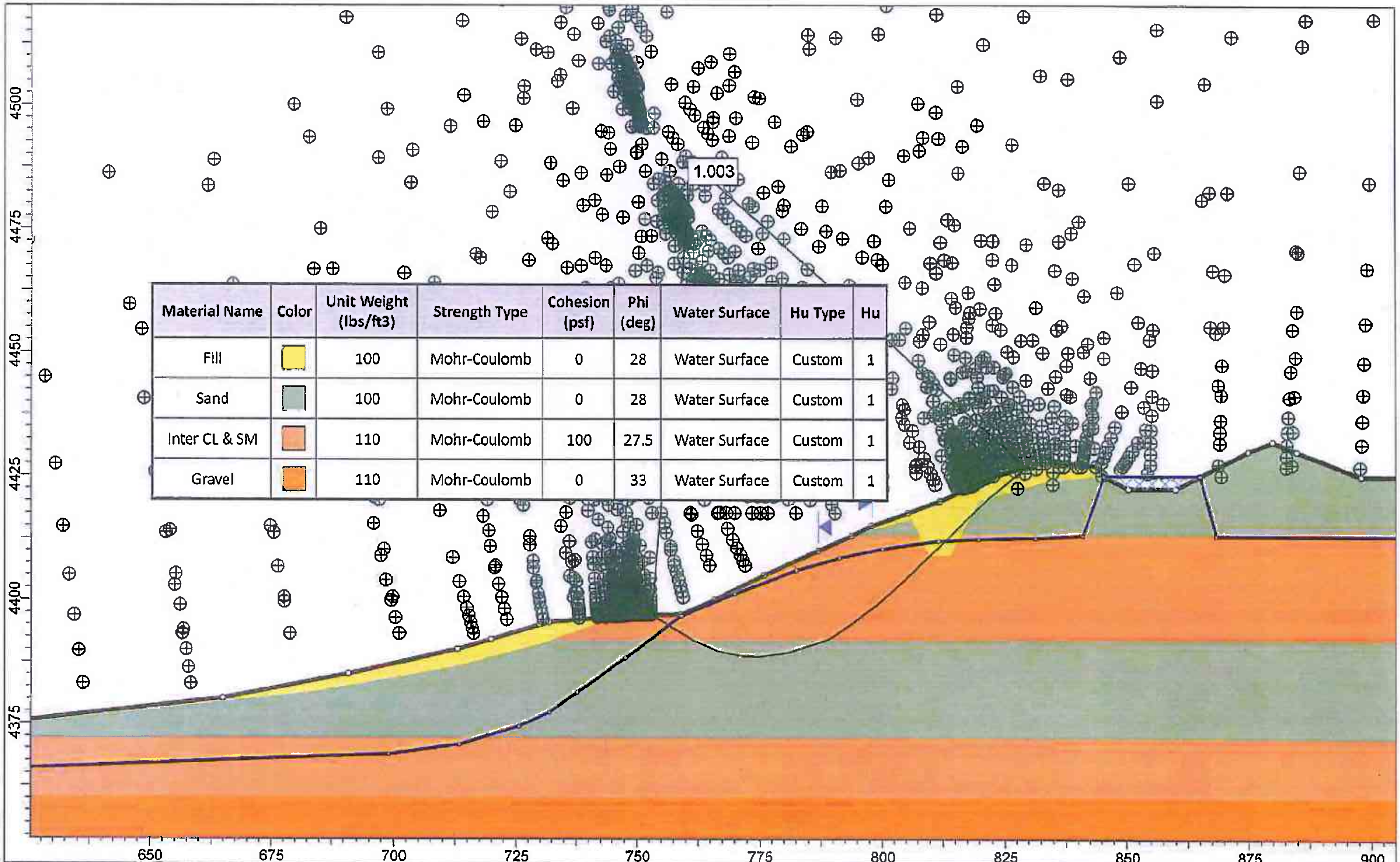


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Clay		110	Mohr-Coulomb	135	26.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1
Structural Fill		135	Mohr-Coulomb	0	36	Water Surface	Custom	1

SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program
	Profile C - C' - 3 to 1 buttress and road - Seismic Analysis
Drawn By	
Scale	1:546
Company	
Date	6/13/2015, 9:36:52 AM
File Name	LoversLane c 3 to 1 with road.slim

Figure 19



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Inter CL & SM		110	Mohr-Coulomb	100	27.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1

