BARR

Geotechnical Investigation for Two Culvert Replacements (Kilometres 95.6 and 100.6) along Highway 93S in Kootenay National Park, BC

Prepared for
Highway Engineering Services, Parks Canada Agency

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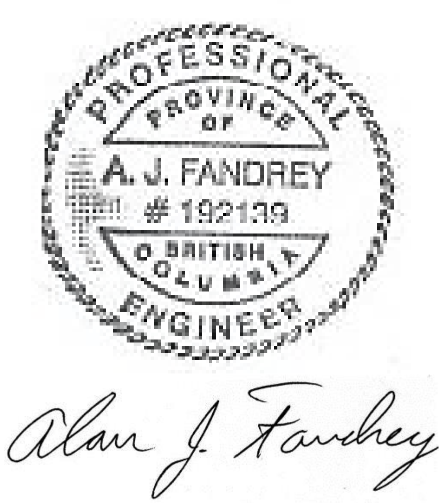

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Date

Glossary

ASTM	American Society for Testing and Materials
CSA	Canadian Standards Association
CFEM	Canadian Foundation Engineering Manual
CL	Lean clay
c'	Effective Apparent cohesion, shear strength that appears to be caused by bonding between soil particles
c	Total Apparent cohesion, shear strength that appears to be caused by bonding between soil particles
c_u	Cohesion corresponding to the undrained loading
GP-GC	Poorly graded gravel with clay
GP	Poorly graded gravel
km	Kilometre
m	Metre
m/s	Metres per second
N-value	Standard penetration resistance, the number of blows required to drive a split-spoon sampler during a standard penetration test a distance of 12 inches (0.3 m) after the initial penetration of 6 inches (0.15 m)
ODEX	An acronym for overburden drilling with an eccentric bit
q_u	Compressive strength of rock determined from unconfined compressive strength testing.
RQD	Rock quality designation, a rough measure of the degree of jointing or fracture in a rock mass
SM-SC	Silty sand with clay/silty sand
SC	Clayey sand
SP-SC	Poorly graded sand with clay
SP	Poorly graded sand
SPDD	Standard Proctor Dry Density
SPT	Standard penetration test, a field test that measures resistance of the soil to the penetration of a standard split-spoon sampler
S_u	Undrained shear strength, the shear strength of soil under undrained conditions
UCS	Unconfined compressive strength, the maximum stress a material can sustain under unconfined loading condition.
USCS	Unified soil classification system
ϕ_{cu}	Undrained angle of friction, an angle of friction corresponding to the undrained conditions
ϕ'	Effective angle of friction, an angle of friction corresponding to the drained conditions
ϕ	Total angle of friction, an angle of friction corresponding to the drained conditions
γ_{sat}	Saturated unit weight, the saturated weight of soil per unit volume
γ_{moist}	Moist unit weight, the weight of soils and voids per unit volume

1.0 Introduction

Barr Engineering and Environmental Science Canada Ltd. (Barr), under authorization and contract with the Highway Engineering Services Parks Canada Agency (HES-PCA), completed a geotechnical investigation to support the culvert replacement for the 95.6 kilometre (km) and 100.6 km locations along Highway 93S, in Kootenay National Park, British Columbia.

This report describes the geotechnical investigation, summarizes the laboratory analysis of selected soil samples, and provides geotechnical recommendations for the replacement of the culvert crossings.

1.1 Proposed Construction

The proposed construction primarily involves replacing two culverts. Sinclair Creek crosses Highway 93S through a culvert which runs beneath the highway at 95.6 km and beneath both the highway and a parking lot at 100.6 km. A geotechnical investigation was performed to understand the site conditions to support the design of replacement culverts.

1.2 Scope of Services

The Barr scope of services for this investigation was to:

- Conduct a field investigation to collect soil and rock core samples (where possible) along likely replacement culvert alignments;
- Perform laboratory testing on selected samples collected during the field investigation;
- Describe the subsurface conditions along with the description of the existing groundwater levels;
- Provide recommendations regarding the foundation bearing capacity, and other geotechnical design parameters for culvert foundation; and
- Provide construction recommendations for any special (non-routine) soil and site conditions.

1.3 Report Organization

The balance of this report is organized as follows:

- Section 2: Fieldwork for Culvert Replacement at 95.6 km
- Section 3: Fieldwork for Culvert Replacement at 100.6 km
- Section 4: Engineering Recommendations
- Section 5: Construction Recommendations
- Section 6: References

2.0 Fieldwork for Culvert Replacement at 95.6 km

Two separate field investigation programs (seismic refraction survey and geotechnical investigation) were conducted at the project location. The seismic refraction survey was performed on October 25 and October 26, 2017. The geotechnical investigation consisted of borings at two locations (Figure 1), and was completed between November 21 and November 29, 2017.

