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February 21, 2020 Our File No. 0013 023 00

Mr. Marvin McDonald, CET
AECOM
99 Commerce Drive
Winnipeg, MB
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RE: Shoal Lake Aqueduct Preservation
Priority 3 Task 11 – Land Drainage Improvements at Mile 77.6 Railway Yard
Geotechnical Investigation Summary Report

This letter provides a summary of the geotechnical investigation to determine the most likely cause of distress to the concrete outfall pipe (dislodged pipe) discharging into Boggy River south east of the Mile 77.6 bridge crossing and provide geotechnical recommendations for pipe repairs. The original scope of work under Task 11 included a preliminary sub-surface investigation. A subsequent Scope Change was approved for additional investigations and analysis to provide recommendations for remedial bank stabilization measures associated with outfall pipe repairs. For design of the remedial measures, the pipe repair was assumed to be undertaken within a shored excavation or open excavation.

Background

The outfall is a 1200 mm diameter concrete pipe with bell and spigot connections and has an invert elevation of approximately 311.6 m at the outlet where it discharges into Boggy River. The pipe runs parallel to and south of the Greater Winnipeg Water District (GWWD) rail line at an offset distance of about 11 m, and close to the south edge of City of Winnipeg's right-of-way (ROW). The location of the south edge of the ROW is uncertain, but likely lies somewhere between the outfall pipe and the row of trees bordering a residence to the south.

The rail line crosses Boggy River on a single-span bridge which was replaced the original timber structure in 2015. The bridge abutment head slopes are at 2 horizontal to 1 vertical (2H:1V) and are armoured with Class 600 riprap. A geotechnical investigation was completed by AGRA Earth and Environmental (AGRA) in 1995 to provide foundation recommendations for the rail bridge. The geotechnical investigation report, which includes 2 test hole logs (one at each abutment) is attached.

At the outfall, the riverbank slopes up from the outlet at 2.5H:1V with a top of bank elevation of approximately 315 m. Bathymetry is not available for the site, but based on record drawings for the GWWD rail bridge just north of the outfall, the base of the channel is at Elev. 310 m, making the height of riverbank approximately 5 m.

Based on visual observations made while on site by TREK in 2012 and 2019, bank movements may have occurred historically in the vicinity of the concrete outfall pipe. At this location, the first joint from the end of the pipe (within the bank) is separated (dislodged) with a vertical misalignment of about

0.5 m resulting in an obstruction during high flows. The end section also tilts back from the river and is partially filled with sediment. The profile of the pipe and the visual observations support the possibility that the pipe distress is associated with rotational bank movement. Alternatively, the outfall pipe misalignment could be a result of subgrade settlement. The intent of the geotechnical program was to identify the most likely cause of the pipe misalignment, determine if remedial slope stabilization measures are necessary, and if they are, provide appropriate geotechnical recommendations.

Sub-Surface Investigation

TH 17-03 was drilled on February 16, 2017 under the supervision of TREK personnel to determine the stratigraphic and groundwater conditions at the site. THs 19-01 to 19-05 were drilled during a supplementary investigation on November 28, 2019 to delineate an organic clay layer encountered in TH 17-03. TH17-03 was drilled south of the outfall while THs 19-01 to 19-05 were drilled north of the outfall between the pipe and rail line at the locations shown on Figure 1. TH17-03 was drilled using an Acker Renegade track-mounted soils rig while test holes TH19-01 to 19-05 were drilled using a Mobile B40 truck-mounted soils rig. Test holes were drilled using a combination of 125 mm solid stem and 170 mm hollow stem auger to depths between 6.1 and 11.3 m below ground surface.

Sub-surface soils observed during drilling were visually classified based on the Unified Soil Classification System (USCS). Samples retrieved during drilling included disturbed samples (grab and split spoon samples) and relatively undisturbed Shelby tube samples. All samples retrieved during the investigation were transported to TREK's soils laboratory in Winnipeg, Manitoba for further testing and classification.

Test hole locations were measured relative to the rail centerline and east abutment face. Geodetic elevations were surveyed using the top of rail at the east bridge abutment as a benchmark, using an elevation of 315.7 m as per City of Winnipeg Record Drawing D-13441. The test hole logs (attached) include a description of the soil units encountered and other pertinent information such as groundwater and sloughing conditions, and a summary of the laboratory testing results.

Soil Stratigraphy and Groundwater Conditions

A brief description of the soil units encountered during drilling is provided below. All interpretations of soil stratigraphy for the purposes of design should refer to the detailed information provided on the attached test hole logs.

In descending order from ground surface, the soil stratigraphy generally consists of sand fill overlying layers of silt, clay, and organic clay at various elevations and thicknesses. The sand fill is loose (when thawed) and extends to depths ranging from 0.9 to 3.3 m. Soft to very soft silt was encountered below the sand fill in all test holes except TH19-02 between depths of 0.9 and 3.7 m. The underlying clay in all test holes (except TH17-03 and 19-04 where it is absent) is highly plastic and soft to firm.

A soft to firm organic clay of variable thickness was encountered in all test holes (except TH19-01) between depths of 3.4 and 6.1 m. Of note are the low unit weight (14.5 to 16.0 kN/m^3) and high moisture content (60 – 95%) within this layer. It appears that a similar layer was encountered in Test Hole 2 at the east bridge abutment (AGRA, 1995).

Seepage and sloughing were observed at 2.1 to 3.3 m below ground surface in all test holes except TH17-03. Water levels ranged from 3.0 to 7.3 m below ground surface immediately after drilling. These observations are short-term and should not be considered reflective of (static) groundwater levels at the site which would require monitoring over an extended period to determine. It is important to recognize that groundwater conditions may vary seasonally, annually, or as a result of construction activities.

Slope Stability Analysis

A slope stability analysis was conducted to further evaluate the likelihood that the outfall pipe misalignment is a result of riverbank movement. The stability of the slope was determined assuming the bank geometry that likely existed immediately after pipe installation (based on the adjacent riverbank geometry) and in its current state. Remedial measures using a granular shear key was analyzed to improve stability and the stability of temporary excavation side slopes during construction (open excavation) was also examined.

Cross-sections were cut from topographic contours generated from survey data provided by AECOM; cross-sections through the outlet centerline (Cross-Section A), 5 m south of the outfall (Cross-Section B), and perpendicular to rail embankment (Cross-Section C) were used in the analysis. Cross-sections north of the outlet were not analyzed, as the rail bridge head slope and side slopes were regraded and riprap armoured when the new rail bridge was constructed in 2015.

The outputs of the slope stability analyses are presented as factors of safety (FS) related to the stability of the slope. With respect to factor of safety targets, the probability of riverbank instabilities occurring increases as values approach unity (FS=1.0). Riverbanks with a FS greater than 1.3 are considered relatively stable and this was the selected design target for remedial measures. Temporary excavation stability was assessed assuming short term (undrained) conditions in cohesive material; temporary excavations with a minimum short-term FS of 2.0 are considered stable.

Numerical Model Description

The stability analysis was conducted using a limit-equilibrium slope stability model (Slope/W) from the GeoStudio 2016 software package (Geo-Slope International Inc.). Groundwater levels were incorporated into the stability model using an assumed piezometric line. Factors of safety were determined for circular slip surfaces using the Morgenstern-Price method of slices and a half-sine interslice force function. Table 1 lists the engineering properties used for the soil units in the numerical modeling. The strength properties selected for the materials are based on lab testing results and local experience with similar soils and associated typical values.

Table 1. Soil Properties used in Stability Modeling

Soil Description	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (deg)
Sand Fill	18.0	0	30
Silt and Clay	18.0	2	25
Organic Clay	15.3	5	14
Silty Clay	17.5	5	17
Shear Key (50 mm Down)	21	0	50

The individual silt and clay layers present at the site (above the organic clay) were combined into one layer in the slope analysis as a simplification. The shear key material properties used in the model are representative of 50 mm down crushed granular compacted to 98% SPMDD.

The groundwater and river levels used in the analysis consider the water level observed during drilling and our experience, and are considered representative of a normal long-term condition:

- River level at Elev. 310.5 m – normal river level from City of Winnipeg Record Drawing D-13441.
- Groundwater level 2 m below ground surface in upper slope.

Stability Prior to Possible Slope Movement

Cross-Section A was modified to approximate the geometry of the riverbank prior to the outfall misalignment based on adjacent riverbank geometry. A factor of safety of 1.01 was calculated through the centerline of the outfall (Figure 2) and the location of the slip surface coincides with the pipe joint misalignment supporting a slope instability caused the dislodged pipe. The instability was likely rotational in nature and would explain the tilted pipe section.

Existing Stability

The existing stability of cross-sections A and B (surveyed geometry) was analyzed to determine the current level of stability in the vicinity of the outfall. Cross-sections A and B have existing factors of safety of 1.29 and 1.15, respectively as shown on Figures 3 and 4. The existing factors of safety are below the design target (FS=1.3) and therefore, remedial measures are required to achieve the target level of stability.

Remedial Measures

Implementation of remedial measures should be considered if the dislodged pipe is to be repaired. The remedial measures should also address the potential for future settlement of the repaired pipe due to compression of the organic clay layer, but also improve the stability of the riverbank to an acceptable level. In this regard, a granular shear key to improve stability in conjunction with the removal of the organic clay layer beneath the pipe were examined. The remedial measures need to be sizeable due to the depth of the pipe, and the extent and thickness of the organic clay layer. The design of the remedial measures was optimized to reduce the extent of the works, in particular the footprint of an open excavation relative to the adjacent property line to the south and the rail line and bridge abutment to the north.

Granular Shear Key

The analysis assumes the fill for the shear key consists of compacted 50 mm down crushed aggregate. The depth and upslope extent of the shear key were adjusted to optimize the geometry and achieve a factor of safety of 1.3 at the outfall centerline. The base of the shear key is at Elev. 311.0 m (0.6 m below the pipe outlet invert), and at its base, extends 14 m upslope of the pipe outlet. The upslope edge of the shear key assumes a 1 horizontal to 1 vertical (1H:1V) cut up to existing grade at Elev. 315.0 m. Assuming the outfall consists of 5.9 m long sections, this shear key excavation will expose two full sections of pipe. The shear key geometry at the outfall centerline is shown on Figure 5.

A shear key excavation base width of 6 m is required to achieve the target FS when considering 3-D stability effects. Although the location of the edge of the City ROW has not been confirmed, it is expected that the shear key will encroach onto the residential property to the south (Figure 6). To minimize this impact, the shear key could be installed in a shored temporary excavation (e.g. trench box).

To evaluate an open excavation, the stability of the temporary slope perpendicular to rail line was also examined. Multiple configurations of the excavation slopes were analyzed, and the design target factor of safety could not be achieved without removing the track, excavating a portion of the rail embankment, and exposing the bridge abutment. The south excavation slope can be flattened to suit to achieve the target factor of safety but would further encroach into the south property as much as 8 m assuming the ROW is close to the south edge of the outfall pipe.

Removal of the Organic Clay

It is plausible that the outfall misalignment may be in part due to settlement of the soft organic clay that is likely present beneath the pipe and could be up to 2.5 m thick. To limit further settlement after repairs due to the additional weight of the granular shear key, the organic clay beneath the pipe should be removed and replaced with compacted granular fill. Figure 6 shows the extent of the trench and Figure 7 shows the recommended trench geometry below the pipe. The trench should be lined with a geotextile separator (non-woven geotextile). Excavation of the trench may be difficult if groundwater and sloughing conditions are encountered. If the trench cannot be maintained in a dry condition, clean granular fill should be used for backfill the trench as this material can be easily placed below water and should be compacted as much as practicable. In the event the trench is dry, 50 mm down crushed aggregate (same material as above) should be used and compacted to 98% SPMDD.

The condition of the base of the shear key excavation should be assessed prior to excavation of the trench to determine if the trench can be fully or partially excavated successfully. If the trench can not be excavated, alternative mitigation measures will be considered (e.g. bridging the organic layer, flexible pipe connections).

Conclusions and Recommendations

Riverbank movement and/or pipe settlement is likely responsible for the dislodged outfall pipe. Inspection photographs do not indicate that any additional pipe movement/separation has not occurred over at least eight years and the existing factor of safety of the riverbank is ranges from 1.15 to 1.29. Given this recent performance and the cost of the remedial measures, the City of Winnipeg may elect to continue to monitor the pipe outfall in its current state provided it remains operational. If the City elects to repair the pipe, the remedial measures proposed should be implemented. The design of these measures is considered to be to a preliminary level and further analysis and design may be required, especially if an open excavation is used for the repair and remedial works. There is some uncertainty relative to the location of the south edge of the ROW/property line. The location of the property line should be established, and the extents of the proposed remedial works may need to be re-examined relative to the property line location.

It is also our understanding the City of Winnipeg is considering re-locating the pipe to the north side of the rail line. Since sub-surface are not known at this location, a geotechnical investigation is recommended to further evaluate this alternative. In the absence of this information and for the purposes of evaluating the feasibility of this option, the organic clay layer should be assumed to be present north of the rail line.

Closure

The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation and laboratory testing). Soil conditions are natural deposits that can be highly variable across a site. If subsurface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work or standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of AECOM (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

TREK Geotechnical
Per:

Feb 21, 2020

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TREK GEOTECHNICAL INC.
No. 4877 Date: Feb 21/20

Attachment

Figures

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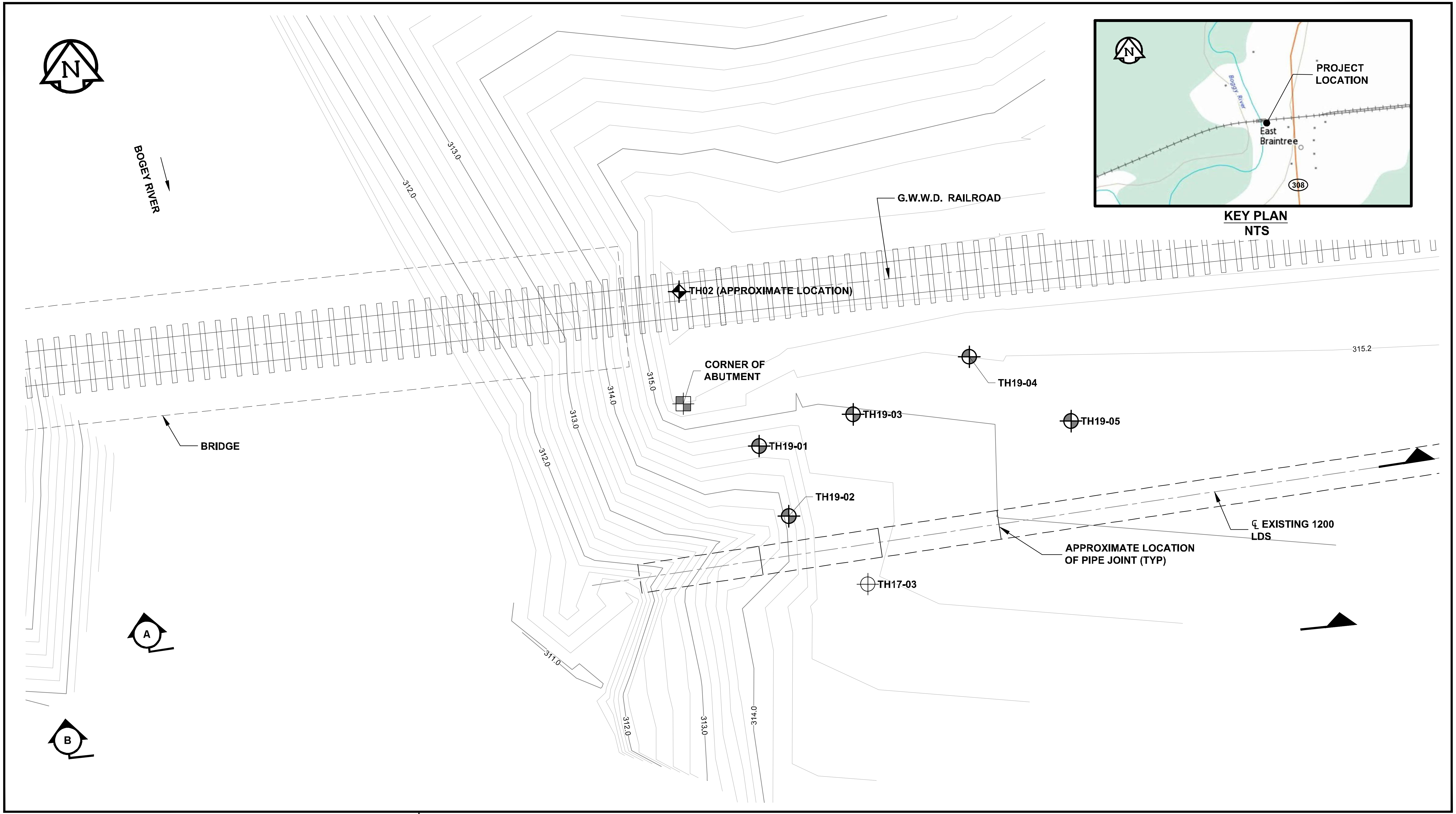

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LEGEND:
- ⊕ TEST HOLE (TREK, 2019)
- ⊕ TEST HOLE (TREK, 2017)
- ◆ TEST HOLE (AGRA EARTH & ENVIRONMENTAL, 1995)

NOTES:
1. CONTOUR INTERVAL 0.20 m (MINOR) to 1.00 m (MAJOR)
2. BASE DRAWING & SURVEY DATA FROM AECOM (2018-05-31)

FIGURE 1
TEST HOLE LOCATION PLAN

Tabloid (279mm x 432mm)

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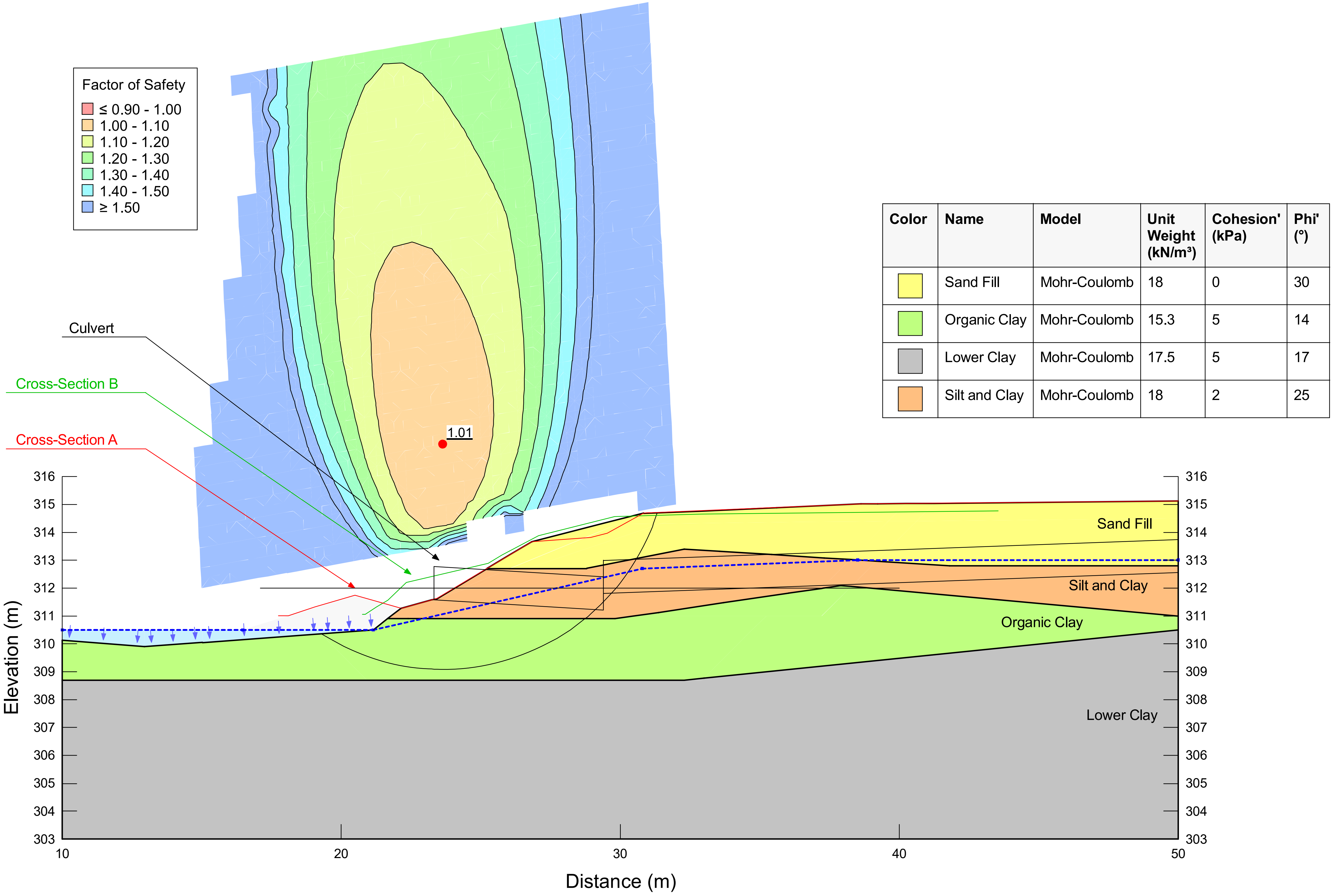

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟨	Sand Fill	Mohr-Coulomb	18	0	30
🟩	Organic Clay	Mohr-Coulomb	15.3	5	14
⬜	Lower Clay	Mohr-Coulomb	17.5	5	17
🟧	Silt and Clay	Mohr-Coulomb	18	2	25

B - Pre-Failure

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FIGURE 2

Outfall Stability Analysis
Cross-Section A - Pre-Failure

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SLA Asset Preservation Program

Tabloid (279mm x 432mm)

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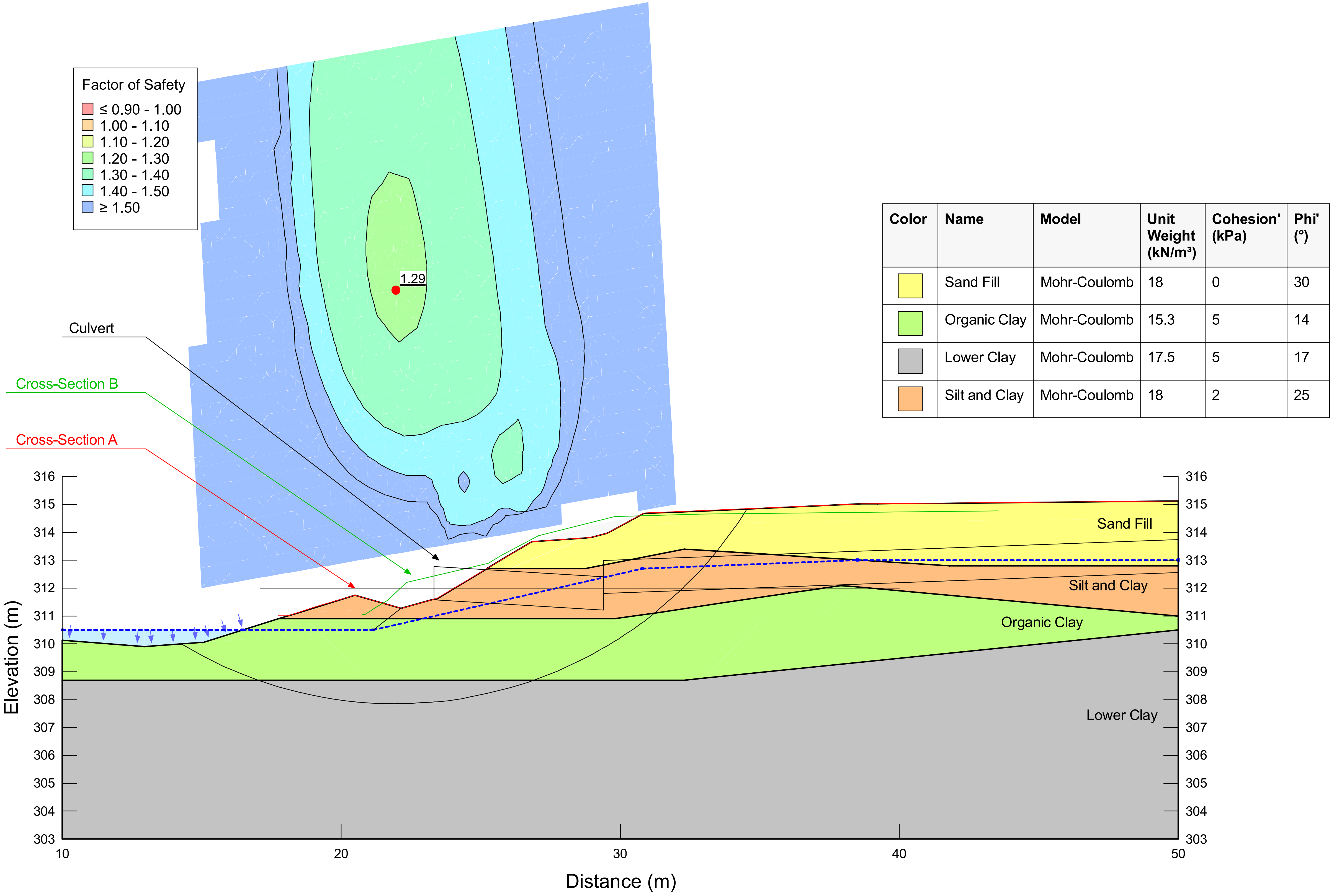