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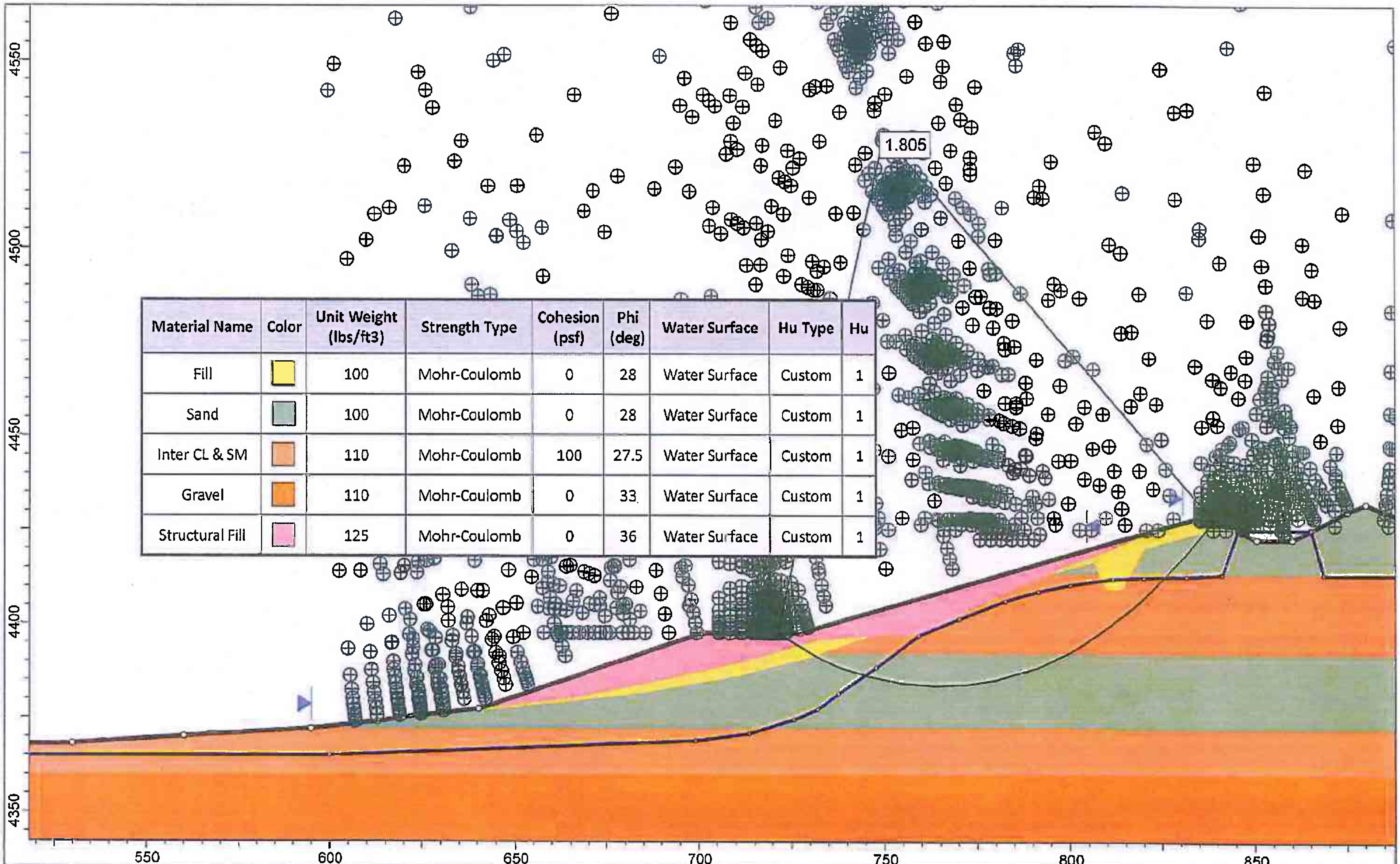
SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program		
	Profile D - D' - Exisiting Condition - Static Analysis		
Drawn By	*Scale* 1:326	*Company*	
Date 6/13/2015, 10:15:11 AM		*File Name*	Loverslane d1.slim

Figure 20



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill	(yellow)	100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand	(grey-green)	100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Inter CL & SM	(light orange)	110	Mohr-Coulomb	100	27.5	Water Surface	Custom	1
Gravel	(orange)	110	Mohr-Coulomb	0	33	Water Surface	Custom	1
Structural Fill	(pink)	125	Mohr-Coulomb	0	36	Water Surface	Custom	1