2.1 Fieldwork

2.1.1 Seismic Refraction Survey

Seismic refraction survey was performed by Shallow Earth Technologies Inc. (SETI) of Calgary, AB, using a Geometrics Inc. Geode seismograph and an array of twenty-four 4.5-Hz. land geophones. This survey was completed between October 25 and October 26, 2017. The results of the seismic refraction survey are provided in Appendix A.

2.1.2 Soil Borings

Barr geotechnical engineers, in consultation with AECOM, defined the boring locations. These locations were primarily selected as they were located along possible culvert relocation alignments. Barr personnel located the boring locations on the day of drilling, while the private utility clearance was completed on November 21, 2017.

Mobile Augers and Research Ltd. of Calgary, AB, using a sonic rig, performed the soil borings between November 26, 2017 and November 29, 2017. The borings were performed in accordance with ASTM Test Method D 1586 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils." The borings were advanced to a maximum depth of 7.6 metres (m) and were backfilled using bentonite chips, excavated soil, and asphalt cold patch, where deemed necessary.

The boring locations and associated details are presented in Table 1, whereas Figure 1 shows the locations of the soil borings. Copies of the soil boring logs are included in Appendix B of this report.

Table 1 Boring Information

Borehole	Northing [m]	Easting [m]	Completion Depth [m]	Depth to Water [m]
95.6-1	572803	5610964	7.6	4.6
95.6-2	572697	5610912	6.1	2.3

Barr personnel were present at the site to observe and coordinate the drilling operations. Materials encountered in the borings were visually and manually classified in accordance with ASTM Test Method D 2488-09a.

Boring logs were prepared to accompany this discussion of subsurface conditions at the site and are included in Appendix B. The logs present the materials encountered in the soil borings, their soil classifications, results of field and laboratory tests, and groundwater measurements.

Standard penetration test (SPT) blow counts necessary to advance the sampler 30 centimetres (cm) (N-values) were recorded in the field and are included in the boring logs (Appendix B). Sampler advancement was stopped if 50 blows were achieved for minimal penetration (less than 15 cm), typically indicating the presence of hard material, especially large gravel and/or bedrock. Results of the standard penetration tests (SPTs) are summarized in Appendix B.

Barr personnel removed the samples (both grab samples and samples from the sampler), logged the samples, and transported selected samples to the laboratory for testing.

2.2 Site Soils

A sampling bias, reflected in sample classification (field and laboratory classification), is likely due to drilling and sampling recovery methods. This bias is caused by the limitations of drilling and sampling recovery methods (being unable to provide a representation of the cobbles and boulders proportions encountered).

2.2.1 Gravel with Silt, Sand, and Clay (GC-GM, GP-GC, GW-GC)

Gravel with silt, sand, and clay (GC-GM, GP-GC, GW-GC) was encountered in all the borings. The thickness generally ranged from 1.5 m to 12 m. The samples consisted of light brown to grayish brown silt to gravel with sand. The SPT N-values ranged from 9 to >50 blows/30 cm, indicating loose to very dense gravel.

2.3 Groundwater

Groundwater was observed in both borings. The drillers checked for groundwater as the borings were advanced, and again after auger withdrawal and before the borings were backfilled. The groundwater level data is provided in Table 1.

The groundwater levels are all short-term readings and stabilized water levels could be higher. Also, the groundwater levels fluctuate seasonally and may rise in times of high precipitation. Therefore, the actual groundwater levels may differ at the time of construction.

2.4 Laboratory Test Results

The laboratory test results on the soil samples are provided in Appendix C.

2.4.1 Moisture Content Tests

A total of seven moisture content tests were performed. The moisture contents ranged from 2.5 to 13.5 percent for sandy, silty clays/sandy, silty clays with gravel. These results indicate the soils on site are generally in a moist condition and their moisture levels are likely influenced by the creek water level.

2.4.2 Particle Size Analysis

A total of five sieve analysis and five hydrometer analyses were performed. The percent fines (percent by weight passing the number 200 sieve) ranged from 7.6 to 20.1 percent.

2.4.3 Moisture-Density Relationship (Proctor Test)

Two (2) moisture-density relationship tests were performed in accordance with ASTM D698-12e2 on grab samples collected from the borings. The oversize correction was performed for coarse-grained samples collected from the borings, in accordance with ASTM D4718/D5718M-15. The maximum dry density for coarse-grained soils ranged from 2,107 kg/m^3 to 2,335 kg/m^3, with optimum moisture content ranging from 5.1 to 7.9 percent (after oversize correction). The results of the compaction testing are included in Appendix C and summarized in Table 2.