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟨	Sand Fill	Mohr-Coulomb	18	0	30
🟩	Organic Clay	Mohr-Coulomb	15.3	5	14
⬜	Lower Clay	Mohr-Coulomb	17.5	5	17
🟧	Silt and Clay	Mohr-Coulomb	18	2	25

A - Existing Stability

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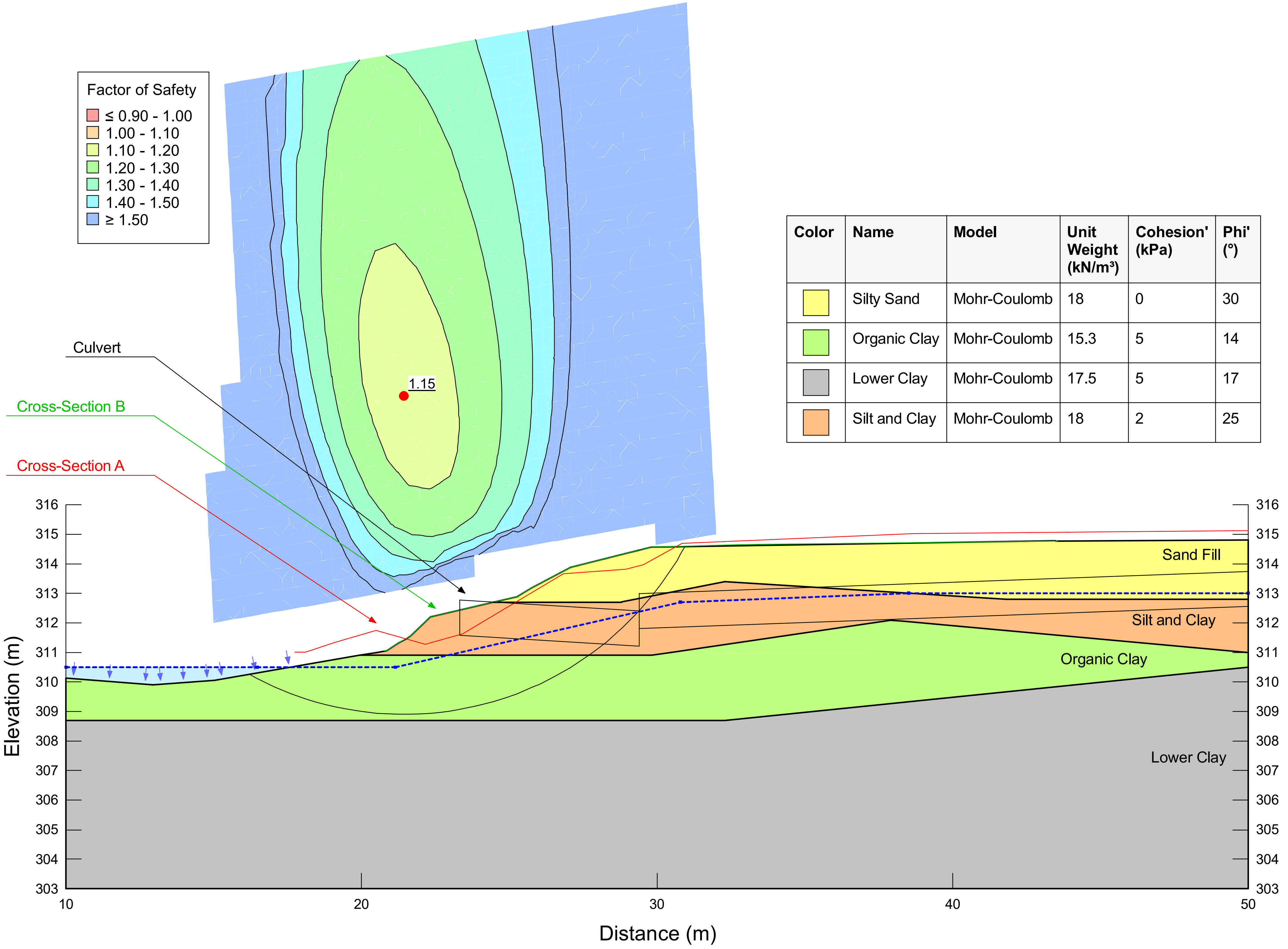
FIGURE 3

Outfall Stability Analysis
Cross-Section A - Existing Stability



Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟨	Silty Sand	Mohr-Coulomb	18	0	30
🟩	Organic Clay	Mohr-Coulomb	15.3	5	14
⬜	Lower Clay	Mohr-Coulomb	17.5	5	17
🟧	Silt and Clay	Mohr-Coulomb	18	2	25

A - Existing Stability

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FIGURE 4

Culvert Stability Analysis
Cross-Section B - Existing Stability

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SLA Asset Preservation Program

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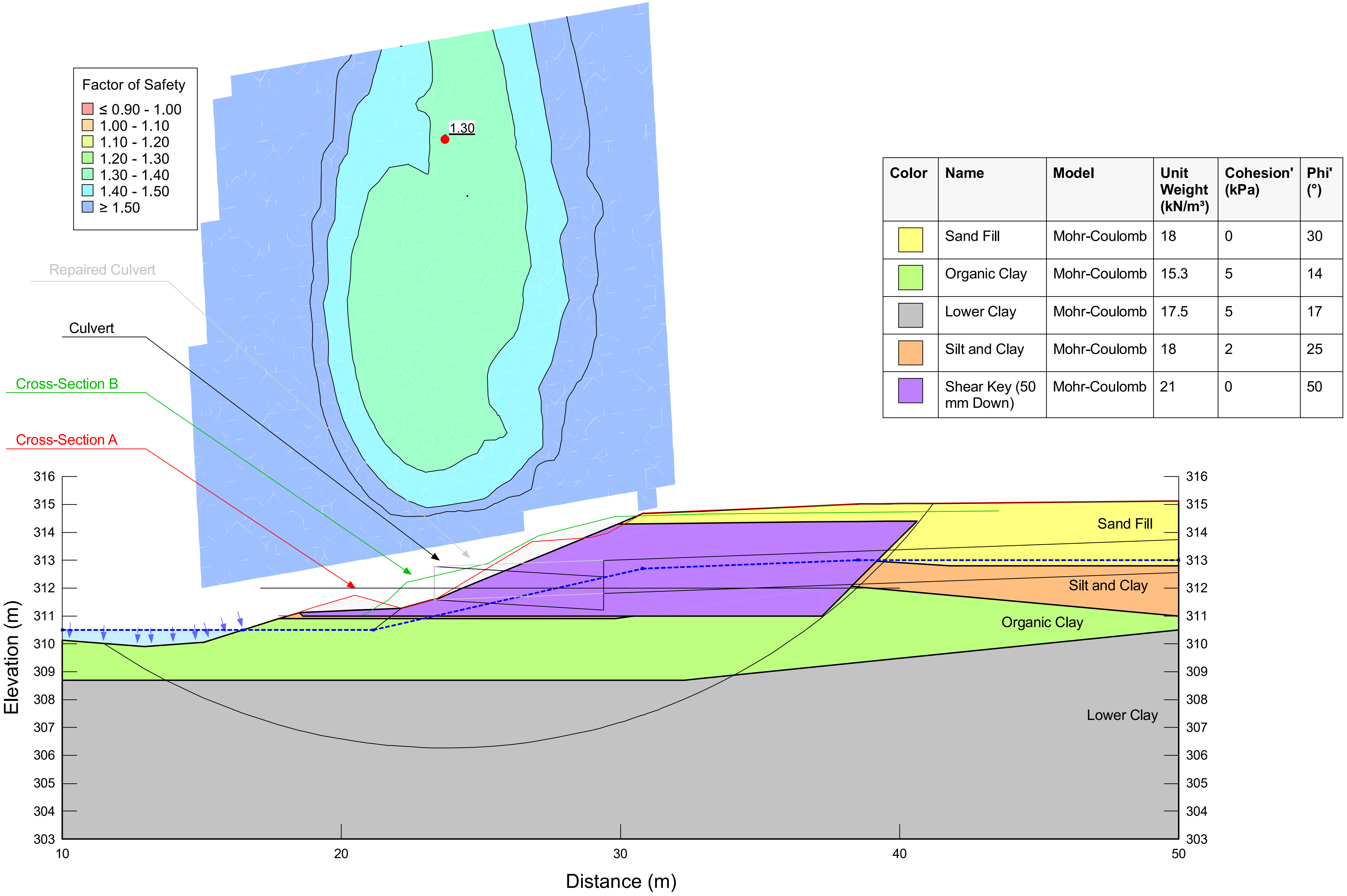

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟨	Sand Fill	Mohr-Coulomb	18	0	30
🟩	Organic Clay	Mohr-Coulomb	15.3	5	14
⬜	Lower Clay	Mohr-Coulomb	17.5	5	17
🟧	Silt and Clay	Mohr-Coulomb	18	2	25
🟪	Shear Key (50 mm Down)	Mohr-Coulomb	21	0	50

C - Shear Key

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FIGURE 5
Outfall Stability Analysis
Cross-Section A - Shear Key

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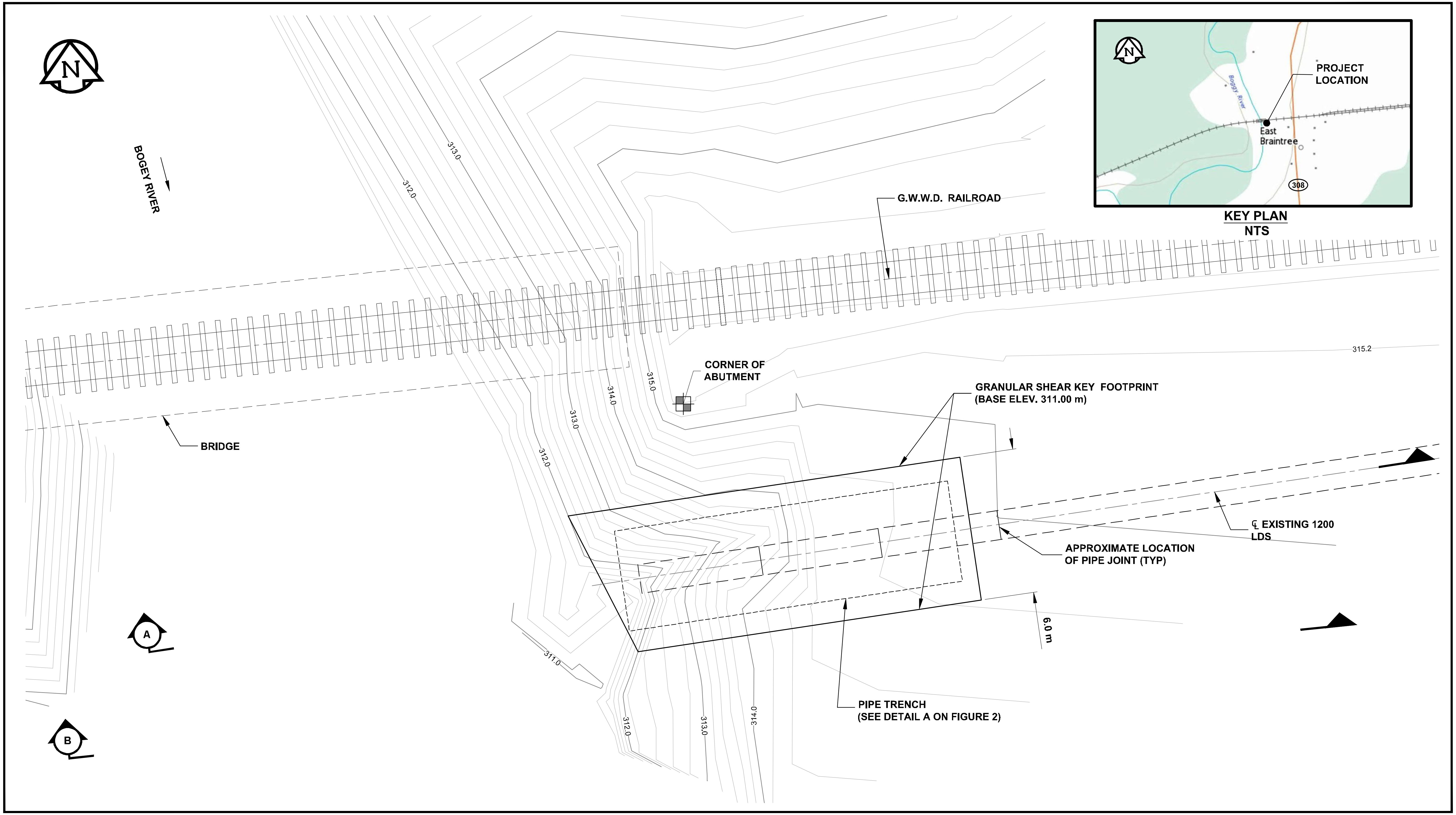

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SCALE = 1 : 150 (279 mm x 432 mm)

NOTES:
1. CONTOUR INTERVAL 0.20 m (MINOR) to 1.00 m (MAJOR)
2. BASE DRAWING & SURVEY DATA FROM AECOM (2018-05-31)

FIGURE 6
REMEDIAL WORKS PLAN

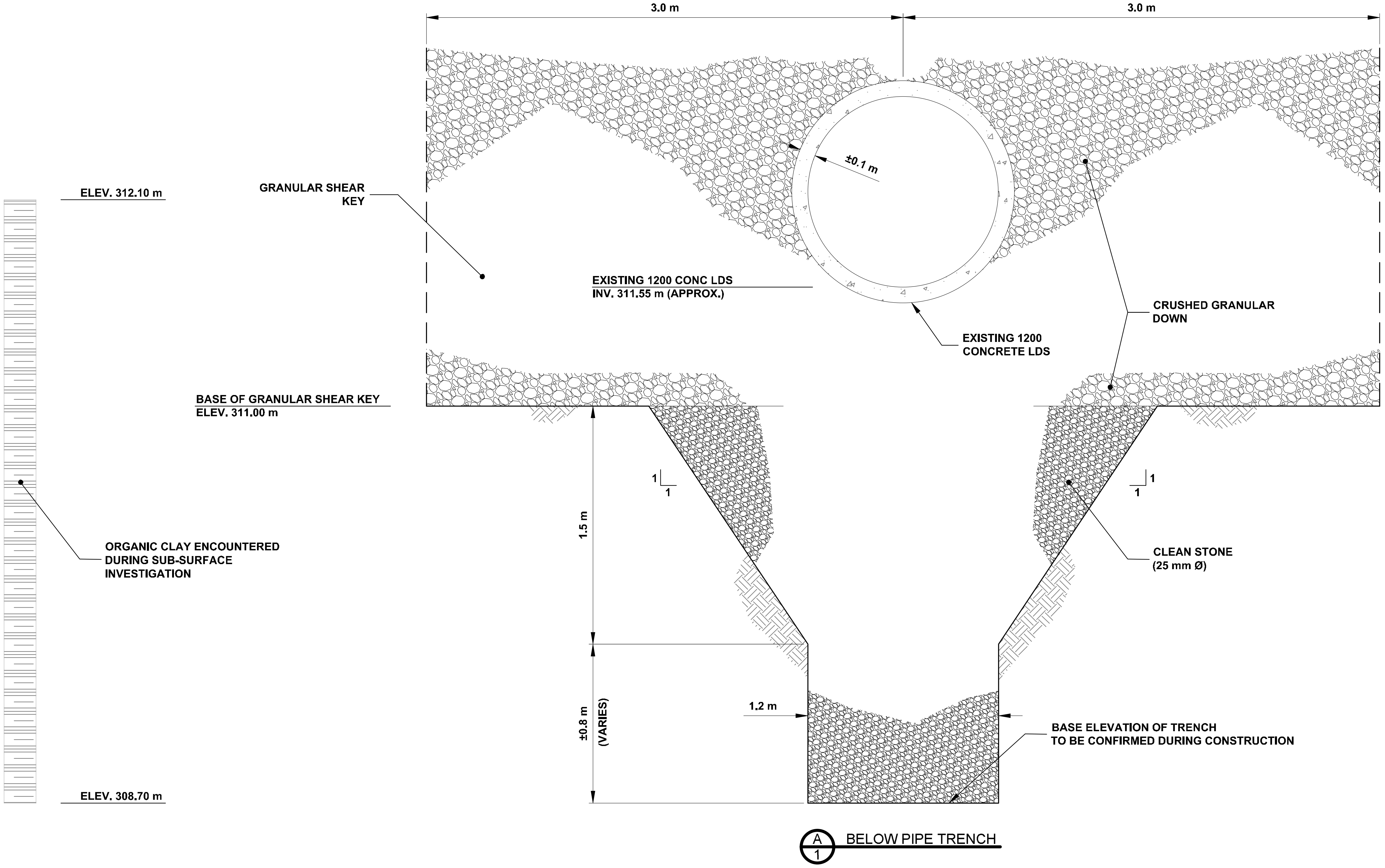

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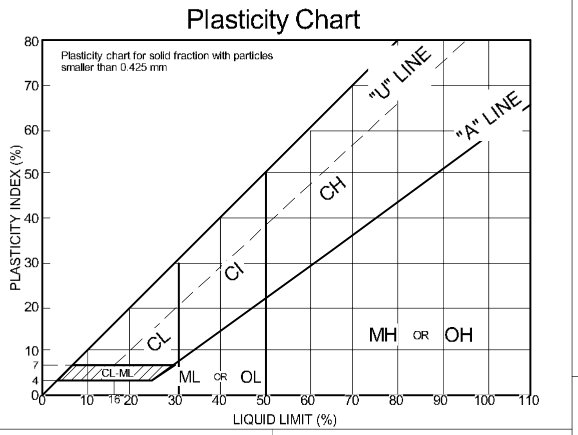
FIGURE 7
REMEDIAL WORKS - TRENCH DETAIL

Sub-Surface Logs

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classification	Symbols	Typical Names	Laboratory Classification Criteria			
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows:	Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	○	Poorly-graded gravels, gravel-sand mixtures, little or no fines			Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	▥	Silty gravels, gravel-sand-silt mixtures			Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures			Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	⁘	Well-graded sands, gravelly sands, little or no fines			$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	░	Poorly-graded sands, gravelly sands, little or no fines			Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures			Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures			Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 			
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays				
			OL	▤	Organic silts and organic silty clays of low plasticity				
	Silts and Clays (Liquid limit greater than 50)		MH	▥	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts				
			CH	▨	Inorganic clays of high plasticity, fat clays				
			OH	≋	Organic clays of medium to high plasticity, organic silts				
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit		Strong colour or odour, and often fibrous texture	

Material		Particle Size mm	ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size mm	ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▨	Bedrock (undifferentiated)	○	Cobbles
░	Concrete	▦	Limestone Bedrock	●	Boulders and Cobbles
▩	Fill	▤	Cemented Shale	▥	Silt Till
		▨	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling
▼ Water Level at End of Drilling
⧨ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

Test Hole TH17-03

1 of 2

Client: AECOM

Project Name: Shoal Lake Aqueduct

Contractor: Maple Leaf Drilling

Method: 170 mm Hollow Stem Auger / HQ Coring, Acker Renegade

Project Number: 0013-023-00

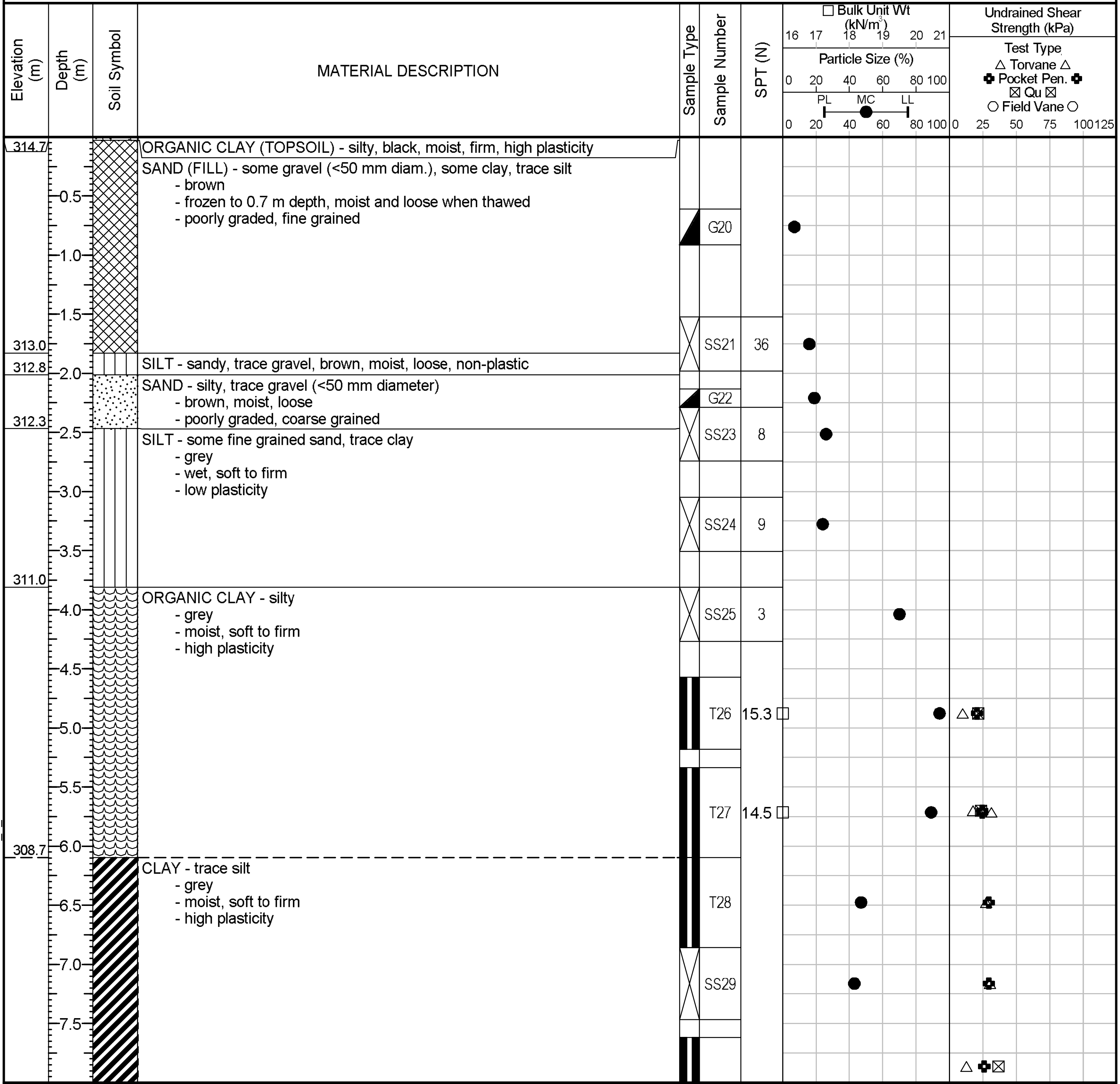
Location: 9.1 m South of rail, 4.6 m East of abutment