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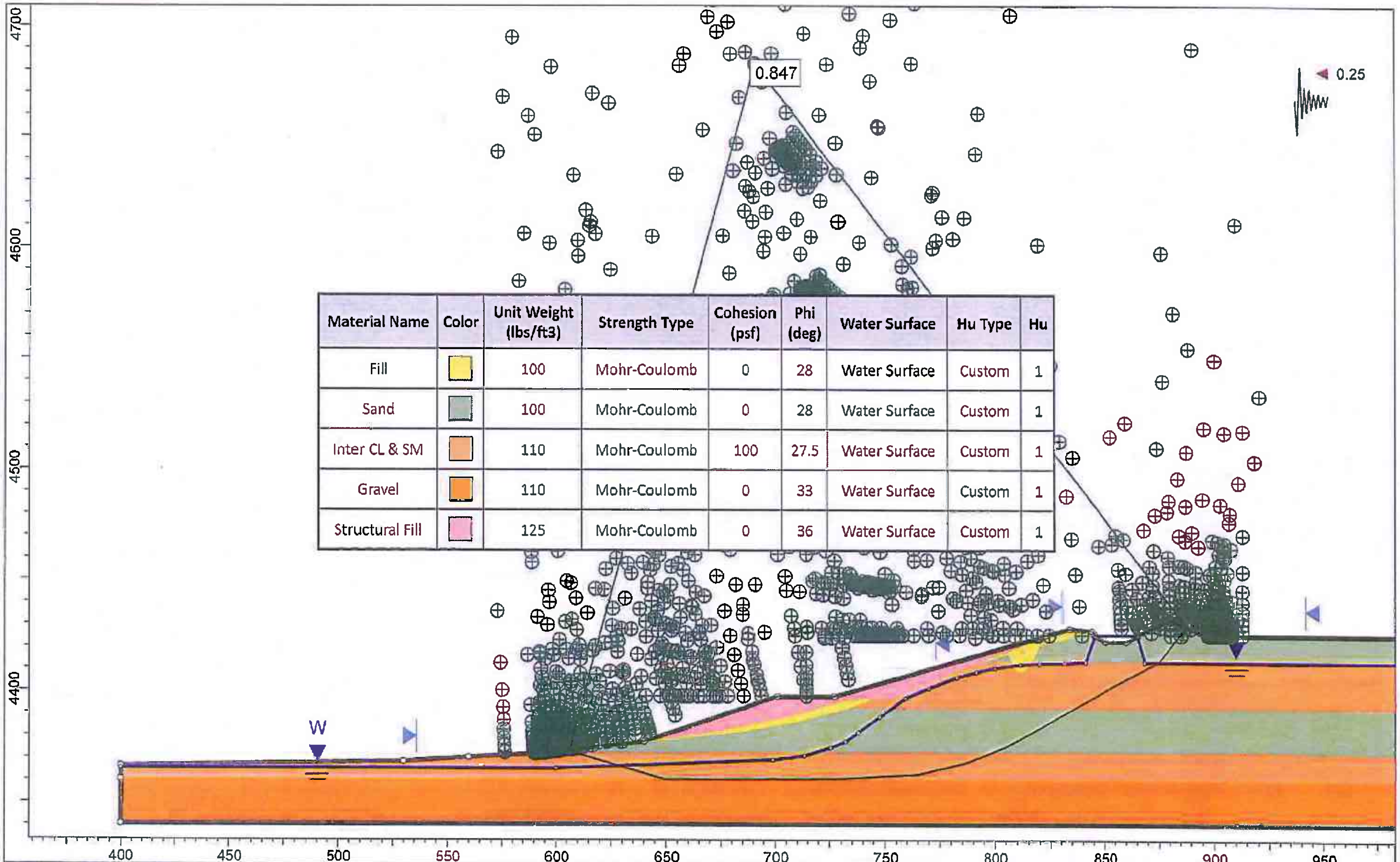
SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program
	Profile D - D' - 3.5 & 3.0 to 1 buttress and road - Static Analysis
Drawn By	
Scale	1:430
Company	
Date	6/13/2015, 10:15:11 AM
File Name	Loverslane d1 w road 3 5 to 1.slim

Figure 21



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Fill		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Sand		100	Mohr-Coulomb	0	28	Water Surface	Custom	1
Inter CL & SM		110	Mohr-Coulomb	100	27.5	Water Surface	Custom	1
Gravel		110	Mohr-Coulomb	0	33	Water Surface	Custom	1
Structural Fill		125	Mohr-Coulomb	0	36	Water Surface	Custom	1

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SLIDEINTERPRET 6.035

Project	SLIDE - An Interactive Slope Stability Program
	Profile D - D' - 3.5 & 3.0 to 1 buttress and road - Seismic Analysis
Drawn By	
Scale	1:727
Company	
Date	6/13/2015, 10:15:11 AM
File Name	Loverslane d1 w road 3 5 to 1 e.slim

Figure 22

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 1150135

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)			
A-1	14	25	97			30					Silty Sand
A-2	1-5			15	68	17		NP			Silty Sand with Gravel
	2	7	96			10					Poorly-graded Sand w/ Silt
	4	7	92			15					Silty Sand
	6	4	100			4					Poorly-graded Sand
	16	43	79			92	38	19			Lean Clay
	39	51	72			98	55	32			Fat Clay
A-3	14	44	74			99					Lean Clay
B-1	2	4	98			3					Fill; Poorly-graded Sand
	4	4	111			5					Fill; Poorly-graded Sand w/Silt
	24	31	89			95			3600		Lean Clay
C-1	9	3	95	19	78	3					Poorly-graded Sand w/Gravel
C-2	2	7	100			11					Fill; Poorly-graded Sand w/Silt
	4	6	105			13					Fill; Poorly-graded Sand w/Silt
	19	11	103	5	93	2					Poorly-graded Sand

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)			
C-3	0 - 14"			54	36	10	27	4			Fill; Poorly-graded Gravel w/ Silt and Sand
	9	31	89			97	40	20			Lean Clay
C-4	6	30	81			75					Lean Clay w/ Sand
D-1	9	31	90			82					Lean Clay w/ Sand
D-2	2	4	104	17	79	4					Fill; Poorly-graded Sand w/ Gravel
	4	3	94			3					Fill; Poorly-graded Sand w/ Gravel
D-3	4	9	101	12	68	20					Fill; Silty Sand
D-4	4	14	95			59					Sandy Llean Clay