Table 2 Summary of Standard Proctor Density Test Results

Borehole	Depth (m)	UCSC Classification	MDD* (kg/m^3)	OMC** (%)
95.6-1	0.8	GW-GC	2335	5.1
95.6-2	0.8	GC-GM	2137	7.7
	4.6	GC-GM	2107	7.9

MDD* - Oversize corrected Maximum dry density, OMC** - Oversize corrected Optimum Moisture Content

2.4.4 California Bearing Ratio

California Bearing Ratio tests (ASTM D1883-16) were conducted on two selected samples. Results ranged from 1.6 to 2.0 at 95% maximum dry density. The results of the California Bearing Ratio testing are included in Appendix C and summarized in Table 3.

Table 3 Summary of California Bearing Ratio Test Results

Borehole	Depth (m)	UCSC Classification	% MDD*	Density (kg/m^3)	CBR Soaked
95.6-1	0.8	GW-GC	95	2058	2.0
			100	2166	6.2
			102	2209	12.0
95.6-2	0.8	GC-GM	95	1987	1.6
			100	2092	5.8
			102	2134	9.1

MDD* - Maximum dry density

2.4.5 Direct Shear test

The presence of coarse-grained soils, difficulty in obtaining undisturbed samples, and low sample recoveries resulted in limited strength testing during the laboratory testing program. One direct shear test (ASTM D3080/D3080M-11) was conducted on the remoulded samples collected from borings. Direct shear test was performed using the consolidated drained (CD) method. Failure was achieved by applying the shear rate (0.01 mm/min) under drained loading conditions. The result of the direct shear testing is included in Appendix C and summarized in Table 4.

Table 4 Summary of Direct Shear Testing Results

Borehole	Depth (m)	UCSC Classification	Cohesion (kPa)	Friction Angle [°]
95.6-1	0.76	GW-GC	20	37.5

2.4.6 Consolidation test

One consolidation shear test (ASTM D2435/D2435M-11) was conducted on the remoulded samples collected from borings. The results of the consolidation testing is included in Appendix C and summarized in Table 4.

Table 5 Summary of Consolidation Test Result

Borehole	Depth (m)	UCSC Classification	Compression Index (C_c)	Pre-consolidation Pressure (P_p) (kPa)	Pre-consolidation Void Ratio (e)
95.6-2	4.6	GC-GM	20	81	0.27

2.4.7 Chemical Tests

One sample was tested for chemical content (chloride and sulphate) and pH. Soil pH was 7.8, chloride content 1371 mg/L, and sulphate content 203 mg/L.

2.4.8 Organic Content Tests

The organic content test was performed on one sample obtained at a depth of 3.5 m below existing ground surface in borehole BH95.6-2, in accordance with ASTM D2974 – 14, "Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils." The result indicated organic content to be 1.7 percent.

2.5 Seismic Refraction Survey Results

The seismic refraction survey found that the hard soil depth ranges from 4.4 to 7.7 m below ground surface, with depth generally increasing towards the west. Modelled bedrock p-wave velocities range from 2,688 m/s to 3,568 m/s, and the modelled overburden velocities range between 668 m/s and 704 m/s.

3.0 Fieldwork for Culvert Replacement at 100.6 km

Two separate field investigation programs (seismic refraction survey and geotechnical investigation) were conducted at the project location. The seismic refraction survey was performed on October 25 and October 26, 2017. The geotechnical investigation consisted of borings at three (3) locations (Figure 1), and was completed between November 21 and November 29, 2017.

3.1 Fieldwork

3.1.1 Seismic Refraction Survey

Seismic refraction survey was performed by Shallow Earth Technologies Inc. (SETI) of Calgary, AB, using a Geometrics Inc. Geode seismograph and an array of twenty-four 4.5-Hz. land geophones. This survey was completed between October 25 and October 26, 2017. The results of the seismic refraction survey are provided in Appendix A.

3.1.2 Soil Borings

3.1.3 Boring Information

Barr geotechnical engineers, in consultation with AECOM, defined the boring locations. These locations were primarily selected as they were located along possible culvert relocation alignments. Barr personnel located the boring locations on the day of drilling, while the private utility clearance was completed on November 21, 2017.

Mobile Augers and Research Ltd. of Calgary, AB, using a sonic rig, performed the soil borings between November 26, 2017 and November 29, 2017. The borings were performed in accordance with ASTM Test Method D 1586 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils." The borings were advanced to a maximum depth of 15.2 m and were backfilled using bentonite chips, excavated soil, and asphalt cold patch, where deemed necessary.

The boring locations and associated details are present in Table 6, whereas Figure 1 shows the locations of the soil borings. Copies of the soil boring logs are included in Appendix B of this report.

Table 6 Boring Information

Borehole	Northing [m]	Easting [m]	Completion Depth [m]	Depth to Water [m]
100.6-1	568342	5609705	15.2	7.6
100.6-2	568417	5609707	9.1	7.6
100.6-3	568469	5609698	9.1	4.6

Barr personnel were present at the site to observe and coordinate the drilling operations. Materials encountered in the borings were visually and manually classified in accordance with ASTM Test Method D 2488-09a.