Ground Elevation: 314.78 m

Date Drilled: 16 February 2017

Sample Type: Grab (G) | Shelby Tube (T) | Split Spoon (SS) / SPT | Split Barrel (SB) / LPT | Core (C)

Particle Size Legend: Fines | Clay | Silt | Sand | Gravel | Cobbles | Boulders



Elevation (m)	Material Description	Sample Number	SPT (N)	Bulk Unit Wt (kN/m³)
314.7	ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity			
	SAND (FILL) - some gravel (<50 mm diam.), some clay, trace silt - brown - frozen to 0.7 m depth, moist and loose when thawed - poorly graded, fine grained	G20		
		SS21	36	
313.0	SILT - sandy, trace gravel, brown, moist, loose, non-plastic			
312.8	SAND - silty, trace gravel (<50 mm diameter) - brown, moist, loose - poorly graded, coarse grained	G22		
312.3	SILT - some fine grained sand, trace clay - grey - wet, soft to firm - low plasticity	SS23	8	
		SS24	9	
311.0	ORGANIC CLAY - silty - grey - moist, soft to firm - high plasticity	SS25	3	
		T26		15.3
		T27		14.5
308.7	CLAY - trace silt - grey - moist, soft to firm - high plasticity	T28		
		SS29		

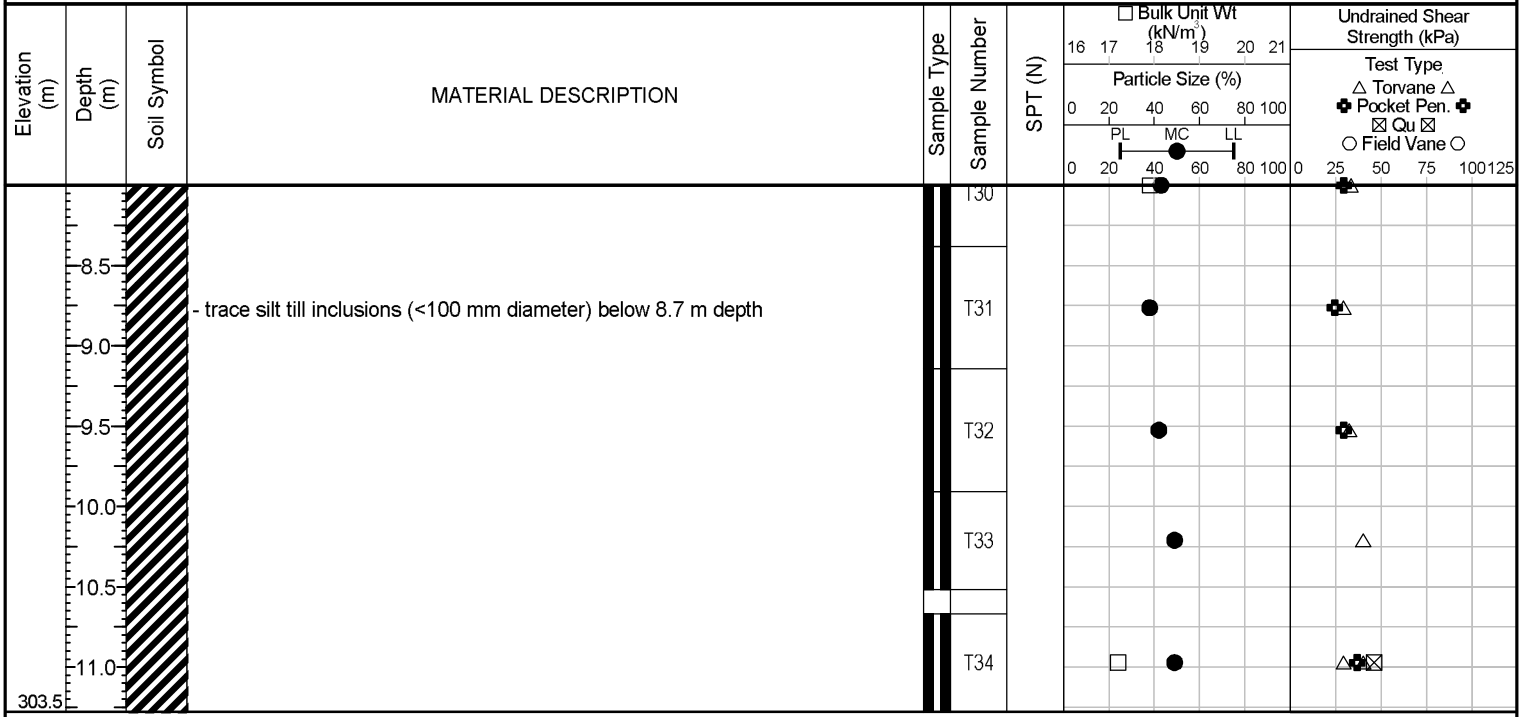
Logged By: Ken Kalynuk **Reviewed By:** Nelson Ferreira **Project Engineer:** Ken Skaftfeld

SUB-SURFACE LOG LOGS 2020-02-21 TH17-03 0_F_SMH 0013-023-00.GPJ TREK.GDT 21/2/20

Sub-Surface Log

Test Hole TH17-03

2 of 2



- trace silt till inclusions (<100 mm diameter) below 8.7 m depth

END OF TEST HOLE AT 11.3 m DEPTH IN CLAY

Notes:

1) Power auger refusal at 2.4 m depth. New test hole drilled 1.5 m south.

2) Drilling method switched from solid stem augers to hollow stem augers at 3.1 m depth.

3) No seepage or sloughing observed.

4) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Ken Kalynuk **Reviewed By:** Nelson Ferreira **Project Engineer:** Ken Skaftfeld

Sub-Surface Log

Test Hole TH19-01

1 of 1

Client: AECOM

Project Name: Shoal Lake Aqueduct

Contractor: Maple Leaf Drilling

Method: 170 mm Hollow Stem Auger, B40 Mobile Truck Mount

Project Number: 0013-023-00

Location: 6.4 m South of rail, 2.7 m East of abutment

Ground Elevation: 315.11 m

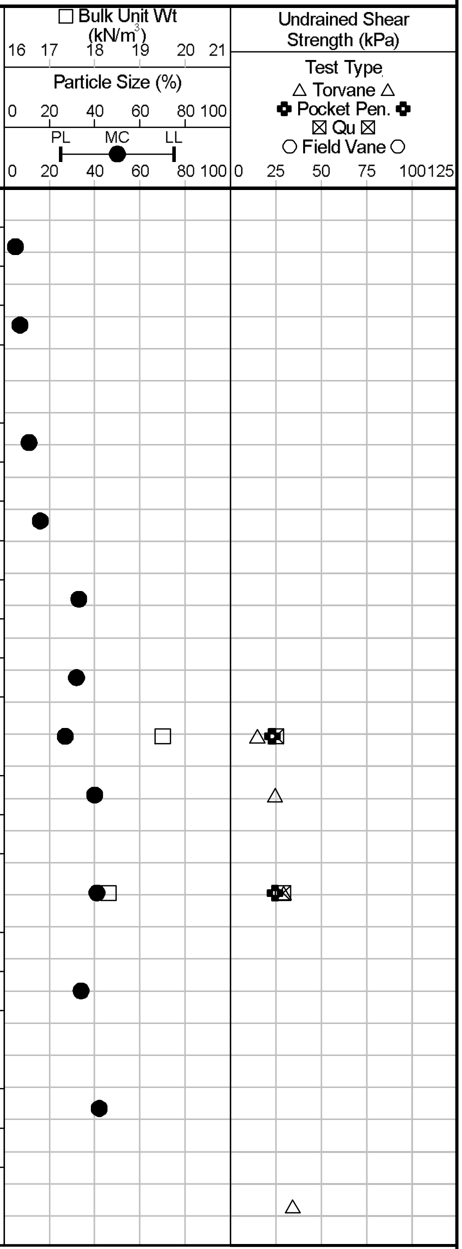
Date Drilled: 28 November 2019

Sample Type: ◢ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ⧗ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ⁙ Sand ● Gravel ▱ Cobbles ▬ Boulders

Elevation (m)	Soil Symbol	MATERIAL DESCRIPTION
315.1	▩	ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity
	▩	SAND (FILL) - some gravel (<25 mm diam, sub-rounded to rounded), trace silt, trace organics - brown - moist, loose, well graded - dark brown, some clay below 1 m depth
312.7	▥	SILT - some clay, trace sand - brown - moist to wet, soft - low plasticity
311.4	▨	CLAY - silty - grey - moist to wet, soft to firm - intermediate plasticity
310.5	▨	CLAY - silty - grey - moist, soft to firm - high plasticity
306.9		

Sample Type	Sample Number
◢	G01
◢	G02
⧗	S03
⧗	S04
⧗	S05
⧗	S06
▮	T07
⧗	S08
▮	T09
⧗	S10
⧗	S11
▮	T12



END OF TEST HOLE AT 8.3 m DEPTH IN CLAY

Notes:

1) Drilling method switched from solid stem augers to hollow stem augers at 1.5 m depth.
2) Seepage and sloughing observed below 3.3 m depth
3) Test hole open to 3.0 m below ground surface after drilling.
4) Water level at 3.0 m below ground surface after drilling.
5) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Matt Klymochko **Reviewed By:** Steven Harms **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH19-02

1 of 1

Client: AECOM

Project Name: Shoal Lake Aqueduct

Contractor: Maple Leaf Drilling

Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Project Number: 0013-023-00

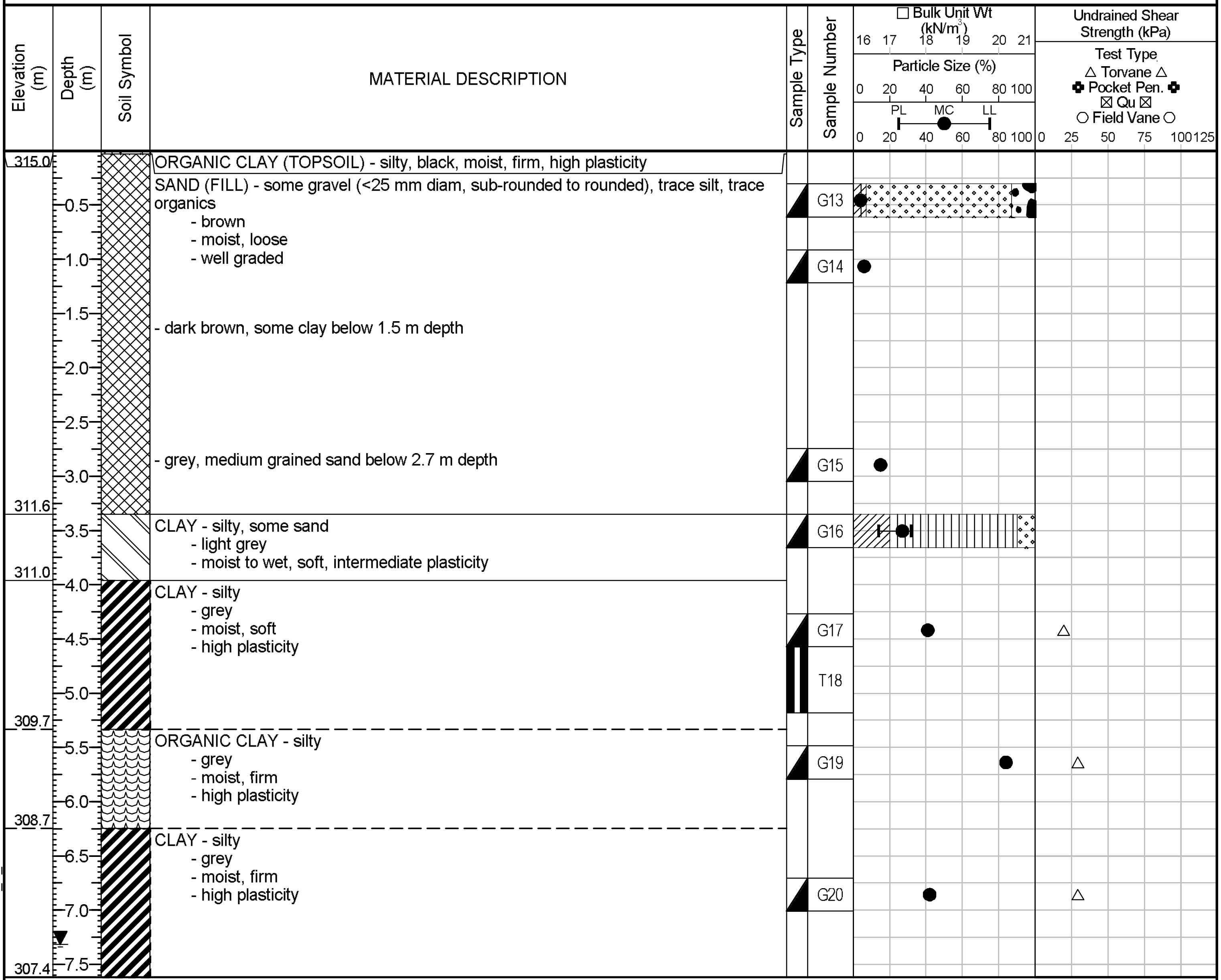
Location: 9.4 m South of rail, 3.6 m East of abutment

Ground Elevation: 315.00 m

Date Drilled: 28 November 2019

Sample Type: Grab (G) | Shelby Tube (T) | Split Spoon (SS) / SPT | Split Barrel (SB) / LPT | Core (C)

Particle Size Legend: Fines | Clay | Silt | Sand | Gravel | Cobbles | Boulders



ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity

SAND (FILL) - some gravel (<25 mm diam, sub-rounded to rounded), trace silt, trace organics
- brown
- moist, loose
- well graded

- dark brown, some clay below 1.5 m depth

- grey, medium grained sand below 2.7 m depth

CLAY - silty, some sand
- light grey
- moist to wet, soft, intermediate plasticity

CLAY - silty
- grey
- moist, soft
- high plasticity

ORGANIC CLAY - silty
- grey
- moist, firm
- high plasticity

CLAY - silty
- grey
- moist, firm
- high plasticity

END OF TEST HOLE AT 7.6 m DEPTH IN CLAY

Notes:

1) Seepage and sloughing observed below 3.3 m depth.
2) Test hole open to 3.7 m below ground surface after drilling.
3) Water level at 7.3 m below ground surface after drilling.
4) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Matt Klymochko **Reviewed By:** Steven Harms **Project Engineer:** Nelson Ferreira

Sub-Surface Log

Test Hole TH19-03

Client: AECOM

Project Name: Shoal Lake Aqueduct

Contractor: Maple Leaf Drilling

Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Project Number: 0013-023-00

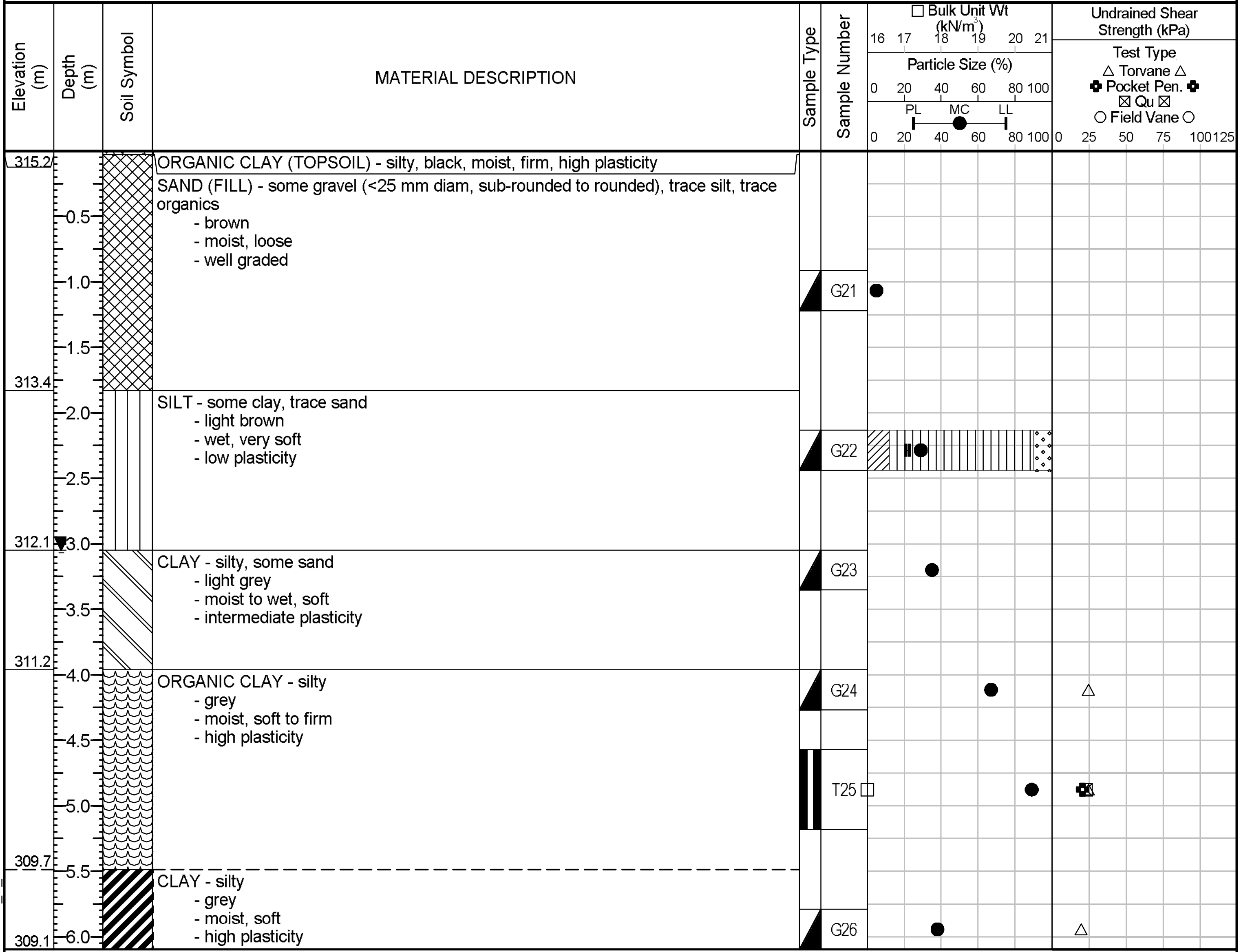
Location: 6.1 m South of rail, 4.6 m East of abutment

Ground Elevation: 315.19 m

Date Drilled: 28 November 2019

Sample Type: ◪ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ☒ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▩ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ▱ Cobbles ▬ Boulders



Elevation (m)	MATERIAL DESCRIPTION	Sample Number
315.2	ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity	
	SAND (FILL) - some gravel (<25 mm diam, sub-rounded to rounded), trace silt, trace organics - brown - moist, loose - well graded	G21
313.4	SILT - some clay, trace sand - light brown - wet, very soft - low plasticity	G22
312.1	CLAY - silty, some sand - light grey - moist to wet, soft - intermediate plasticity	G23
311.2	ORGANIC CLAY - silty - grey - moist, soft to firm - high plasticity	G24 T25
309.7	CLAY - silty - grey - moist, soft - high plasticity	G26
309.1		

END OF TEST HOLE AT 6.1 m DEPTH IN CLAY

Notes:

1) Seepage and sloughing observed below 3.3 m depth.
2) Test hole open to 3.0 m below ground surface after drilling.
3) Water level at 3.0 m below ground surface after drilling.
4) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Matt Klymochko **Reviewed By:** Steven Harms **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

Sub-Surface Log

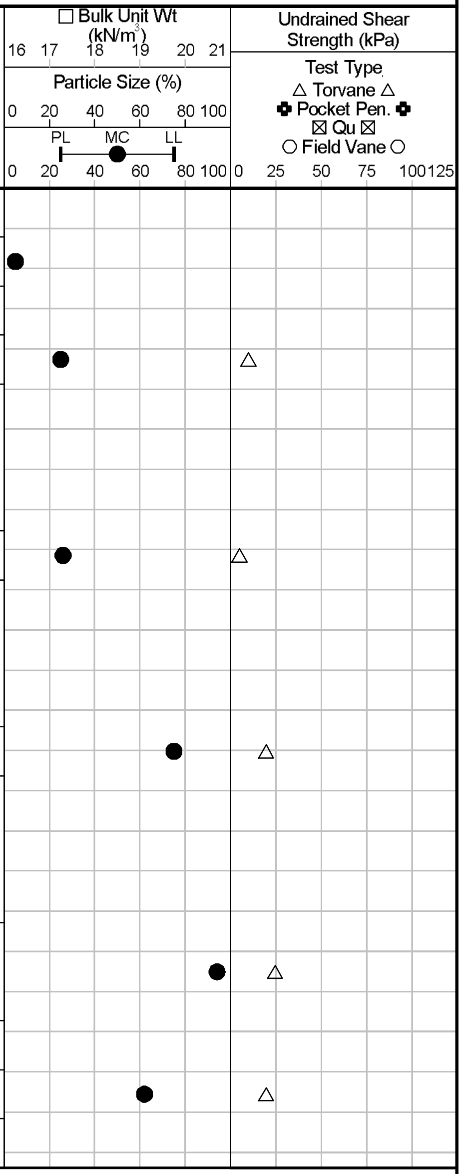
Test Hole TH19-04
1 of 1

Client: AECOM
Project Name: Shoal Lake Aqueduct
Contractor: Maple Leaf Drilling
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Project Number: 0013-023-00
Location: 2.1 m South of rail, 10.7 m East of abutment
Ground Elevation: 315.50 m
Date Drilled: 28 November 2019

Sample Type: Grab (G) | Shelby Tube (T) | Split Spoon (SS) / SPT | Split Barrel (SB) / LPT | Core (C)

Particle Size Legend: Fines | Clay | Silt | Sand | Gravel | Cobbles | Boulders

Elevation (m)	Depth (m)	Soil Symbol	MATERIAL DESCRIPTION	Sample Type	Sample Number
315.5			ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity		
	0.5		SAND (FILL) - some gravel (<25 mm diam, sub-rounded to rounded), trace silt, trace organics - brown - moist, loose - well graded	G	G27
314.6	1.0 1.5 2.0 2.5 3.0		SILT - some clay, trace sand - light brown - moist to wet, very soft - low plasticity	G G	G28 G29
312.1	3.5 4.0 ▼ 4.5 5.0 5.5 6.0		ORGANIC CLAY - silty - grey - moist to wet, soft - high plasticity	G T G	G30 T31 G32
309.4					



END OF TEST HOLE AT 6.1 m DEPTH IN ORGANIC CLAY
Notes:
1) Seepage and sloughing observed below 2.1 m depth.
2) Test hole open to 4.2 m below ground surface after drilling.
3) Water level at 4.2 m below ground surface after drilling.
4) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Matt Klymochko **Reviewed By:** Steven Harms **Project Engineer:** Nelson Ferreira

Sub-Surface Log

Test Hole TH19-05

1 of 1

Client: AECOM

Project Name: Shoal Lake Aqueduct

Contractor: Maple Leaf Drilling

Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Project Number: 0013-023-00

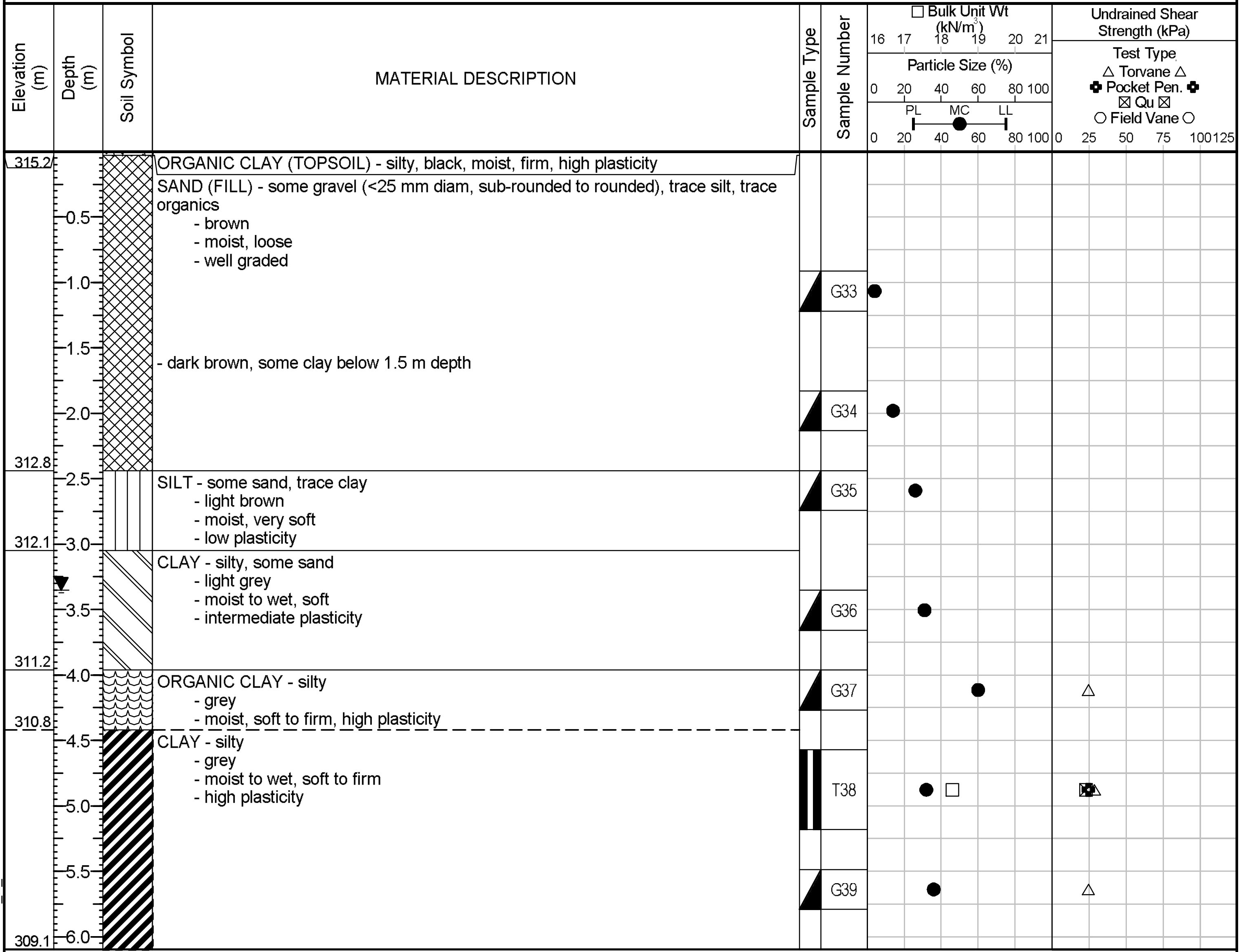
Location: 6.4 m South of rail, 16.2 m East of abutment

Ground Elevation: 315.20 m

Date Drilled: 28 November 2019

Sample Type: ◩ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ☒ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▦ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ▱ Cobbles ▬ Boulders



ORGANIC CLAY (TOPSOIL) - silty, black, moist, firm, high plasticity

SAND (FILL) - some gravel (<25 mm diam, sub-rounded to rounded), trace silt, trace organics
- brown
- moist, loose
- well graded

- dark brown, some clay below 1.5 m depth

SILT - some sand, trace clay
- light brown
- moist, very soft
- low plasticity

CLAY - silty, some sand
- light grey
- moist to wet, soft
- intermediate plasticity

ORGANIC CLAY - silty
- grey
- moist, soft to firm, high plasticity

CLAY - silty
- grey
- moist to wet, soft to firm
- high plasticity

END OF TEST HOLE AT 6.1 m DEPTH IN CLAY

Notes:

1) Seepage and sloughing observed below 3.3 m depth.

2) Test hole open to 3.3 m below ground surface after drilling.

3) Water level at 3.3 m below ground surface after drilling.

4) Test hole backfilled with auger cuttings and bentonite chips to surface.

Logged By: Matt Klymochko **Reviewed By:** Steven Harms **Project Engineer:** Nelson Ferreira

Existing Geotechnical Information

AGRA
Earth & Environmental

AGRA Earth &
Environmental Limited
95 Scurfield Boulevard
Winnipeg, Manitoba
Canada R3Y 1G4
Tel. (204) 488-2997
Fax. (204) 489-8261

December 14, 1995
Project: WX-03838

DWL Engineering Inc.
210 - 530 Kenaston Blvd.
Winnipeg, Manitoba
R3N 1Z4

Attention: Mr. Fred Kemp, P. Eng.

Dear Sir:

RE: GEOTECHNICAL INVESTIGATION
PROPOSED GREATER WINNIPEG WATER DISTRICT RAILWAY BRIDGE
EAST BRAINTREE, MANITOBA

1.0 INTRODUCTION

As authorized by Mr. Fred Kemp, P. Eng., acting on behalf of DWL Engineering Inc., AGRA Earth & Environmental Limited (AEE) performed a geotechnical investigation for a proposed bridge on the Greater Winnipeg Water District (GWWD) railway line at East Braintree, Manitoba. The scope of the geotechnical investigation was to determine the subsurface soil stratigraphy and auger refusal depths at each proposed abutment location in order that a preliminary indication of approximate steel H pile refusal depths could be established.

The work was undertaken in accordance with a proposal submitted to Fred Kemp Engineering Ltd., on August 9, 1995.

2.0 DESCRIPTION OF SITE AND PROPOSED FACILITIES

The site of the proposed railway bridge is located at the GWWD crossing of the Boggy River, about 2 km south of the Trans Canada Highway at the town of East Braintree, Manitoba. A wooden bridge was present at the site. The existing bridge was about 27 m long.

The design details for the proposed new bridge were not made available to AEE at the time of this report. However, it was understood that the bridge would be a single span steel structure. The new abutments would be located in close proximity to the existing abutments, which are about 7 m from the water's edge. No new fills were proposed.

3.0 RESULTS OF INVESTIGATION

3.1 Field Work

A total of 2 test holes were drilled at the site on November 21 and 22, 1995. The test holes were drilled with a track mounted drill rig equipped with 200 mm hollow stem augers and wire line sampling equipment. The drill rig was placed on the rails and the test holes were drilled between the railway ties immediately behind the existing bridge abutments. The test hole locations are shown on the attached plan, Figure 1.

Test Hole 1 was drilled at the proposed west abutment location and was augered to a depth of 24.8 m from grade, where auger refusal occurred on suspected boulders. After auger refusal had occurred, a dynamic cone was driven to a depth of 28.5 m from grade, where cone refusal occurred. It is not known if the cone refused on bedrock or on boulders within the glacial till.

Test Hole 2 was drilled at the proposed east abutment location and was drilled to a depth of 23.2 m from grade. At this depth, refusal of both the hollow stem augers and the standard penetration test (SPT) sampler occurred. Driving a dynamic cone was not attempted at this location.

Disturbed soil samples were recovered at selected depths within both test holes by means of a sampler used in the SPT. The SPT consists of the driving of a 50 mm diameter split barrel sampler a total of 450 mm into the soil using a drop weight weighing 63.5 kg and falling 76 cm. The number of blows required to drive the sampler the final 300 mm is recorded as the N value shown on the test hole logs. The N value is a measure of the relative density of cohesionless soils or relative consistency of cohesive soils. It can be correlated empirically to soil strength and stiffness parameters relevant to the design and performance of foundations. The dynamic cone driven at Test Hole 1 does not retrieve samples for visual classification. However, as with the SPT, the number of blows to drive the cone 300 mm are recorded and the cone penetration resistance is a measure of the relative density of the soil. It should be appreciated, however, that build up of frictional forces along the drill rods trailing the cone often lead to misleading values for the cone penetration, once the cone has penetrated substantially into the soil.

The recovered soil samples were visually classified at the time of drilling by AEE's field technician. The soil profiles, as determined at the time of drilling, are shown on the test hole logs, Figures 2 and 3.

3.2 Laboratory Testing

In the laboratory, moisture contents were determined for all soil samples obtained from the test holes, as a check on the relative moisture contents throughout the drilled depths and across the site.

4.0 SUBSOIL STRATIGRAPHY

The subsurface soil stratigraphy encountered at the site consisted of the following, as noted in descending order from the ground surface:

- granular fill (ballast)
- sand
- clay
- glacial till with sand layers

Rail ballast (crushed rock) was present at the ground surface at both test hole locations. The ballast was 3.1 m thick at Test Hole 1 and 2.7 m thick at Test Hole 2.

Underlying the fill soils was a poorly graded, fine sand. The sand contained some silt and was brown, moist and loose. At Test Hole 1, the sand layer extended to 6.6 m from grade and was saturated below a depth of 4.9 m. At Test Hole 2, the sand was moist throughout and extended to 4.0 m from grade.

A highly plastic clay was present below the sand at both test holes. The clay was moist to very moist, soft to very soft and grey. Silt lenses were present within the clay throughout the deposit. A decrease in moisture contents with depth (with no corresponding gain in soil strength) indicates an increase in silt content and a decrease in plasticity with depth. The clay layer extended to about 13.0 m from grade at Test Hole 1 and 14.5 m from grade at Test Hole 2.

At Test Hole 1, a glacial silt till was present below the clay, at 13.0 m from grade. The till was initially medium dense, low to non-plastic, sandy and moist. A layer of wet, loose, fine, silty sand was observed from 16.0 to 19.5 m from grade, and was underlain by additional glacial till. The composition of the glacial till underlying the sand was similar to that of the till above the sand, however was loose to medium dense and very sandy. Cobbles and boulders were present within the till below about 22.5 m from grade.

At Test Hole 2, a layer of sand was present immediately below the clay. The sand was fine, poorly graded, medium dense and grey. The sand extended to 17.0 m from grade after which a glacial silt till, similar to that described for Test Hole 1 was identified. Auger refusal occurred at 23.2 m from grade, however it could not be confirmed if refusal occurred on bedrock or on boulders within the till.

5.0 RECOMMENDATIONS

Driven steel H piles are considered to be a feasible foundation alternative for the proposed bridge. Bored piles are not considered suitable, given the loose, wet overburden soils present at the site. The depth to bedrock at the site likely negates the use of conventional driven precast concrete piles.

Refusal to drilling and/or the dynamic cone occurred at depths of 28.5 and 23.2 m below grade in Test Holes 1 and 2, respectively. It could not be determined if refusal occurred on bedrock or boulders in the till. Therefore, it is possible that piles would penetrate to greater depth.

Ideally, it would be desirable to drive a test pile at each abutment to establish refusal depth. If this is not practical, contract documents should recognize the potential requirement for additional pile length.

Steel H piles driven to practical refusal on the granite bedrock can be designed on the basis of an allowable capacity equal to 0.3 times the yield stress of the steel. Practical pile refusal can be considered to be about 15 blows per 25 mm of pile penetration, assuming that the piles are driven with a hammer having a minimum driving energy of 40 kJ per blow and consist of conventional HP310 sections. Actual refusal criteria should be established once the actual pile sizes and steel area is known. All piles should be fitted with rock points (driving shoes) for penetration into the underlying bedrock. Due to the long pile lengths necessary and the difficult driving conditions expected near the refusal depths (as a result of boulders), a light weight steel section is not recommended. A minimum HP 310 x 130 steel pile is recommended. Pile spacing should not be less than 2.5 pile diameters, centre to centre.

Full time monitoring of the pile driving operation by qualified geotechnical personnel is recommended in order to assess pile behaviour near and at refusal.

During the final design stage, the lateral load capacity of the steel H piles should be assessed. Due to the loose, soft overburden soils present at this location, and as substantial point resistance will likely not be achieved, the piles will not have a high lateral load capacity. It is likely that if substantial lateral loads are present, resistance may require the use of battered piles.

6.0 CLOSURE

The findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations have been based on the results of field and laboratory investigations combined with an interpolation of soil and groundwater conditions between test hole locations. If conditions encountered during construction appear to be different than those shown by the test holes drilled at this site, this office should be notified in order that the recommendations can be reviewed.

Yours truly,

AGRA Earth & Environmental Limited

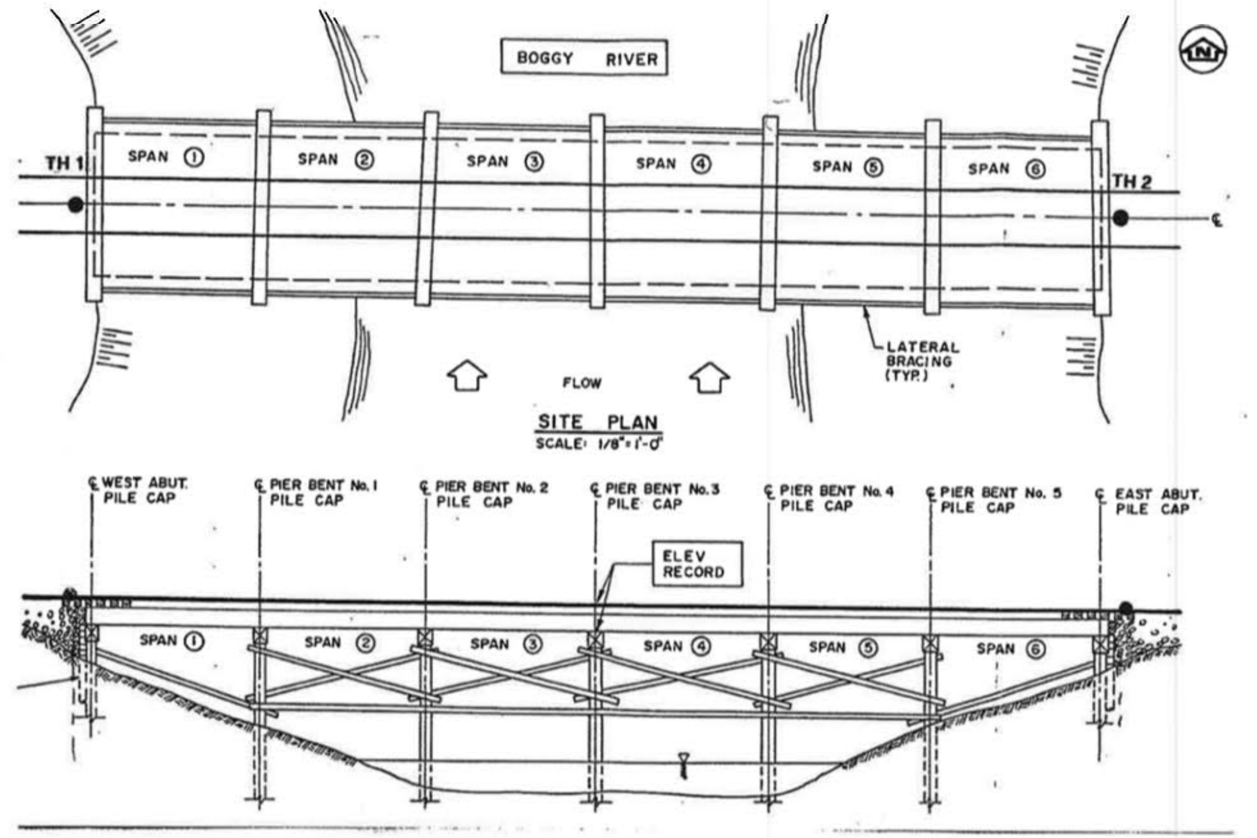
15-12-95
H. D.
PANKRATZ

Harley Pankratz, P.Eng.
Manager; Winnipeg Operations

Reviewed by:
Brian A. Ross, P.Eng.
Vice President; Manitoba/Saskatchewan

3738REP1.HDP

Dist: (2) Addressee
(2) Fred Kemp Engineering



AGRA
Earth & Environmental Limited

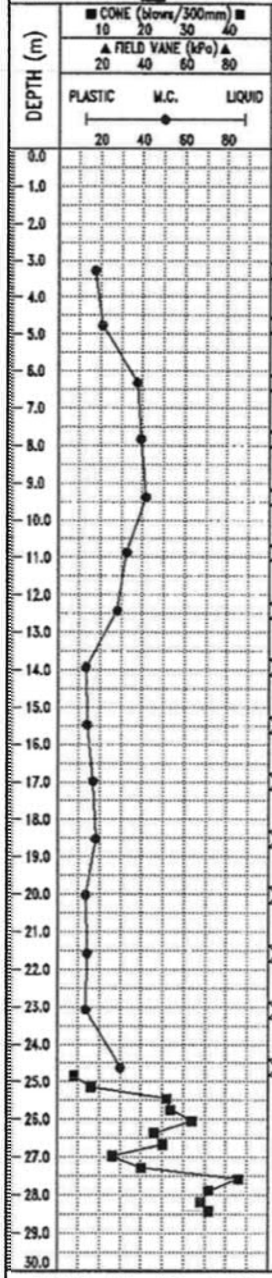
DELCAN WESTERN LTD.

TESTHOLE LOCATION PLAN
EAST BRAINTREE BRIDGE
GREATER WINNIPEG WATER DISTRICT
EAST BRAINTREE, MB.

Drawn: BY OTHERS	Scale: NTS	Date: DEC 95	Project No: WX-03838	Figure: 1

PROJECT: GEO. BRIDGE INVESTIGATION	DRILLER: PADDOCK DRILLING LTD.	TEST HOLE NO: 1
CLIENT: DELCAN WESTERN LTD.	DRILL: RM-30	PROJECT NO: WX-03838
LOCATION: EAST BRAINTREE, WEST ABUTMENT	AUGER: 200mm HSA	ELEVATION: 99.846 (m)

SAMPLE TYPE ■ SHELBY TUBE ▨ CUTTINGS ☒ SPT ☰ CORE ▥ NO RECOVERY ▮ CONT. SAMPLE



SAMPLE TYPE	SAMPLE NO	SPT(N)
☒	1	5
☒	2	6
☒	3	3
☒	4	3
☒	5	2
☒	6	3
☒	7	3
☒	8	10
☒	9	13
☒	10	8
☒	11	8
☒	12	6
☒	13	9
☒	14	12
☒	15	12

USC	SOIL DESCRIPTION	COMMENTS
Fl	FILL - BALLAST GRAVEL frozen to 0.6m	
SP	SAND - poorly graded, fine, moist, loose, brown, traces of silt - wet below 4.9m - wood pieces present between 6.4m & 6.6m	
CH	CLAY - high plastic, moist, soft, grey, traces of silt lensing.	
ML	SILT (GLACIAL TILL) - low to non-plastic, moist, loose to medium dense grey, some wet sand lenses present.	
SP	SAND - poorly graded, fine, wet, loose, brown	
ML	SILT (GLACIAL TILL) - low to non-plastic, moist, medium dense, grey, very sandy. - cobbles/boulders at 22.5m - wet at refusal	
	Auger refusal at 24.8m from grade. Drove dynamic cone from 24.8m to 28.5m. Backfilled hole upon completion.	
	Abrupt cone refusal at 28.5m from grade.	

ELEVATION(m): 99.0 98.0 97.0 96.0 95.0 94.0 93.0 92.0 91.0 90.0 89.0 88.0 87.0 86.0 85.0 84.0 83.0 82.0 81.0 80.0 79.0 78.0 77.0 76.0 75.0 74.0 73.0 72.0 71.0 70.0

AGRA Earth & Environmental Limited Winnipeg, Manitoba	LOGGED BY: DRS	COMPLETION DEPTH: 28.5 m
	REVIEWED BY: BAR	COMPLETE: 22/11/95
	Fig. No: 2	Page 1 of 1

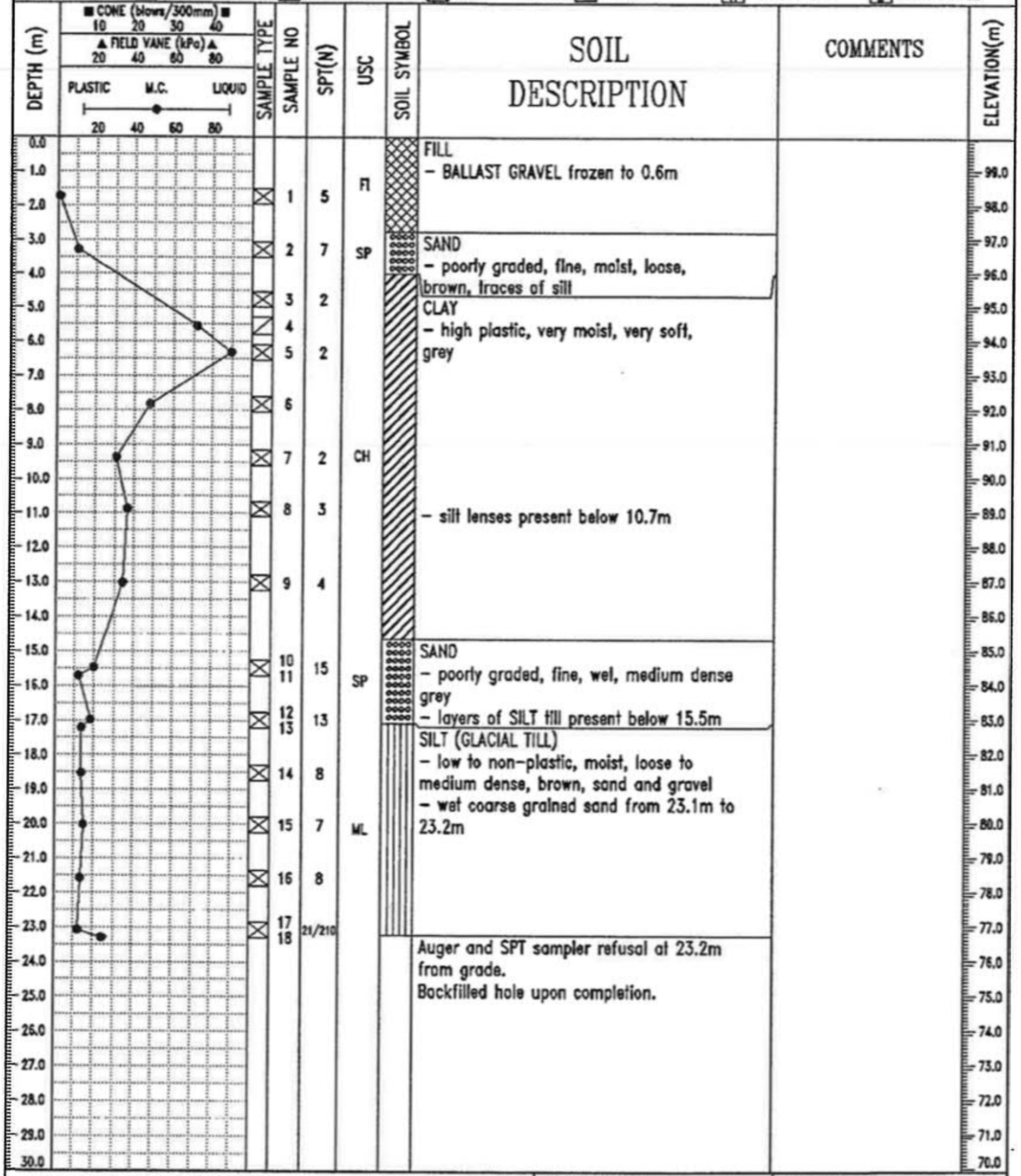
95/12/14 10:27AM

PROJECT: GEO. BRIDGE INVESTIGATION
CLIENT: DELCAN WESTERN LTD.
LOCATION: EAST BRAINTREE, EAST ABUTMENT

DRILLER: PADDOCK DRILLING LTD.
DRILL: RM-30
AUGER: 200mm HSA

TEST HOLE NO: 2
PROJECT NO: WX-03838
ELEVATION: 99.918 (m)

SAMPLE TYPE ■ SHELBY TUBE ◸ CUTTINGS ☒ SPT ☰ CORE ▥ NO RECOVERY ▮ CONT. SAMPLE



SAMPLE TYPE	SAMPLE NO	SPT(N)	USC
☒	1	5	FI
☒	2	7	SP
☒	3	2	
◸	4		
☒	5	2	
☒	6		
☒	7	2	CH
☒	8	3	
☒	9	4	
☒	10 11	15	SP
☒	12 13	13	
☒	14	8	
☒	15	7	ML
☒	16	8	
☒	17 18	21/210	

FILL
- BALLAST GRAVEL frozen to 0.6m

SAND
- poorly graded, fine, moist, loose, brown, traces of silt

CLAY
- high plastic, very moist, very soft, grey
- silt lenses present below 10.7m

SAND
- poorly graded, fine, wet, medium dense grey
- layers of SILT till present below 15.5m

SILT (GLACIAL TILL)
- low to non-plastic, moist, loose to medium dense, brown, sand and gravel
- wet coarse grained sand from 23.1m to 23.2m

Auger and SPT sampler refusal at 23.2m from grade.
Backfilled hole upon completion.

AGRA Earth & Environmental Limited
Winnipeg, Manitoba

LOGGED BY: DRS
REVIEWED BY: BAR
Fig. No: 3

COMPLETION DEPTH: 23.2 m
COMPLETE: 21/11/95
Page 1 of 1

95/12/14 10:00AM

Laboratory Testing

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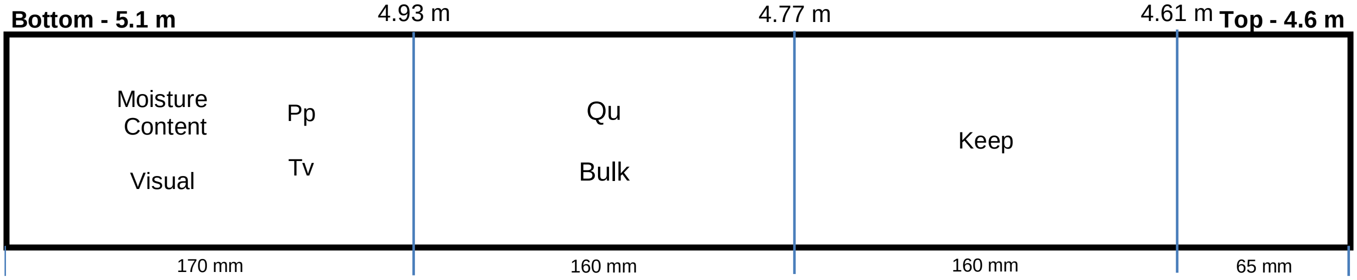
Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation
Test Hole	TH17-03
Sample #	T26
Depth (m)	4.6 - 5.2
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Tube Extraction

Recovery (mm) 555



Visual Classification

Material	Clay
Composition	silty
trace silt inclusions (<15mmø)	
Color	grey
Moisture	moist
Consistency	soft
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.10
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	9.8

Pocket Penetrometer

Reading	**1**	0.35
	2	0.45
	3	0.45
	Average	0.42
Undrained Shear Strength (kPa)		20.4

Moisture Content

Tare ID	W97
Mass tare (g)	8.5
Mass wet + tare (g)	334.2
Mass dry + tare (g)	176.1
Moisture %	94.3%

Unit Weight

Bulk Weight (g)		942.7
Length (mm)	**1**	145.86
	2	145.78
	3	145.54
	4	145.45
Average Length (m)		0.146
Diam. (mm)	**1**	72.87
	2	72.40
	3	72.56
	4	72.48
Average Diameter (m)		0.073
Volume (m^3)		6.03E-04
Bulk Unit Weight (kN/m^3)		15.3
Bulk Unit Weight (pcf)		97.7
Dry Unit Weight (kN/m^3)		7.9
Dry Unit Weight (pcf)		50.3

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Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Test Hole	TH17-03
Sample #	T26
Depth (m)	4.6 - 5.2
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Unconfined Strength

	kPa	ksf
Max q_u	42.8	0.9
Max S_u	21.4	0.4

Specimen Data

Description Clay - silty, trace silt inclusions (<15mmø), grey, moist, soft, high plasticity

Length	145.7	(mm)	**Moisture %**	94%	
Diameter	72.6	(mm)	**Bulk Unit Wt.**	15.3	(kN/m^3)
L/D Ratio	2.0		**Dry Unit Wt.**	7.9	(kN/m^3)
Initial Area	0.00414	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.10	9.8	0.20
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.35	17.2	0.36
	0.45	22.1	0.46
	0.45	22.1	0.46
Average	**0.42**	**20.4**	**0.43**

Failure Geometry

Sketch:

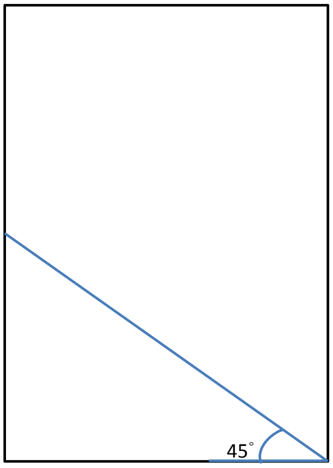

Photo:

Project 0013-023-00
Location Shoal Lake Aqueduct Preservation
Hole No. TH17-03 Sample No. T26
Depth 15-17'
Technician KS Date Feb 21, 2017

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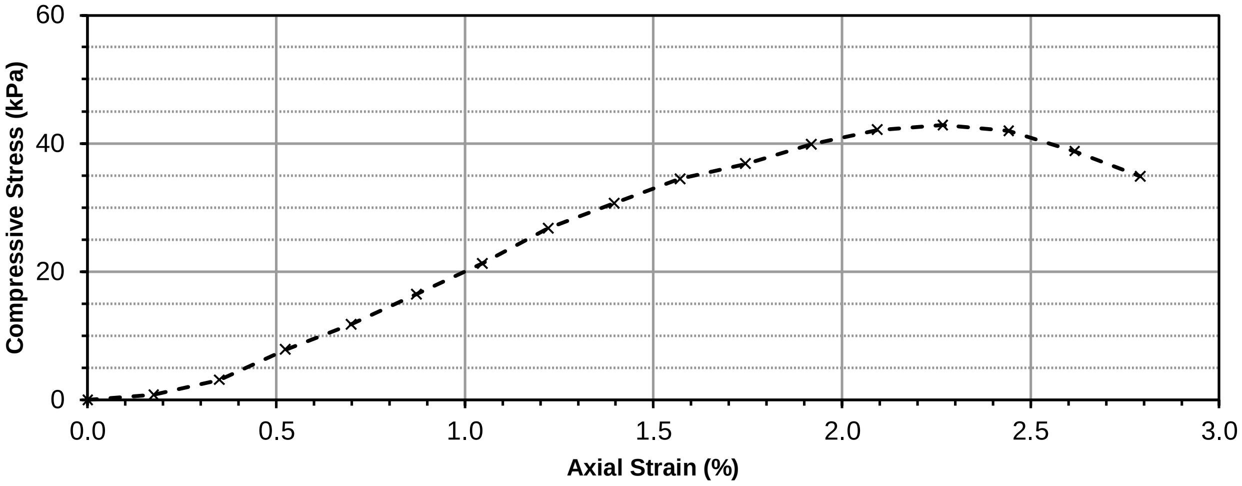
Unconfined Compressive Strength
ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct Preservation

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004137	0.0	0.00	0.00
10	1	0.2540	0.17	0.004144	3.3	0.79	0.39
20	4	0.5080	0.35	0.004152	13.1	3.15	1.57
30	10	0.7620	0.52	0.004159	32.7	7.86	3.93
40	15	1.0160	0.70	0.004166	49.1	11.78	5.89
50	21	1.2700	0.87	0.004173	68.8	16.48	8.24
60	27	1.5240	1.05	0.004181	89.0	21.29	10.64
70	34	1.7780	1.22	0.004188	112.1	26.76	13.38
80	39	2.0320	1.40	0.004196	128.6	30.65	15.33
90	44	2.2860	1.57	0.004203	145.1	34.51	17.26
100	47	2.5400	1.74	0.004211	155.0	36.81	18.40
110	51	2.7940	1.92	0.004218	168.1	39.86	19.93
120	54	3.0480	2.09	0.004226	178.0	42.13	21.06
130	55	3.3020	2.27	0.004233	181.4	42.84	21.42
140	54	3.5560	2.44	0.004241	178.0	41.98	20.99
150	50	3.8100	2.62	0.004248	164.9	38.80	19.40
160	45	4.0640	2.79	0.004256	148.3	34.86	17.43

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Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Test Hole	TH17-03
Sample #	T27
Depth (m)	5.3 - 6.1
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Tube Extraction

Recovery (mm) 660

Bottom - 6 m	5.71 m	5.50 m	4.61 m **Top - 5.3 m**

Moisture Content Visual	Pp Tv	Qu Bulk	Keep
295 mm		160 mm	205 mm

Visual Classification

Material	Clay
Composition	silty

trace silt inclusions (<15mmø)

Color	grey
Moisture	moist
Consistency	soft
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.18
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	17.2

Pocket Penetrometer

Reading	**1**	0.50
	2	0.50
	3	0.50
	Average	0.50
Undrained Shear Strength (kPa)		24.5

Moisture Content

Tare ID	N100
Mass tare (g)	8.5
Mass wet + tare (g)	283.7
Mass dry + tare (g)	154.2
Moisture %	88.9%

Unit Weight

Bulk Weight (g)		922.8
Length (mm)	**1**	149.49
	2	149.59
	3	149.53
	4	149.26
Average Length (m)		0.149
Diam. (mm)	**1**	72.93
	2	72.71
	3	72.82
	4	72.88
Average Diameter (m)		0.073
Volume (m^3)		6.23E-04
Bulk Unit Weight (kN/m^3)		14.5
Bulk Unit Weight (pcf)		92.5
Dry Unit Weight (kN/m^3)		7.7
Dry Unit Weight (pcf)		49.0

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Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Test Hole	TH17-03
Sample #	T27
Depth (m)	5.3 - 6.1
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Unconfined Strength

	kPa	ksf
Max q_u	47.5	1.0
Max S_u	23.7	0.5

Specimen Data

Description Clay - silty, trace silt inclusions (<15mmø), grey, moist, soft, high plasticity

Length	149.5	(mm)	**Moisture %**	89%	
Diameter	72.8	(mm)	**Bulk Unit Wt.**	14.5	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	7.7	(kN/m^3)
Initial Area	0.00417	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.18	17.2	0.36
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.50	24.5	0.51
	0.50	24.5	0.51
Average	**0.50**	**24.5**	**0.51**

Failure Geometry

Sketch:

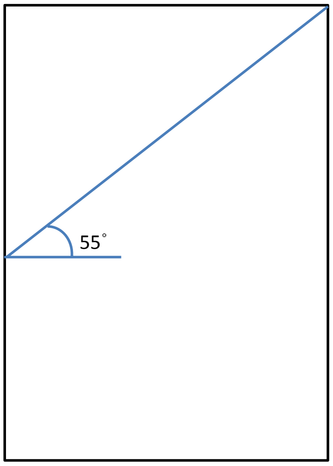

Photo:

Project 0013-023-33
Location Shoal Lake Aqueduct Preservation
Hole No. TH17-03 Sample No. T27
Depth 17.5-20'
Technician KS Date Feb 21, 2017

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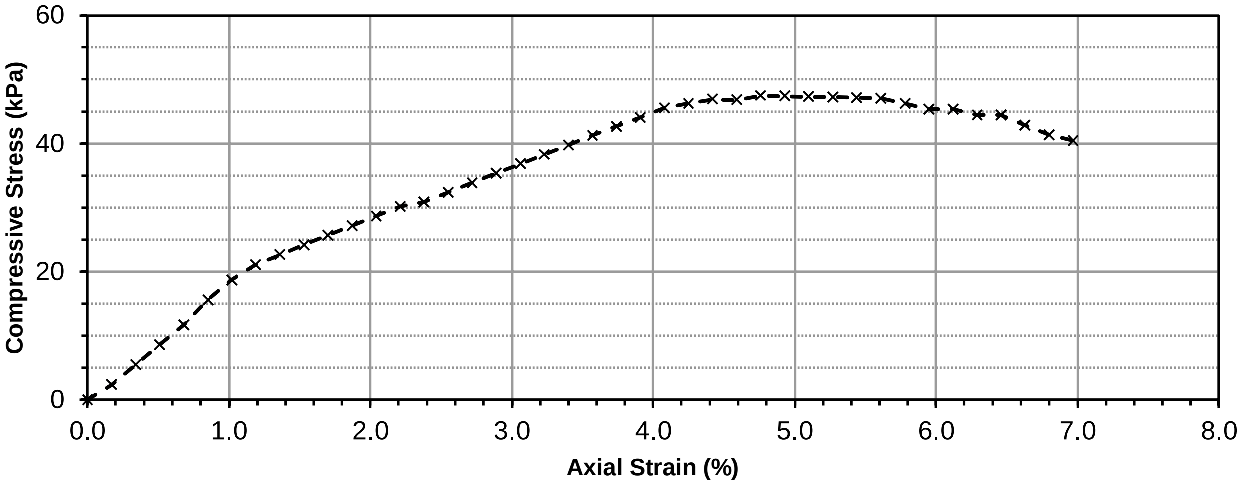
Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct Preservation

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004166	0.0	0.00	0.00
10	3	0.2540	0.17	0.004174	9.8	2.35	1.17
20	7	0.5080	0.34	0.004181	22.9	5.47	2.74
30	11	0.7620	0.51	0.004188	36.0	8.59	4.30
40	15	1.0160	0.68	0.004195	49.1	11.70	5.85
50	20	1.2700	0.85	0.004202	65.5	15.59	7.79
60	24	1.5240	1.02	0.004209	78.6	18.68	9.34
70	27	1.7780	1.19	0.004217	89.0	21.11	10.55
80	29	2.0320	1.36	0.004224	95.6	22.63	11.32
90	31	2.2860	1.53	0.004231	102.2	24.16	12.08
100	33	2.5400	1.70	0.004239	108.8	25.67	12.84
110	35	2.7940	1.87	0.004246	115.4	27.18	13.59
120	37	3.0480	2.04	0.004253	122.0	28.68	14.34
130	39	3.3020	2.21	0.004261	128.6	30.18	15.09
140	40	3.5560	2.38	0.004268	131.9	30.90	15.45
150	42	3.8100	2.55	0.004275	138.5	32.39	16.19
160	44	4.0640	2.72	0.004283	145.1	33.87	16.93
170	46	4.3180	2.89	0.004290	151.7	35.35	17.68
180	48	4.5720	3.06	0.004298	158.3	36.82	18.41
190	50	4.8260	3.23	0.004306	164.9	38.29	19.14
200	52	5.0800	3.40	0.004313	171.4	39.75	19.87
210	54	5.3340	3.57	0.004321	178.0	41.20	20.60
220	56	5.5880	3.74	0.004328	184.6	42.66	21.33
230	58	5.8420	3.91	0.004336	191.2	44.10	22.05

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct Preservation

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	60	6.0960	4.0785	0.004344	197.8	45.54	22.77
250	61	6.3500	4.25	0.004351	201.1	46.22	23.11
260	62	6.6040	4.42	0.004359	204.4	46.89	23.44
270	62	6.8580	4.59	0.004367	204.4	46.81	23.40
280	63	7.1120	4.76	0.004375	207.7	47.49	23.74
290	63	7.3660	4.93	0.004382	207.7	47.40	23.70
300	63	7.6200	5.10	0.004390	207.7	47.32	23.66
310	63	7.8740	5.27	0.004398	207.7	47.23	23.62
320	63	8.1280	5.44	0.004406	207.7	47.15	23.57
330	63	8.3820	5.61	0.004414	207.7	47.06	23.53
340	62	8.6360	5.78	0.004422	204.4	46.22	23.11
350	61	8.8900	5.95	0.004430	201.1	45.40	22.70
360	61	9.1440	6.12	0.004438	201.1	45.31	22.66
370	60	9.3980	6.29	0.004446	197.8	44.49	22.25
380	60	9.6520	6.46	0.004454	197.8	44.41	22.21
390	58	9.9060	6.63	0.004462	191.2	42.86	21.43
400	56	10.1600	6.80	0.004470	184.6	41.30	20.65
410	55	10.4140	6.97	0.004479	181.4	40.49	20.25

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Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation
Test Hole	TH17-03
Sample #	T30
Depth (m)	7.6 - 8.4
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Tube Extraction

Recovery (mm) 565

Bottom - 8.2 m — 8.02 m — 7.86 m — 7.70 m — **Top - 7.6 m**

Moisture Content Visual Pp Tv	Qu Bulk	Keep	
145 mm	160 mm	160 mm	100 mm

Visual Classification

Material	Clay
Composition	silty
trace gravel (<15mmø)	
Color	grey
Moisture	moist
Consistency	soft to firm
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.13
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	12.3

Pocket Penetrometer

Reading	**1**	0.50
	2	0.55
	3	0.55
	Average	0.53
Undrained Shear Strength (kPa)		26.2

Moisture Content

Tare ID	D43
Mass tare (g)	8.8
Mass wet + tare (g)	293.4
Mass dry + tare (g)	207.8
Moisture %	43.0%

Unit Weight

Bulk Weight (g)		1116.0
Length (mm)	**1**	148.92
	2	148.67
	3	148.93
	4	148.88
Average Length (m)		0.149
Diam. (mm)	**1**	72.27
	2	72.46
	3	72.39
	4	72.24
Average Diameter (m)		0.072
Volume (m^3)		6.12E-04
Bulk Unit Weight (kN/m^3)		17.9
Bulk Unit Weight (pcf)		113.9
Dry Unit Weight (kN/m^3)		12.5
Dry Unit Weight (pcf)		79.6

Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Test Hole	TH17-03
Sample #	T30
Depth (m)	7.6 - 8.4
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Unconfined Strength

	kPa	ksf
Max q_u	73.2	1.5
Max S_u	36.6	0.8

Specimen Data

Description Clay - silty, trace gravel (<15mmø), grey, moist, soft to firm, high plasticity

Length	148.9	(mm)	**Moisture %**	43%	
Diameter	72.3	(mm)	**Bulk Unit Wt.**	17.9	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	12.5	(kN/m^3)
Initial Area	0.00411	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.13	12.3	0.26
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.55	27.0	0.56
	0.55	27.0	0.56
Average	**0.53**	**26.2**	**0.55**

Failure Geometry

Sketch:

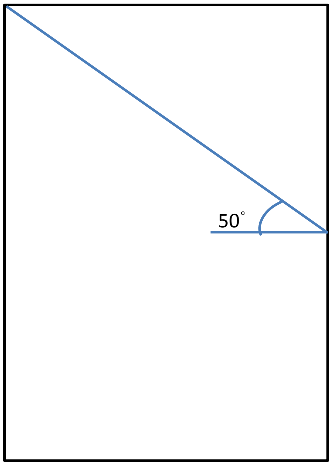
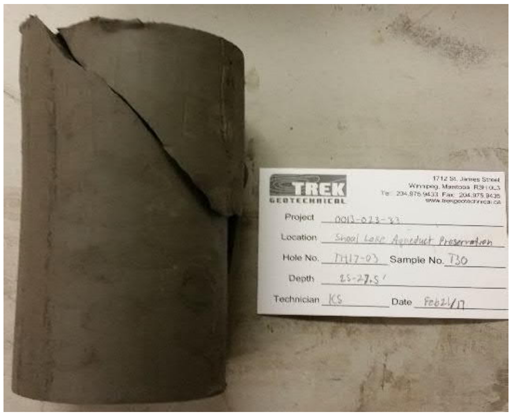


Photo:



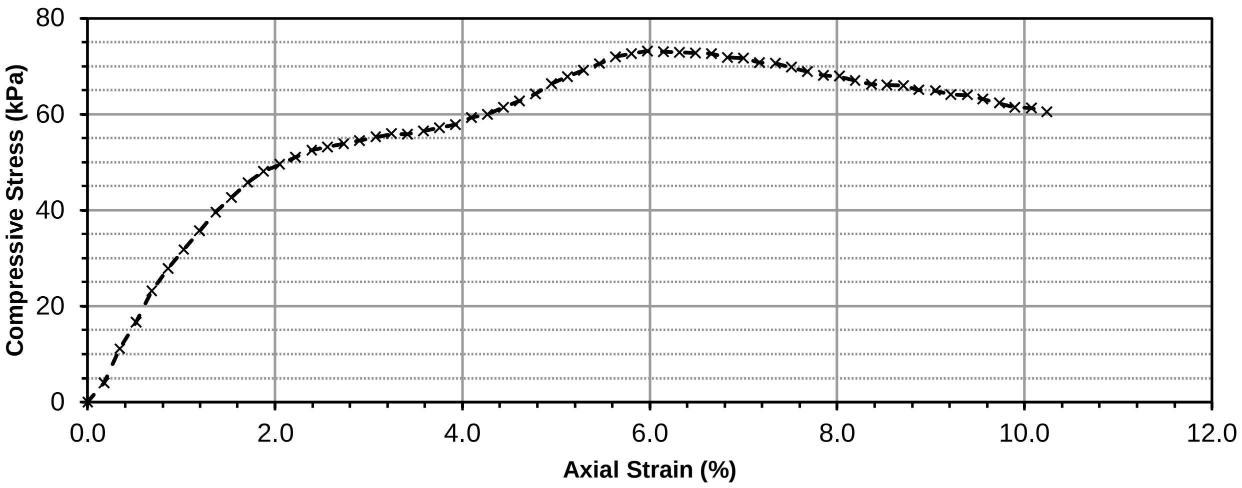
Project 0013-023-33
Location Shoal Lake Aqueduct Preservation
Hole No. TH17-03 Sample No. T30
Depth 25-27.5'
Technician KS Date Feb21/17

Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004110	0.0	0.00	0.00
10	5	0.2540	0.17	0.004117	16.3	3.97	1.98
20	14	0.5080	0.34	0.004124	45.8	11.11	5.55
30	21	0.7620	0.51	0.004131	68.8	16.65	8.32
40	29	1.0160	0.68	0.004138	95.6	23.10	11.55
50	35	1.2700	0.85	0.004145	115.4	27.83	13.92
60	40	1.5240	1.02	0.004153	131.9	31.76	15.88
70	45	1.7780	1.19	0.004160	148.3	35.66	17.83
80	50	2.0320	1.37	0.004167	164.9	39.56	19.78
90	54	2.2860	1.54	0.004174	178.0	42.65	21.32
100	58	2.5400	1.71	0.004181	191.2	45.73	22.87
110	61	2.7940	1.88	0.004189	201.1	48.01	24.01
120	63	3.0480	2.05	0.004196	207.7	49.51	24.75
130	65	3.3020	2.22	0.004203	214.3	50.99	25.49
140	67	3.5560	2.39	0.004211	220.9	52.46	26.23
150	68	3.8100	2.56	0.004218	224.2	53.15	26.58
160	69	4.0640	2.73	0.004225	227.5	53.84	26.92
170	70	4.3180	2.90	0.004233	230.8	54.52	27.26
180	71	4.5720	3.07	0.004240	234.1	55.21	27.61
190	72	4.8260	3.24	0.004248	237.4	55.89	27.94
200	72	5.0800	3.41	0.004255	237.4	55.79	27.89
210	73	5.3340	3.58	0.004263	240.7	56.46	28.23
220	74	5.5880	3.75	0.004270	244.0	57.13	28.57
230	75	5.8420	3.92	0.004278	247.3	57.80	28.90

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct Preservation

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	77	6.0960	4.0954	0.004286	253.9	59.24	29.62
250	78	6.3500	4.27	0.004293	257.2	59.90	29.95
260	80	6.6040	4.44	0.004301	263.8	61.33	30.67
270	82	6.8580	4.61	0.004309	270.4	62.75	31.38
280	84	7.1120	4.78	0.004316	276.9	64.16	32.08
290	87	7.3660	4.95	0.004324	286.8	66.33	33.17
300	89	7.6200	5.12	0.004332	293.4	67.74	33.87
310	91	7.8740	5.29	0.004340	300.0	69.14	34.57
320	93	8.1280	5.46	0.004347	306.6	70.53	35.26
330	95	8.3820	5.63	0.004355	313.2	71.91	35.96
340	96	8.6360	5.80	0.004363	316.5	72.55	36.27
350	97	8.8900	5.97	0.004371	319.8	73.17	36.58
360	97	9.1440	6.14	0.004379	319.8	73.04	36.52
370	97	9.3980	6.31	0.004387	319.8	72.90	36.45
380	97	9.6520	6.48	0.004395	319.8	72.77	36.39
390	97	9.9060	6.66	0.004403	319.8	72.64	36.32
400	96	10.1600	6.83	0.004411	316.5	71.76	35.88
410	96	10.4140	7.00	0.004419	316.5	71.63	35.81
420	95	10.6680	7.17	0.004427	313.2	70.74	35.37
430	95	10.9220	7.34	0.004436	313.2	70.61	35.31
440	94	11.1760	7.51	0.004444	309.9	69.74	34.87
450	93	11.4300	7.68	0.004452	306.6	68.87	34.44
460	92	11.6840	7.85	0.004460	303.3	68.01	34.00
470	92	11.9380	8.02	0.004468	303.3	67.88	33.94
480	91	12.1920	8.19	0.004477	300.0	67.02	33.51
490	90	12.4460	8.36	0.004485	296.7	66.16	33.08
500	90	12.7000	8.53	0.004493	296.7	66.04	33.02
510	90	12.9540	8.70	0.004502	296.7	65.92	32.96
520	89	13.2080	8.87	0.004510	293.4	65.06	32.53
530	89	13.4620	9.04	0.004519	293.4	64.94	32.47
540	88	13.7160	9.21	0.004527	290.2	64.09	32.05
550	88	13.9700	9.39	0.004536	290.2	63.97	31.99

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Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation
Test Hole	TH17-03
Sample #	T34
Depth (m)	10.7 - 11.3
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Tube Extraction

Recovery (mm) 565

Bottom - 11.2 m 11.1 m 11.0 m 10.8 m **Top - 10.7 m**

Moisture Content Visual Pp Tv	Qu Bulk	Keep	
140 mm	160 mm	160 mm	105 mm

Visual Classification

Material	Clay
Composition	silty
-	
Color	grey
Moisture	moist
Consistency	soft to firm
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.30
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	29.4

Pocket Penetrometer

Reading	**1**	0.75
	2	0.75
	3	0.75
	Average	0.75
Undrained Shear Strength (kPa)		36.8

Moisture Content

Tare ID	W23
Mass tare (g)	8.6
Mass wet + tare (g)	314
Mass dry + tare (g)	213.9
Moisture %	48.8%

Unit Weight

Bulk Weight (g)		1085.3
Length (mm)	**1**	149.59
	2	149.23
	3	149.82
	4	150.19
Average Length (m)		0.150
Diam. (mm)	**1**	72.42
	2	73.03
	3	72.42
	4	72.30
Average Diameter (m)		0.073
Volume (m^3)		6.19E-04
Bulk Unit Weight (kN/m^3)		17.2
Bulk Unit Weight (pcf)		109.5
Dry Unit Weight (kN/m^3)		11.6
Dry Unit Weight (pcf)		73.6

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Unconfined Compressive Strength
ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct Preservation

Test Hole	TH17-03
Sample #	T34
Depth (m)	10.7 - 11.3
Sample Date	21-Feb-17
Test Date	2-Mar-17
Technician	MM

Unconfined Strength

	kPa	ksf
Max q_u	92.2	1.9
Max S_u	46.1	1.0

Specimen Data

Description Clay - silty, grey, moist, soft to firm, high plasticity

Length	149.7	(mm)
Diameter	72.5	(mm)
L/D Ratio	2.1	
Initial Area	0.00413	(m^2)
Load Rate	1.00	(%/min)

Moisture %	49%	
Bulk Unit Wt.	17.2	(kN/m^3)
Dry Unit Wt.	11.6	(kN/m^3)
Liquid Limit	-	
Plastic Limit	-	
Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

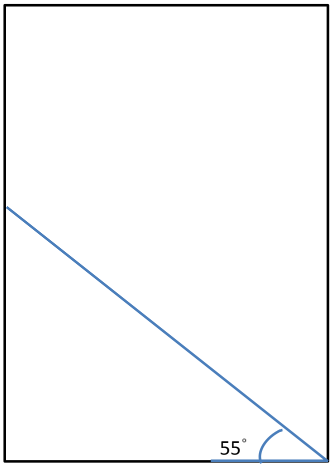
Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.30	29.4	0.61
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.75	36.8	0.77
	0.75	36.8	0.77
	0.75	36.8	0.77
Average	**0.75**	**36.8**	**0.77**

Failure Geometry

Sketch:



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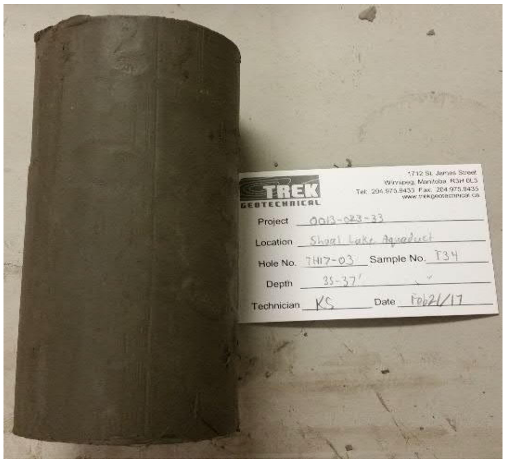

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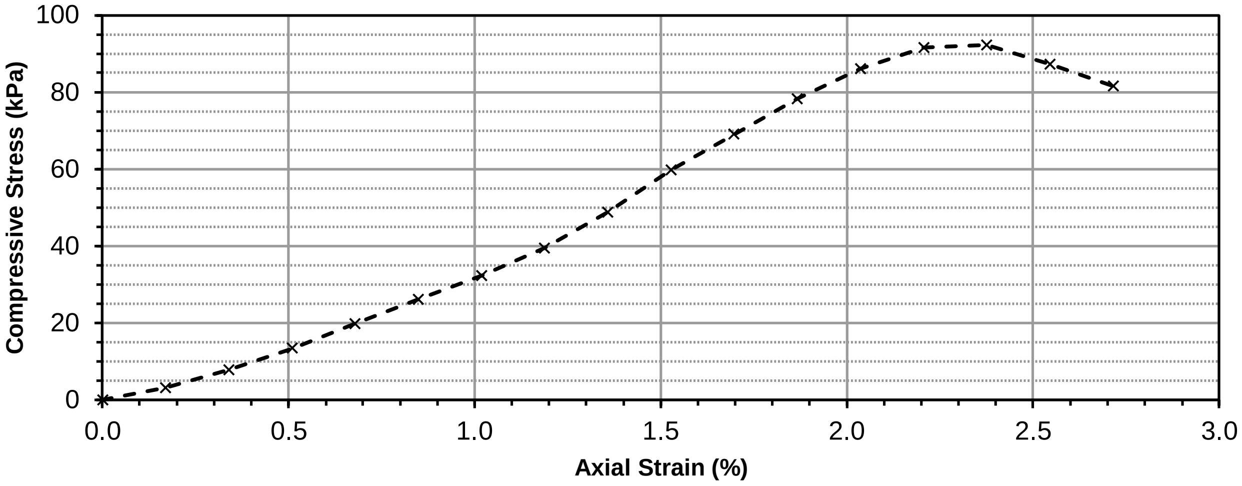
Project 0013-023-33
Location Shoal Lake Aqueduct
Hole No. TH17-03 Sample No. T34
Depth 35-37'
Technician KS Date Feb21/17

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct Preservation

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004133	0.0	0.00	0.00
10	4	0.2540	0.17	0.004140	13.1	3.16	1.58
20	10	0.5080	0.34	0.004147	32.7	7.89	3.94
30	17	0.7620	0.51	0.004154	55.7	13.40	6.70
40	25	1.0160	0.68	0.004161	82.4	19.81	9.90
50	33	1.2700	0.85	0.004168	108.8	26.10	13.05
60	41	1.5240	1.02	0.004176	135.2	32.37	16.19
70	50	1.7780	1.19	0.004183	164.9	39.41	19.71
80	62	2.0320	1.36	0.004190	204.4	48.78	24.39
90	76	2.2860	1.53	0.004197	250.6	59.70	29.85
100	88	2.5400	1.70	0.004204	290.2	69.01	34.51
110	100	2.7940	1.87	0.004212	329.7	78.28	39.14
120	110	3.0480	2.04	0.004219	363.4	86.13	43.06
130	117	3.3020	2.21	0.004226	387.0	91.56	45.78
140	118	3.5560	2.38	0.004234	390.3	92.20	46.10
150	112	3.8100	2.54	0.004241	370.1	87.28	43.64
160	105	4.0640	2.71	0.004248	346.6	81.57	40.79

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Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-01
Sample #	T07
Depth (m)	4.0 - 4.6
Sample Date	28-Nov-19
Test Date	03-Dec-19
Technician	SB

Tube Extraction

Recovery (mm) 680

Bottom - 4.6 m	4.48 m	4.32 m	4.25 m	4.20 m	4.04 m **Top - 4 m**
Toss	Qu Bulk	Moisture Content PP,TV Visual	Toss	Keep	Toss
160 mm	160 mm	70 mm	50 mm	160 mm	80 mm

Visual Classification

Material	SILT
Composition	trace clay
trace sand	
Color	grey
Moisture	moist
Consistency	soft
Plasticity	low plasticity
Structure	laminated dark and light grey silt (<5 mm thick)
Gradation	-

Torvane

Reading	0.15
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	14.7

Pocket Penetrometer

Reading	**1**	0.40
	2	0.50
	3	0.50
	Average	0.47
Undrained Shear Strength (kPa)		22.9

Moisture Content

Tare ID	P06
Mass tare (g)	8.7
Mass wet + tare (g)	268.5
Mass dry + tare (g)	213.2
Moisture %	27.0%

Unit Weight

Bulk Weight (g)		1243.2
Length (mm)	**1**	149.11
	2	147.44
	3	149.60
	4	150.40
Average Length (m)		0.149
Diam. (mm)	**1**	72.87
	2	72.79
	3	73.76
	4	72.87
Average Diameter (m)		0.073
Volume (m^3)		6.25E-04
Bulk Unit Weight (kN/m^3)		19.5
Bulk Unit Weight (pcf)		124.1
Dry Unit Weight (kN/m^3)		15.3
Dry Unit Weight (pcf)		97.7

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Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct

Test Hole	TH19-01
Sample #	T07
Depth (m)	4.0 - 4.6
Sample Date	28-Nov-19
Test Date	3-Dec-19
Technician	SB

Unconfined Strength

	kPa	ksf
Max q_u	49.6	1.0
Max S_u	24.8	0.5

Specimen Data

Description SILT - trace clay, trace sand, grey, moist, soft, low plasticity, laminated dark and light grey silt (<5 mm thick)

Length	149.1	(mm)	**Moisture %**	27%	
Diameter	73.1	(mm)	**Bulk Unit Wt.**	19.5	(kN/m^3)
L/D Ratio	2.0		**Dry Unit Wt.**	15.3	(kN/m^3)
Initial Area	0.00419	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

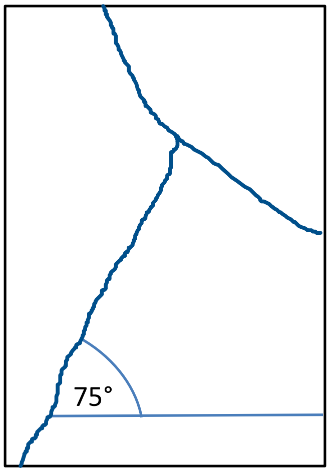
Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.15	14.7	0.31
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.40	19.6	0.41
	0.50	24.5	0.51
	0.50	24.5	0.51
Average	**0.47**	**22.9**	**0.48**

Failure Geometry

Sketch:



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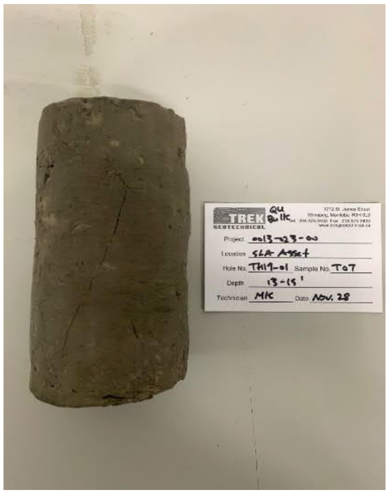
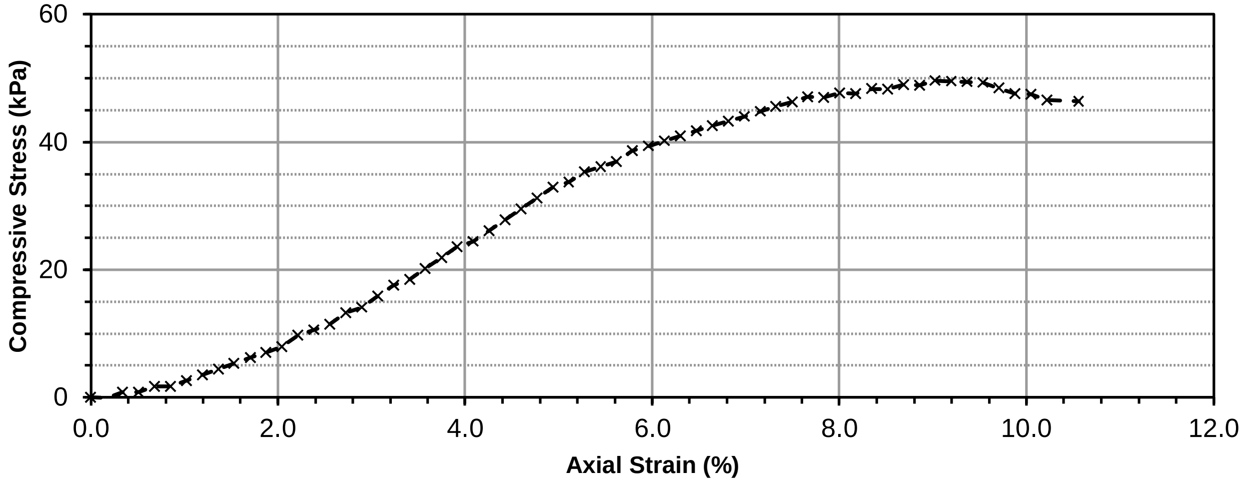


Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004194	0.0	0.00	0.00
10	0	0.2540	0.17	0.004201	-0.4	-0.10	-0.05
20	1	0.5080	0.34	0.004208	3.4	0.81	0.41
30	1	0.7620	0.51	0.004215	3.4	0.81	0.41
40	2	1.0160	0.68	0.004222	7.3	1.72	0.86
50	2	1.2700	0.85	0.004230	7.3	1.72	0.86
60	3	1.5240	1.02	0.004237	11.1	2.62	1.31
70	4	1.7780	1.19	0.004244	14.9	3.51	1.76
80	5	2.0320	1.36	0.004252	18.7	4.41	2.20
90	6	2.2860	1.53	0.004259	22.6	5.30	2.65
100	7	2.5400	1.70	0.004266	26.4	6.19	3.09
110	8	2.7940	1.87	0.004274	30.2	7.07	3.54
120	9	3.0480	2.04	0.004281	34.1	7.95	3.98
130	11	3.3020	2.21	0.004289	41.7	9.73	4.86
140	12	3.5560	2.38	0.004296	45.5	10.60	5.30
150	13	3.8100	2.55	0.004304	49.4	11.47	5.74
160	15	4.0640	2.73	0.004311	57.0	13.23	6.61
170	16	4.3180	2.90	0.004319	60.8	14.09	7.04
180	18	4.5720	3.07	0.004326	68.5	15.83	7.92
190	20	4.8260	3.24	0.004334	76.2	17.57	8.79
200	21	5.0800	3.41	0.004342	80.0	18.42	9.21
210	23	5.3340	3.58	0.004349	87.6	20.15	10.08
220	25	5.5880	3.75	0.004357	95.3	21.87	10.94
230	27	5.8420	3.92	0.004365	103.0	23.59	11.79

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	28	6.0960	4.09	0.004372	106.8	24.42	12.21
250	30	6.3500	4.26	0.004380	114.4	26.13	13.06
260	32	6.6040	4.43	0.004388	122.1	27.82	13.91
270	34	6.8580	4.60	0.004396	129.8	29.52	14.76
280	36	7.1120	4.77	0.004404	137.4	31.20	15.60
290	38	7.3660	4.94	0.004412	145.1	32.88	16.44
300	39	7.6200	5.11	0.004420	148.9	33.69	16.84
310	41	7.8740	5.28	0.004427	156.5	35.36	17.68
320	42	8.1280	5.45	0.004435	160.4	36.16	18.08
330	43	8.3820	5.62	0.004443	164.2	36.95	18.48
340	45	8.6360	5.79	0.004451	171.9	38.61	19.30
350	46	8.8900	5.96	0.004460	175.7	39.40	19.70
360	47	9.1440	6.13	0.004468	179.5	40.18	20.09
370	48	9.3980	6.30	0.004476	183.3	40.96	20.48
380	49	9.6520	6.47	0.004484	187.2	41.74	20.87
390	50	9.9060	6.64	0.004492	191.0	42.52	21.26
400	51	10.1600	6.81	0.004500	194.8	43.28	21.64
410	52	10.4140	6.98	0.004509	198.6	44.04	22.02
420	53	10.6680	7.15	0.004517	202.3	44.79	22.40
430	54	10.9220	7.32	0.004525	206.1	45.55	22.77
440	55	11.1760	7.49	0.004533	209.9	46.30	23.15
450	56	11.4300	7.66	0.004542	213.7	47.04	23.52
460	56	11.6840	7.83	0.004550	213.7	46.96	23.48
470	57	11.9380	8.00	0.004559	217.4	47.70	23.85
480	57	12.1920	8.18	0.004567	217.4	47.61	23.80
490	58	12.4460	8.35	0.004576	221.2	48.35	24.17
500	58	12.7000	8.52	0.004584	221.2	48.26	24.13
510	59	12.9540	8.69	0.004593	225.0	48.99	24.49
520	59	13.2080	8.86	0.004601	225.0	48.90	24.45
530	60	13.4620	9.03	0.004610	228.8	49.62	24.81
540	60	13.7160	9.20	0.004618	228.8	49.53	24.77
550	60	13.9700	9.37	0.004627	228.8	49.44	24.72
560	60	14.2240	9.54	0.004636	228.8	49.35	24.67
570	59	14.4780	9.71	0.004645	225.0	48.44	24.22
580	58	14.7320	9.88	0.004653	221.2	47.54	23.77
590	58	14.9860	10.05	0.004662	221.2	47.45	23.72
600	57	15.2400	10.22	0.004671	217.4	46.55	23.27
620	57	15.7480	10.56	0.004689	217.4	46.37	23.19

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Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-01
Sample #	T09
Depth (m)	5.2 - 5.8
Sample Date	28-Nov-19
Test Date	3-Dec-19
Technician	SB

Tube Extraction

Recovery (mm) 635

Bottom - 5.8 m	5.66 m	5.50 m	5.43 m **Top - 5.2 m**
Qu Bulk	Keep	Moisture Content PP,TV Visual	Toss
160 mm	160 mm	70 mm	245 mm

Visual Classification

Material	CLAY
Composition	Silty

trace silt inclusion (<5 mm diam.)

Color	dark grey
Moisture	moist
Consistency	soft to firm
Plasticity	intermediate plasticity
Structure	-
Gradation	-

Torvane

Reading	0.30
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	29.4

Pocket Penetrometer

Reading	**1**	0.50
	2	0.50
	3	0.50
	Average	0.50
Undrained Shear Strength (kPa)		24.5

Moisture Content

Tare ID	E13
Mass tare (g)	8.8
Mass wet + tare (g)	293.6
Mass dry + tare (g)	210.4
Moisture %	41.3%

Unit Weight

Bulk Weight (g)		1170.2
Length (mm)	**1**	152.64
	2	152.90
	3	153.00
	4	152.52
Average Length (m)		0.153
Diam. (mm)	**1**	72.20
	2	71.57
	3	72.43
	4	72.66
Average Diameter (m)		0.072
Volume (m^3)		6.26E-04
Bulk Unit Weight (kN/m^3)		18.3
Bulk Unit Weight (pcf)		116.8
Dry Unit Weight (kN/m^3)		13.0
Dry Unit Weight (pcf)		82.6

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Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct

Test Hole	TH19-01
Sample #	T09
Depth (m)	5.2 - 5.8
Sample Date	28-Nov-19
Test Date	3-Dec-19
Technician	SB

Unconfined Strength

	kPa	ksf
Max q_u	57.1	1.2
Max S_u	28.5	0.6

Specimen Data

Description CLAY - Silty, trace silt inclusion (<5 mm diam.), dark grey, moist, soft to firm, intermediate plasticity

Length	152.8	(mm)	**Moisture %**	41%	
Diameter	72.2	(mm)	**Bulk Unit Wt.**	18.3	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	13.0	(kN/m^3)
Initial Area	0.00410	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.30	29.4	0.61
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.50	24.5	0.51
	0.50	24.5	0.51
Average	**0.50**	**24.5**	**0.51**

Failure Geometry

Sketch:

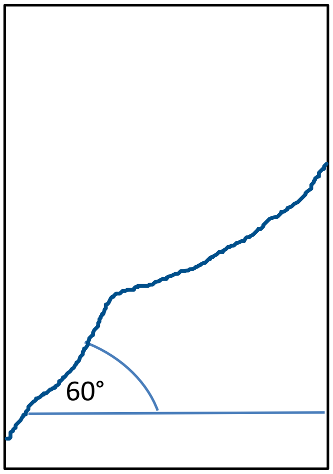
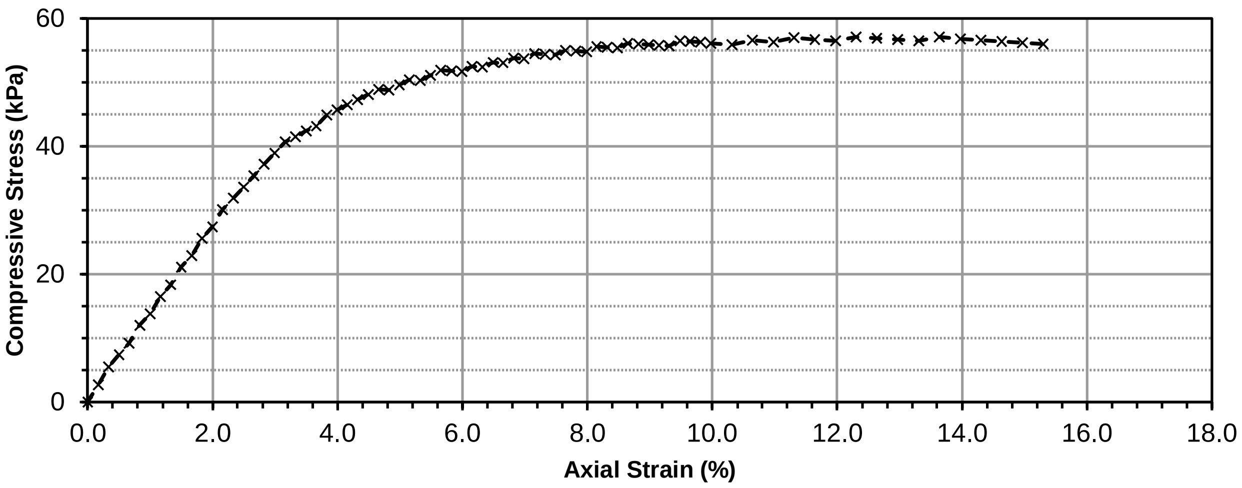


Photo:

Unconfined Compressive Strength
ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004096	0.0	0.00	0.00
10	3	0.2540	0.17	0.004103	11.1	2.70	1.35
20	6	0.5080	0.33	0.004110	22.6	5.49	2.75
30	8	0.7620	0.50	0.004116	30.2	7.34	3.67
40	10	1.0160	0.67	0.004123	37.9	9.19	4.59
50	13	1.2700	0.83	0.004130	49.4	11.95	5.98
60	15	1.5240	1.00	0.004137	57.0	13.78	6.89
70	18	1.7780	1.16	0.004144	68.5	16.53	8.27
80	20	2.0320	1.33	0.004151	76.2	18.35	9.17
90	23	2.2860	1.50	0.004158	87.6	21.08	10.54
100	25	2.5400	1.66	0.004165	95.3	22.88	11.44
110	28	2.7940	1.83	0.004172	106.8	25.59	12.80
120	30	3.0480	2.00	0.004179	114.4	27.38	13.69
130	33	3.3020	2.16	0.004186	125.9	30.08	15.04
140	35	3.5560	2.33	0.004193	133.6	31.85	15.93
150	37	3.8100	2.49	0.004201	141.2	33.62	16.81
160	39	4.0640	2.66	0.004208	148.9	35.38	17.69
170	41	4.3180	2.83	0.004215	156.5	37.14	18.57
180	43	4.5720	2.99	0.004222	164.2	38.89	19.45
190	45	4.8260	3.16	0.004229	171.9	40.63	20.32
200	46	5.0800	3.33	0.004237	175.7	41.47	20.73
210	47	5.3340	3.49	0.004244	179.5	42.30	21.15
220	48	5.5880	3.66	0.004251	183.3	43.13	21.56
230	50	5.8420	3.82	0.004259	191.0	44.85	22.42

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	51	6.0960	3.99	0.004266	194.8	45.66	22.83
250	52	6.3500	4.16	0.004273	198.6	46.46	23.23
260	53	6.6040	4.32	0.004281	202.3	47.26	23.63
270	54	6.8580	4.49	0.004288	206.1	48.06	24.03
280	55	7.1120	4.66	0.004296	209.9	48.86	24.43
290	55	7.3660	4.82	0.004303	209.9	48.77	24.39
300	56	7.6200	4.99	0.004311	213.7	49.56	24.78
310	57	7.8740	5.15	0.004318	217.4	50.35	25.17
320	57	8.1280	5.32	0.004326	217.4	50.26	25.13
330	58	8.3820	5.49	0.004334	221.2	51.04	25.52
340	59	8.6360	5.65	0.004341	225.0	51.82	25.91
350	59	8.8900	5.82	0.004349	225.0	51.73	25.87
360	59	9.1440	5.99	0.004357	225.0	51.64	25.82
370	60	9.3980	6.15	0.004364	228.8	52.42	26.21
380	60	9.6520	6.32	0.004372	228.8	52.32	26.16
390	61	9.9060	6.48	0.004380	232.5	53.09	26.55
400	61	10.1600	6.65	0.004388	232.5	53.00	26.50
410	62	10.4140	6.82	0.004395	236.3	53.76	26.88
420	62	10.6680	6.98	0.004403	236.3	53.67	26.83
430	63	10.9220	7.15	0.004411	240.1	54.43	27.21
440	63	11.1760	7.32	0.004419	240.1	54.33	27.16
450	63	11.4300	7.48	0.004427	240.1	54.23	27.12
460	64	11.6840	7.65	0.004435	243.9	54.99	27.49
470	64	11.9380	7.81	0.004443	243.9	54.89	27.44
480	64	12.1920	7.98	0.004451	243.9	54.79	27.39
490	65	12.4460	8.15	0.004459	247.6	55.54	27.77
500	65	12.7000	8.31	0.004467	247.6	55.43	27.72
510	65	12.9540	8.48	0.004475	247.6	55.33	27.67
520	66	13.2080	8.65	0.004483	251.4	56.08	28.04
530	66	13.4620	8.81	0.004492	251.4	55.97	27.99
540	66	13.7160	8.98	0.004500	251.4	55.87	27.94
550	66	13.9700	9.14	0.004508	251.4	55.77	27.88
560	66	14.2240	9.31	0.004516	251.4	55.67	27.83
570	67	14.4780	9.48	0.004525	255.2	56.40	28.20
580	67	14.7320	9.64	0.004533	255.2	56.30	28.15
590	67	14.9860	9.81	0.004541	255.2	56.19	28.10
600	67	15.2400	9.98	0.004550	255.2	56.09	28.04
620	67	15.7480	10.31	0.004567	255.2	55.88	27.94
640	68	16.2560	10.64	0.004584	259.0	56.50	28.25
660	68	16.7640	10.97	0.004601	259.0	56.29	28.14
680	69	17.2720	11.31	0.004618	262.7	56.90	28.45
700	69	17.7800	11.64	0.004635	262.7	56.68	28.34
720	69	18.2880	11.97	0.004653	262.7	56.47	28.23
740	70	18.7960	12.30	0.004671	266.5	57.06	28.53

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
760	70	18.7960	12.30	0.004671	266.5	56.85	28.42
780	70	19.3040	12.64	0.004688	266.5	56.63	28.32
800	70	19.8120	12.97	0.004706	266.5	56.42	28.21
820	71	20.3200	13.30	0.004724	270.3	57.00	28.50
840	71	20.8280	13.63	0.004742	270.3	56.78	28.39
860	71	21.3360	13.97	0.004761	270.3	56.56	28.28
880	71	21.8440	14.30	0.004779	270.3	56.34	28.17
900	71	22.3520	14.63	0.004798	270.3	56.12	28.06
920	71	22.8600	14.96	0.004817	270.3	55.90	27.95
940	71	23.3680	15.30	0.004836	270.3	55.68	27.84

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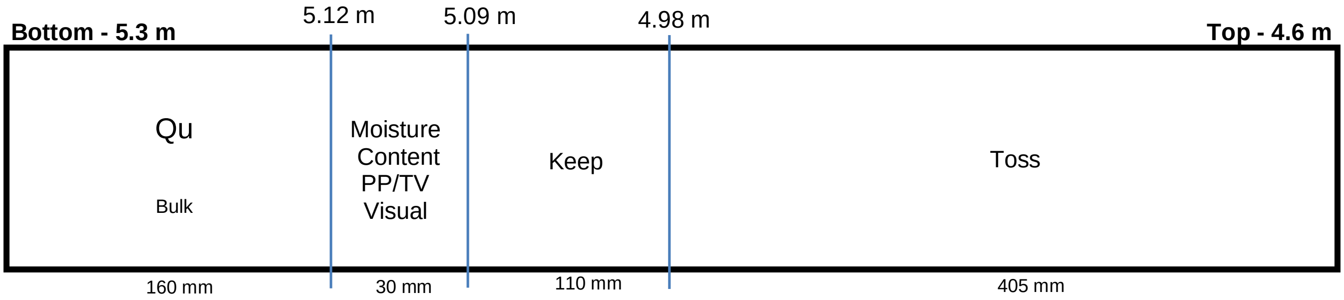
Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-03
Sample #	T25
Depth (m)	4.6 - 5.2
Sample Date	28-Nov-19
Test Date	11-Dec-19
Technician	SB

Tube Extraction

Recovery (mm) 705



Visual Classification

Material	CLAY
Composition	silty
Color	dark grey
Moisture	moist
Consistency	soft
Plasticity	intermediate plasticity
Structure	-
Gradation	-

Torvane

Reading	0.23
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	22.6

Pocket Penetrometer

Reading	**1**	0.40
	2	0.45
	3	0.40
	Average	0.42
Undrained Shear Strength (kPa)		20.4

Moisture Content

Tare ID	F11
Mass tare (g)	8.8
Mass wet + tare (g)	166.3
Mass dry + tare (g)	92.1
Moisture %	89.1%

Unit Weight

Bulk Weight (g)		1011.5
Length (mm)	**1**	151.65
	2	151.62
	3	152.14
	4	151.35
Average Length (m)		0.152
Diam. (mm)	**1**	71.65
	2	72.35
	3	72.42
	4	72.10
Average Diameter (m)		0.072
Volume (m^3)		6.20E-04
Bulk Unit Weight (kN/m^3)		16.0
Bulk Unit Weight (pcf)		101.9
Dry Unit Weight (kN/m^3)		8.5
Dry Unit Weight (pcf)		53.9

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Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct

Test Hole	TH19-03
Sample #	T25
Depth (m)	4.6 - 5.2
Sample Date	28-Nov-19
Test Date	11-Dec-19
Technician	SB

Unconfined Strength

	kPa	**ksf**
Max q_u	46.2	1.0
Max S_u	23.1	0.5

Specimen Data

Description CLAY - silty, , dark grey, moist, soft, intermediate plasticity

Length	151.7	(mm)	**Moisture %**	89%	
Diameter	72.1	(mm)	**Bulk Unit Wt.**	16.0	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	8.5	(kN/m^3)
Initial Area	0.00409	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.23	22.6	0.47

Vane Size
m

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.40	19.6	0.41
	0.45	22.1	0.46
	0.40	19.6	0.41
Average	**0.42**	**20.4**	**0.43**

Failure Geometry

Sketch:

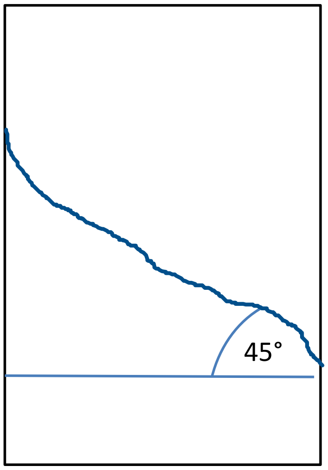
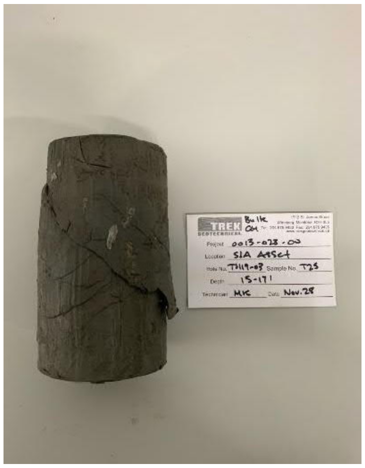


Photo:

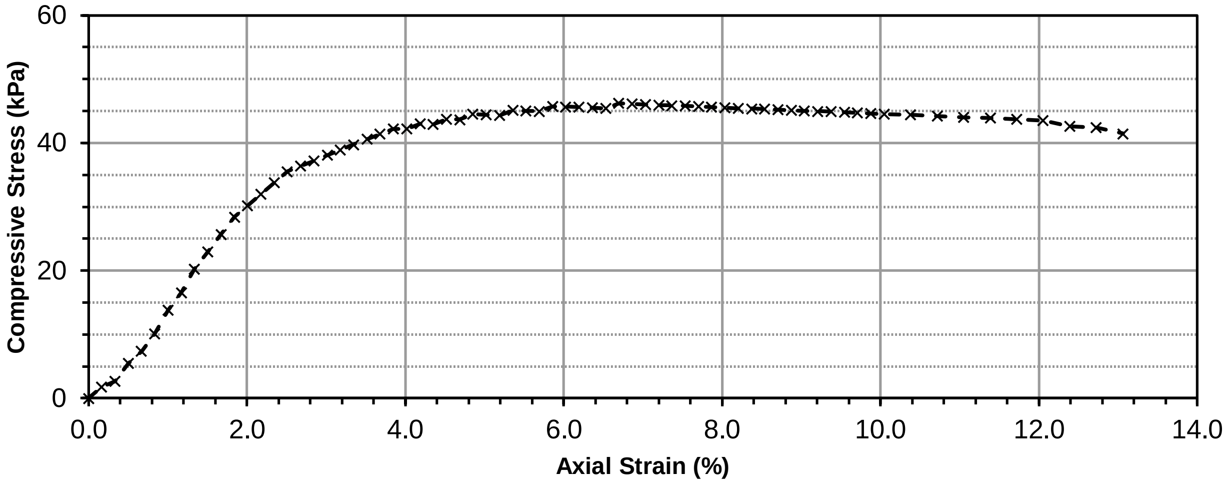


Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004086	0.0	0.00	0.00
10	2	0.2540	0.17	0.004093	7.3	1.77	0.89
20	3	0.5080	0.33	0.004100	11.1	2.70	1.35
30	6	0.7620	0.50	0.004107	22.6	5.50	2.75
40	8	1.0160	0.67	0.004114	30.2	7.35	3.67
50	11	1.2700	0.84	0.004121	41.7	10.12	5.06
60	15	1.5240	1.00	0.004128	57.0	13.81	6.91
70	18	1.7780	1.17	0.004135	68.5	16.57	8.28
80	22	2.0320	1.34	0.004142	83.8	20.24	10.12
90	25	2.2860	1.51	0.004149	95.3	22.97	11.49
100	28	2.5400	1.67	0.004156	106.8	25.70	12.85
110	31	2.7940	1.84	0.004163	118.3	28.41	14.21
120	33	3.0480	2.01	0.004170	125.9	30.20	15.10
130	35	3.3020	2.18	0.004177	133.6	31.98	15.99
140	37	3.5560	2.34	0.004184	141.2	33.75	16.88
150	39	3.8100	2.51	0.004191	148.9	35.52	17.76
160	40	4.0640	2.68	0.004199	152.7	36.37	18.19
170	41	4.3180	2.85	0.004206	156.5	37.22	18.61
180	42	4.5720	3.01	0.004213	160.4	38.07	19.03
190	43	4.8260	3.18	0.004220	164.2	38.91	19.45
200	44	5.0800	3.35	0.004228	168.0	39.74	19.87
210	45	5.3340	3.52	0.004235	171.9	40.58	20.29
220	46	5.5880	3.68	0.004243	175.7	41.41	20.71
230	47	5.8420	3.85	0.004250	179.5	42.24	21.12

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	47	6.0960	4.02	0.004257	179.5	42.17	21.08
250	48	6.3500	4.19	0.004265	183.3	42.99	21.50
260	48	6.6040	4.35	0.004272	183.3	42.92	21.46
270	49	6.8580	4.52	0.004280	187.2	43.73	21.87
280	49	7.1120	4.69	0.004287	187.2	43.66	21.83
290	50	7.3660	4.86	0.004295	191.0	44.47	22.24
300	50	7.6200	5.02	0.004302	191.0	44.39	22.20
310	50	7.8740	5.19	0.004310	191.0	44.32	22.16
320	51	8.1280	5.36	0.004318	194.8	45.11	22.56
330	51	8.3820	5.53	0.004325	194.8	45.03	22.52
340	51	8.6360	5.69	0.004333	194.8	44.95	22.48
350	52	8.8900	5.86	0.004341	198.6	45.74	22.87
360	52	9.1440	6.03	0.004348	198.6	45.66	22.83
370	52	9.3980	6.20	0.004356	198.6	45.58	22.79
380	52	9.6520	6.36	0.004364	198.6	45.50	22.75
390	52	9.9060	6.53	0.004372	198.6	45.42	22.71
400	53	10.1600	6.70	0.004380	202.3	46.20	23.10
410	53	10.4140	6.87	0.004387	202.3	46.12	23.06
420	53	10.6680	7.03	0.004395	202.3	46.03	23.02
430	53	10.9220	7.20	0.004403	202.3	45.95	22.97
440	53	11.1760	7.37	0.004411	202.3	45.87	22.93
450	53	11.4300	7.54	0.004419	202.3	45.78	22.89
460	53	11.6840	7.70	0.004427	202.3	45.70	22.85
470	53	11.9380	7.87	0.004435	202.3	45.62	22.81
480	53	12.1920	8.04	0.004443	202.3	45.53	22.77
490	53	12.4460	8.20	0.004451	202.3	45.45	22.73
500	53	12.7000	8.37	0.004460	202.3	45.37	22.68
510	53	12.9540	8.54	0.004468	202.3	45.29	22.64
520	53	13.2080	8.71	0.004476	202.3	45.20	22.60
530	53	13.4620	8.87	0.004484	202.3	45.12	22.56
540	53	13.7160	9.04	0.004492	202.3	45.04	22.52
550	53	13.9700	9.21	0.004501	202.3	44.95	22.48
560	53	14.2240	9.38	0.004509	202.3	44.87	22.44
570	53	14.4780	9.54	0.004517	202.3	44.79	22.39
580	53	14.7320	9.71	0.004526	202.3	44.71	22.35
590	53	14.9860	9.88	0.004534	202.3	44.62	22.31
600	53	15.2400	10.05	0.004543	202.3	44.54	22.27
620	53	15.7480	10.38	0.004560	202.3	44.37	22.19
640	53	16.2560	10.72	0.004577	202.3	44.21	22.10
660	53	16.7640	11.05	0.004594	202.3	44.04	22.02
680	53	17.2720	11.39	0.004611	202.3	43.88	21.94
700	53	17.7800	11.72	0.004629	202.3	43.71	21.86
720	53	18.2880	12.06	0.004646	202.3	43.55	21.77
740	52	18.7960	12.39	0.004664	198.6	42.57	21.28

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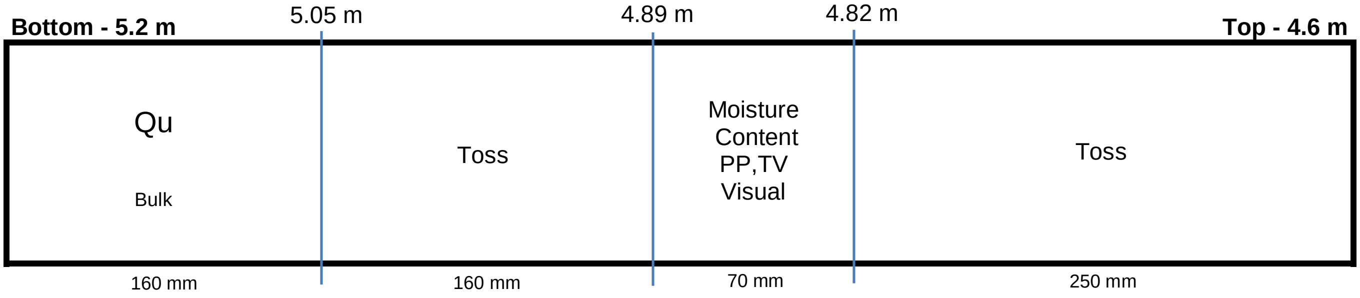
Shelby Tube Visual

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-05
Sample #	T38
Depth (m)	4.6 - 5.2
Sample Date	28-Nov-19
Test Date	03-Dec-19
Technician	SB

Tube Extraction

Recovery (mm) 640



Visual Classification

Material	CLAY
Composition	Silty
trace silt inclusion (<5 mm diam.)	
Color	dark grey
Moisture	moist
Consistency	soft to firm
Plasticity	intermediate plasticity
Structure	-
Gradation	-

Torvane

Reading	0.29
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	28.4

Pocket Penetrometer

Reading	**1**	0.50
	2	0.50
	3	0.50
	Average	0.50
Undrained Shear Strength (kPa)		24.5

Moisture Content

Tare ID	D2
Mass tare (g)	8.3
Mass wet + tare (g)	283.5
Mass dry + tare (g)	217.2
Moisture %	31.7%

Unit Weight

Bulk Weight (g)		1178.3
Length (mm)	**1**	152.55
	2	153.81
	3	152.74
	4	152.41
Average Length (m)		0.153
Diam. (mm)	**1**	72.23
	2	72.84
	3	72.09
	4	72.93
Average Diameter (m)		0.073
Volume (m^3)		6.32E-04
Bulk Unit Weight (kN/m^3)		18.3
Bulk Unit Weight (pcf)		116.5
Dry Unit Weight (kN/m^3)		13.9
Dry Unit Weight (pcf)		88.4

Unconfined Compressive Strength

ASTM D2166

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct

Test Hole	TH19-05
Sample #	T38
Depth (m)	4.6 - 5.2
Sample Date	28-Nov-19
Test Date	3-Dec-19
Technician	SB

Unconfined Strength

	kPa	ksf
Max q_u	45.5	1.0
Max S_u	22.8	0.5

Specimen Data

Description CLAY - Silty, trace silt inclusion (<5 mm diam.), dark grey, moist, soft to firm, intermediate plasticity

Length	152.9	(mm)	**Moisture %**	32%	
Diameter	72.5	(mm)	**Bulk Unit Wt.**	18.3	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	13.9	(kN/m^3)
Initial Area	0.00413	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.29	28.4	0.59
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.50	24.5	0.51
	0.50	24.5	0.51
Average	**0.50**	**24.5**	**0.51**

Failure Geometry

Sketch:

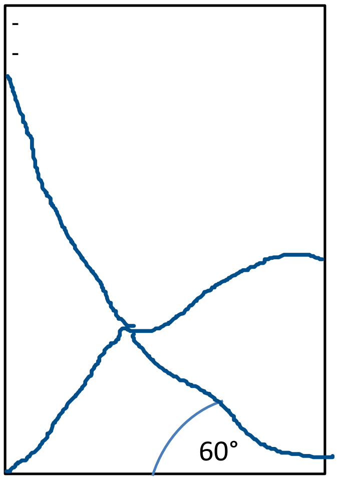
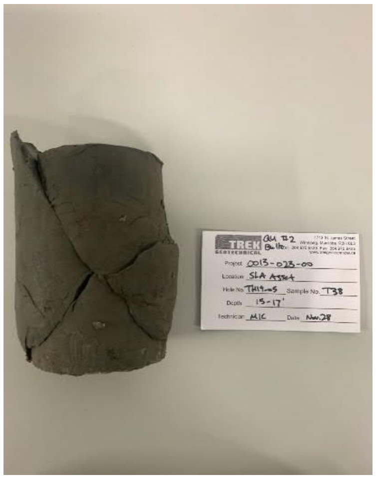


Photo:

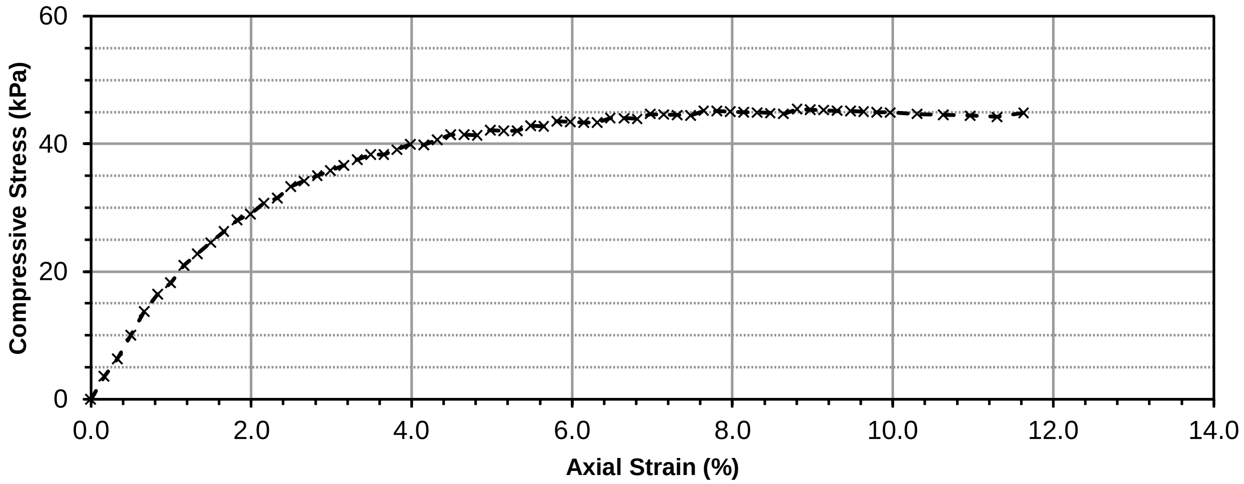


Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004131	0.0	0.00	0.00
10	4	0.2540	0.17	0.004138	14.9	3.60	1.80
20	7	0.5080	0.33	0.004145	26.4	6.37	3.18
30	11	0.7620	0.50	0.004152	41.7	10.05	5.02
40	15	1.0160	0.66	0.004158	57.0	13.71	6.86
50	18	1.2700	0.83	0.004165	68.5	16.45	8.22
60	20	1.5240	1.00	0.004172	76.2	18.25	9.13
70	23	1.7780	1.16	0.004179	87.6	20.97	10.49
80	25	2.0320	1.33	0.004186	95.3	22.76	11.38
90	27	2.2860	1.50	0.004194	103.0	24.55	12.28
100	29	2.5400	1.66	0.004201	110.6	26.33	13.17
110	31	2.7940	1.83	0.004208	118.3	28.11	14.05
120	32	3.0480	1.99	0.004215	122.1	28.97	14.48
130	34	3.3020	2.16	0.004222	129.8	30.73	15.37
140	35	3.5560	2.33	0.004229	133.6	31.59	15.79
150	37	3.8100	2.49	0.004236	141.2	33.34	16.67
160	38	4.0640	2.66	0.004244	145.1	34.18	17.09
170	39	4.3180	2.82	0.004251	148.9	35.03	17.51
180	40	4.5720	2.99	0.004258	152.7	35.87	17.93
190	41	4.8260	3.16	0.004265	156.5	36.70	18.35
200	42	5.0800	3.32	0.004273	160.4	37.53	18.77
210	43	5.3340	3.49	0.004280	164.2	38.36	19.18
220	43	5.5880	3.66	0.004288	164.2	38.30	19.15
230	44	5.8420	3.82	0.004295	168.0	39.12	19.56

Unconfined Compressive Strength

ASTM D2166

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	45	6.0960	3.99	0.004302	171.9	39.95	19.97
250	45	6.3500	4.15	0.004310	171.9	39.88	19.94
260	46	6.6040	4.32	0.004317	175.7	40.69	20.35
270	47	6.8580	4.49	0.004325	179.5	41.51	20.75
280	47	7.1120	4.65	0.004332	179.5	41.44	20.72
290	47	7.3660	4.82	0.004340	179.5	41.36	20.68
300	48	7.6200	4.98	0.004348	183.3	42.17	21.09
310	48	7.8740	5.15	0.004355	183.3	42.10	21.05
320	48	8.1280	5.32	0.004363	183.3	42.02	21.01
330	49	8.3820	5.48	0.004370	187.2	42.83	21.41
340	49	8.6360	5.65	0.004378	187.2	42.75	21.38
350	50	8.8900	5.82	0.004386	191.0	43.55	21.77
360	50	9.1440	5.98	0.004394	191.0	43.47	21.74
370	50	9.3980	6.15	0.004401	191.0	43.40	21.70
380	50	9.6520	6.31	0.004409	191.0	43.32	21.66
390	51	9.9060	6.48	0.004417	194.8	44.10	22.05
400	51	10.1600	6.65	0.004425	194.8	44.02	22.01
410	51	10.4140	6.81	0.004433	194.8	43.94	21.97
420	52	10.6680	6.98	0.004441	198.6	44.71	22.36
430	52	10.9220	7.14	0.004449	198.6	44.63	22.32
440	52	11.1760	7.31	0.004457	198.6	44.55	22.28
450	52	11.4300	7.48	0.004465	198.6	44.47	22.24
460	53	11.6840	7.64	0.004473	202.3	45.24	22.62
470	53	11.9380	7.81	0.004481	202.3	45.16	22.58
480	53	12.1920	7.98	0.004489	202.3	45.07	22.54
490	53	12.4460	8.14	0.004497	202.3	44.99	22.50
500	53	12.7000	8.31	0.004505	202.3	44.91	22.46
510	53	12.9540	8.47	0.004513	202.3	44.83	22.41
520	53	13.2080	8.64	0.004521	202.3	44.75	22.37
530	54	13.4620	8.81	0.004530	206.1	45.50	22.75
540	54	13.7160	8.97	0.004538	206.1	45.42	22.71
550	54	13.9700	9.14	0.004546	206.1	45.33	22.67
560	54	14.2240	9.30	0.004555	206.1	45.25	22.63
570	54	14.4780	9.47	0.004563	206.1	45.17	22.58
580	54	14.7320	9.64	0.004571	206.1	45.09	22.54
590	54	14.9860	9.80	0.004580	206.1	45.00	22.50
600	54	15.2400	9.97	0.004588	206.1	44.92	22.46
620	54	15.7480	10.30	0.004605	206.1	44.75	22.38
640	54	16.2560	10.63	0.004622	206.1	44.59	22.29
660	54	16.7640	10.97	0.004640	206.1	44.42	22.21
680	54	17.2720	11.30	0.004657	206.1	44.26	22.13
700	55	17.7800	11.63	0.004674	209.9	44.90	22.45
720	55	18.2880	11.96	0.004692	209.9	44.73	22.37
740	55	18.7960	12.29	0.004710	209.9	44.56	22.28

Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
760	55	19.3040	12.63	0.004728	209.9	44.39	22.20
780	55	19.8120	12.96	0.004746	209.9	44.22	22.11
800	55	20.3200	13.29	0.004764	209.9	44.06	22.03
820	55	20.8280	13.62	0.004782	209.9	43.89	21.94
840	55	21.3360	13.96	0.004801	209.9	43.72	21.86
860	55	21.8440	14.29	0.004819	209.9	43.55	21.77
880	55	22.3520	14.62	0.004838	209.9	43.38	21.69
900	55	22.8600	14.95	0.004857	209.9	43.21	21.61
920	55	23.3680	15.29	0.004876	209.9	43.04	21.52

TREK GEOTECHNICAL
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Atterberg Limits
ASTM D4318-10e1

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

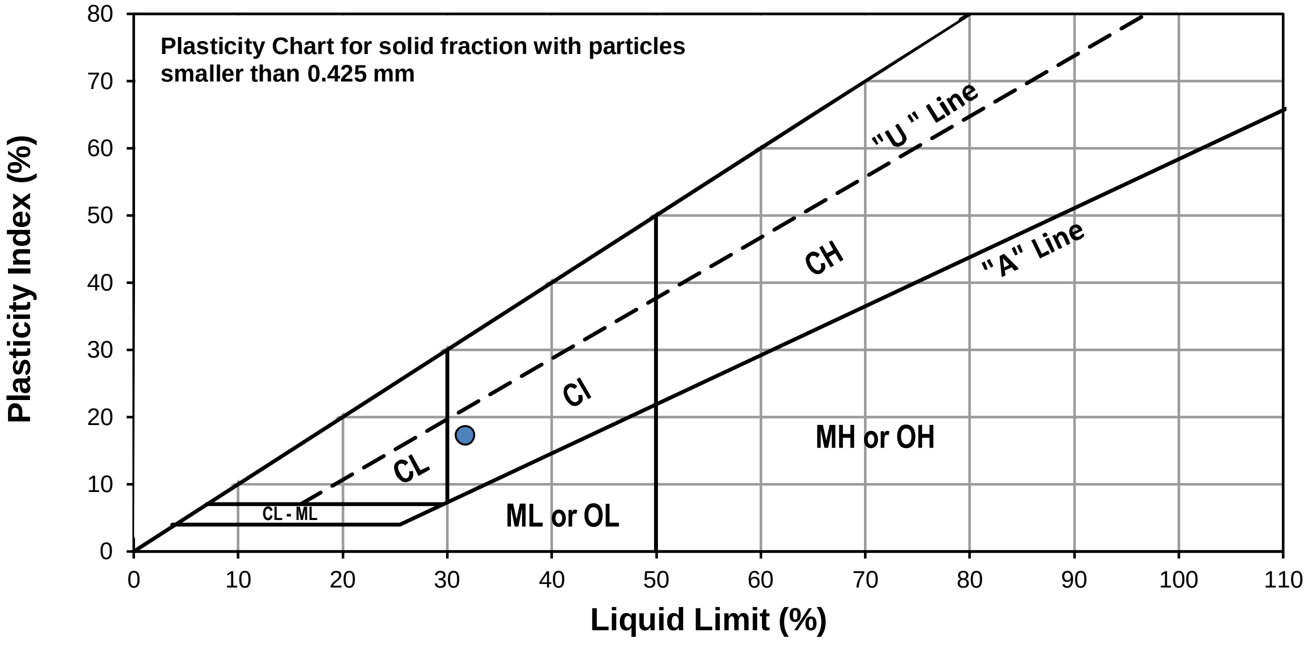
Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Test Hole TH19-02
Sample # G16
Depth (m) 3.4 - 3.7
Sample Date 28-Nov-19
Test Date 4-Dec-19
Technician AD

Liquid Limit	32
Plastic Limit	14
Plasticity Index	17

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	18	26	35		
Mass Wet Soil + Tare (g)	29.984	27.546	26.729		
Mass Dry Soil + Tare (g)	26.104	24.281	23.759		
Mass Tare (g)	14.269	13.943	14.051		
Mass Water (g)	3.880	3.265	2.970		
Mass Dry Soil (g)	11.835	10.338	9.708		
Moisture Content (%)	32.784	31.583	30.593		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.117	13.942			
Mass Wet Soil + Tare (g)	20.257	21.912			
Mass Dry Soil + Tare (g)	19.494	20.895			
Mass Water (g)	0.763	1.017			
Mass Dry Soil (g)	5.377	6.953			
Moisture Content (%)	14.190	14.627			

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Atterberg Limits
ASTM D4318-10e1

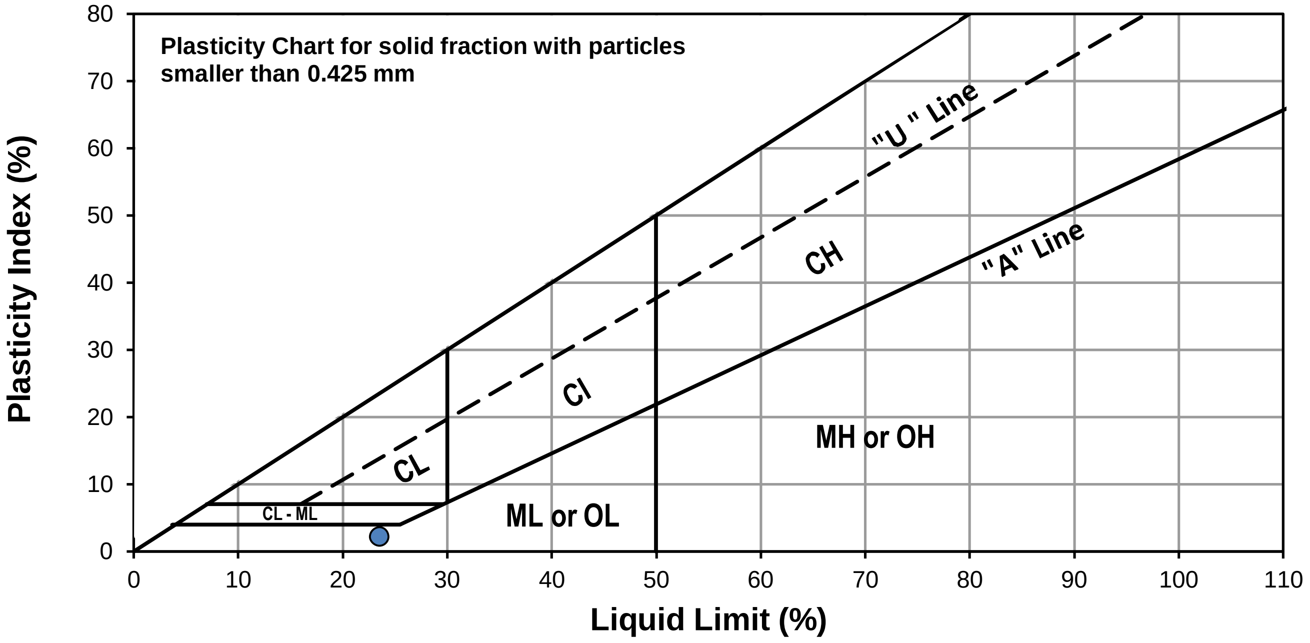
Project No. 0013-023-00
Client AECOM
Project Shoal Lake Aqueduct

Test Hole TH19-03
Sample # G22
Depth (m) 2.1 - 2.4
Sample Date 28-Nov-19
Test Date 22-Jan-20
Technician BMH

Liquid Limit 23
Plastic Limit 21
Plasticity Index 2

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	15	21	28		
Mass Wet Soil + Tare (g)	27.180	25.799	27.810		
Mass Dry Soil + Tare (g)	24.593	23.563	25.262		
Mass Tare (g)	14.081	14.191	14.296		
Mass Water (g)	2.587	2.236	2.548		
Mass Dry Soil (g)	10.512	9.372	10.966		
Moisture Content (%)	24.610	23.858	23.235		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.206	13.883			
Mass Wet Soil + Tare (g)	22.247	22.488			
Mass Dry Soil + Tare (g)	20.832	20.980			
Mass Water (g)	1.415	1.508			
Mass Dry Soil (g)	6.626	7.097			
Moisture Content (%)	21.355	21.248			

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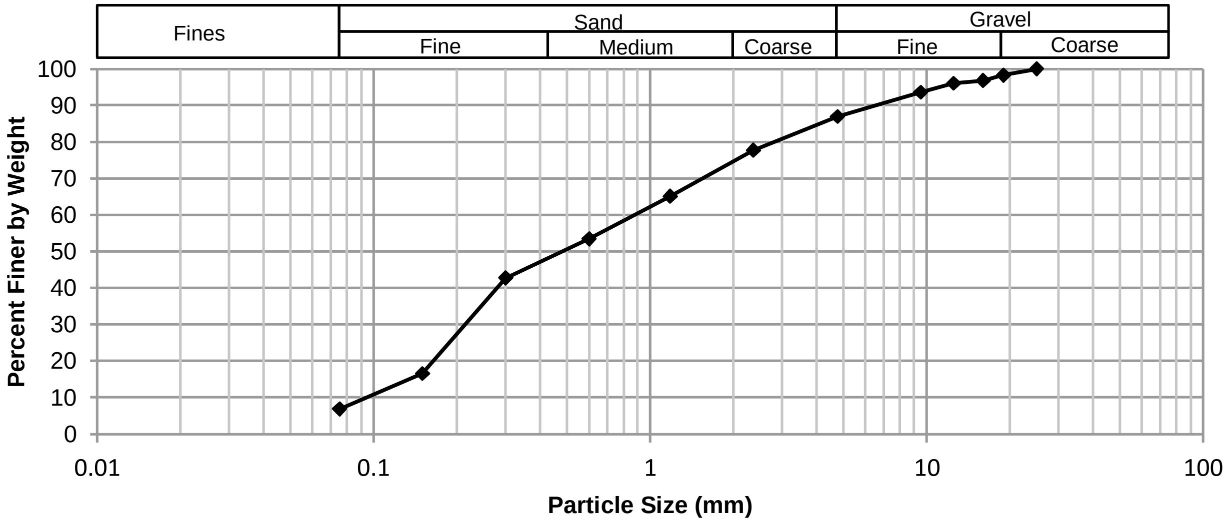
Grain Size Analysis (Sieve Method)
ASTM C136-06

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-02
Sample #	G13
Depth	1.0 - 2.0
Date Sampled	28-Nov-19
Date Tested	4-Dec-19
Technician	AD

Total Weight (g)	1473.2
Gravel %	13.1
Sand %	80.1
Fines %	6.8

Particle Size Distribution Curve



Sieve Opening (mm)	Percent Passing	Specification (Min-Max)
25.0	100	-
19.0	98	-
16.0	97	-
12.5	96	-
9.5	94	-
4.8	87	-
2.36	78	-
1.18	65	-
0.600	53	-
0.300	43	-
0.150	17	-
0.075	7	-

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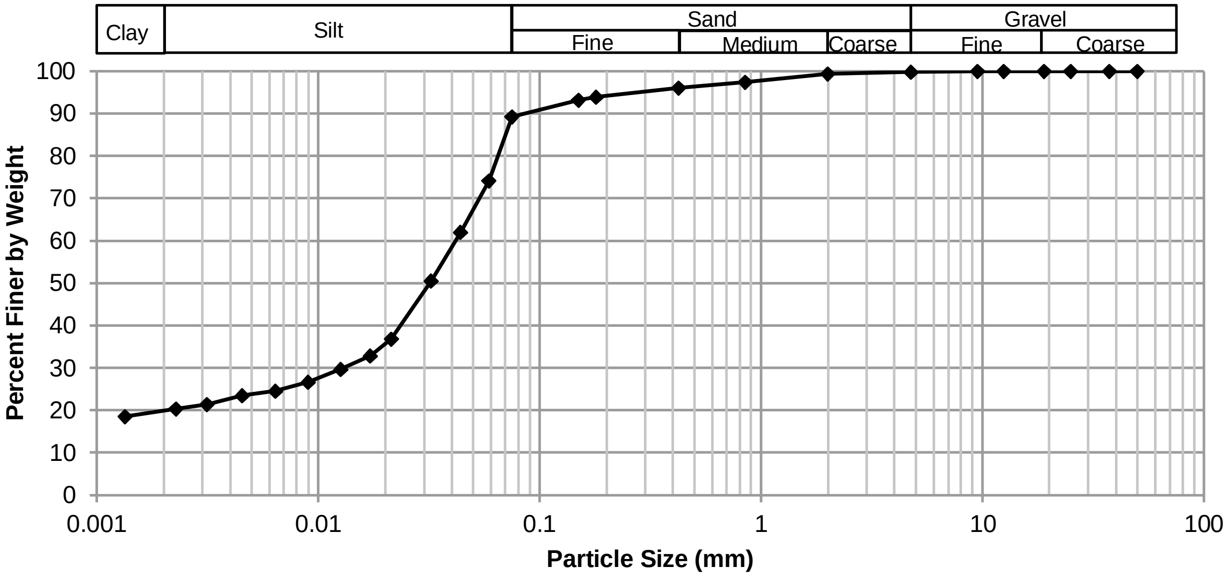
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-02
Sample #	G16
Depth (m)	3.4 - 3.7
Sample Date	28-Nov-19
Test Date	5-Dec-19
Technician	AD

Gravel	0.2%
Sand	10.5%
Silt	69.5%
Clay	19.8%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	99.77	0.0750	89.26
37.5	100.00	2.00	99.41	0.0590	74.14
25.0	100.00	0.850	97.44	0.0438	62.02
19.0	100.00	0.425	96.07	0.0324	50.52
12.5	100.00	0.180	93.89	0.0214	36.85
9.50	100.00	0.150	93.19	0.0172	32.81
4.75	99.77	0.075	89.26	0.0127	29.70
				0.0090	26.65
				0.0064	24.54
				0.0045	23.43
				0.0032	21.45
				0.0023	20.34
				0.0013	18.56

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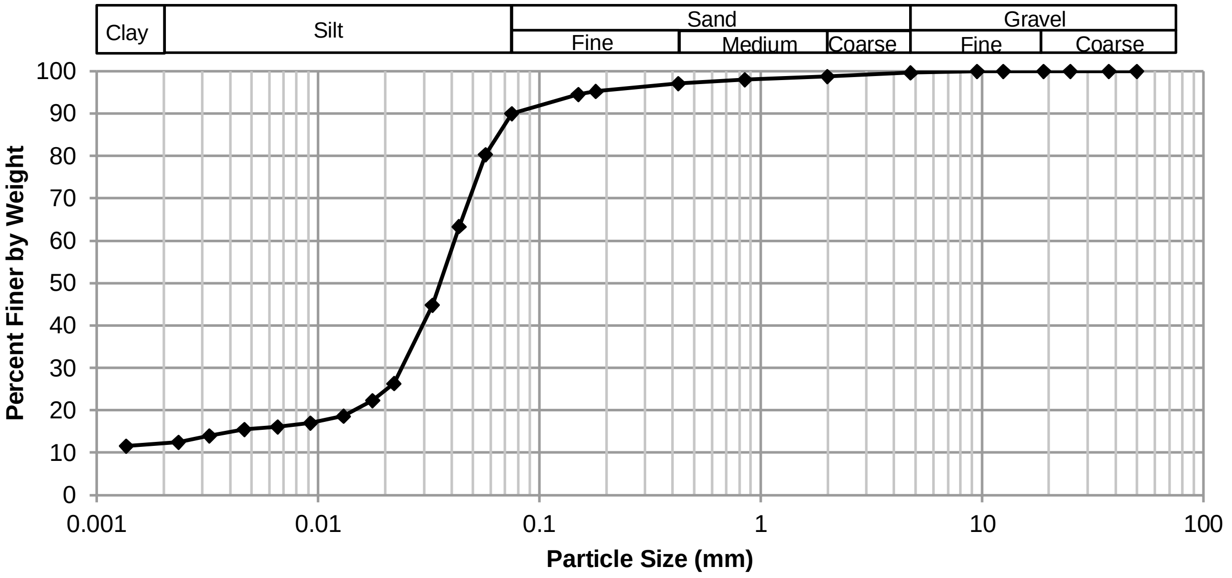
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	0013-023-00
Client	AECOM
Project	Shoal Lake Aqueduct
Test Hole	TH19-03
Sample #	G22
Depth (m)	2.1 - 2.4
Sample Date	28-Nov-19
Test Date	22-Jan-20
Technician	BMH

Gravel	0.4%
Sand	9.6%
Silt	77.8%
Clay	12.2%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	99.62	0.0750	90.01
37.5	100.00	2.00	98.83	0.0571	80.40
25.0	100.00	0.850	98.02	0.0434	63.40
19.0	100.00	0.425	97.17	0.0328	44.86
12.5	100.00	0.180	95.25	0.0221	26.32
9.50	100.00	0.150	94.55	0.0176	22.30
4.75	99.62	0.075	90.01	0.0130	18.60
				0.0093	17.05
				0.0066	16.12
				0.0046	15.57
				0.0032	14.02
				0.0023	12.54
				0.0014	11.60