Boring logs were prepared to accompany the discussion of subsurface conditions at the site and are included in Appendix B. The logs present the materials encountered in the soil borings, their soil classifications, results of field and laboratory tests, and groundwater measurements.

Standard penetration test (SPT) blow counts necessary to advance the sampler 30 cm (N-values) were recorded in the field and are included in the boring logs (Appendix B). Sampler advancement was stopped if 50 blows were achieved for minimal penetration (less than 15 cm), typically indicating the presence of hard material, especially large gravel and/or bedrock. Results of the standard penetration tests (SPTs) are summarized in Appendix B.

Barr personnel removed the samples (both grab samples and samples from the sampler), logged the samples, and transported selected samples to the laboratory for testing.

3.2 Site Soils

A sampling bias, reflected in sample classification (field and laboratory classification) is likely due to drilling and sampling recovery methods. This bias is caused by the limitations of drilling and sampling recovery methods (being unable to provide a representation of the cobbles and boulders proportions encountered).

In general, the soil borings indicated asphalt and approximately 2.5-3.0 m of fill at the surface underlain by gravelly and sandy soils (BH-100.6-1; BH-100.6-2; and BH-100.6-3). These materials are described below.

3.2.1 Gravel with Silt, Clay, and Sand (GP-GC, GC-GM, GW-GC)

Gravel with silt, clay, and sand (GP-GC, GC-GM, GW-GC) was encountered in all the borings. The thickness generally ranged from 1.5 m to 12 m. The samples consisted of light brown to grayish brown silt to gravel with sand. The SPT N-values ranged from 8 to >50 blows/30 cm, indicating loose to very dense gravel.

3.2.2 Lean Clay with Sand (CL)

Lean clay with sand (CL) was encountered in only one borehole (BH-100.6-2). The thickness of the layer was 5.33 m. The samples were brown in colour. The SPT N-values ranged from 8 to 11 blows/30 cm, indicating firm material.

3.3 Groundwater

Groundwater was observed in all borings. The drillers checked for groundwater as the borings were advanced, and again after auger withdrawal and before the borings were backfilled. The groundwater level data is provided in Table 6.

The groundwater levels are all short-term readings and stabilized water levels could be higher. Also, the groundwater levels fluctuate seasonally and may rise in times of high precipitation. Therefore, the actual groundwater levels may differ at the time of construction.

3.4 Laboratory Test Results

The laboratory test results on the soil samples are provided in Appendix C.

3.4.1 Moisture Content Tests

A total of 16 moisture content tests were performed. The moisture contents ranged from 1.6 to 22.7. These results indicate the soils on site are generally in a moist to wet condition and are likely highly influenced by the creek.

3.4.2 Atterberg Limits Tests

A total of three Atterberg limit tests were performed. The plastic limits and liquid limits ranged from 17 to 20 percent and 33 to 43 percent, respectively. The plasticity index ranged from 16 to 23 percent.

3.4.3 Particle Size Analysis

A total of 10 sieve analysis and 10 hydrometer analyses were performed. The percent fines (percent by weight passing the number 200 sieve) ranged from 5.4 to 71.8 percent.

3.4.4 Moisture-Density Relationship (Proctor Test)

Three (3) moisture-density relationship tests were performed in accordance with ASTM D698-12e2 on grab samples collected from the borings. The oversize correction was performed for coarse-grained samples collected from the borings, in accordance with ASTM D4718/D5718M-15. The maximum dry density for coarse-grained soils, after correction, ranged from 2,169 kg/m^3 to 2,389 kg/m^3, with optimum moisture content ranging from 4.9 to 8.3 percent. The results of the compaction testing are included in Appendix C and summarized in Table 2.

Table 7 Summary of Standard Proctor Density Test Results

Borehole	Depth (m)	UCSC Classification	MDD* (kg/m^3)	OMC** (%)
100.6-1	0.8	GP-GC	2358	5.5%
	7.6	GP-GC	2389	4.9%
100.6-2	7.6	GC-GM	2169	8.3%

MDD* - Oversize corrected Maximum dry density, OMC** - Oversize corrected Optimum Moisture Content

3.4.5 California Bearing Ratio

One California Bearing Ratio test (ASTM D1883-16) was conducted, resulting in a CBR value of 2.9 at 95% maximum dry density. The results of the California Bearing Ratio testing are included in Appendix C and summarized in Table 8.

Table 8 Summary of California Bearing Ratio Test Results

Borehole	Depth (m)	UCSC Classification	% MDD*	Density (kg/m^3)	CBR Soaked
100.6-1	0.8	GP-GC	95	2096	2.9
			100	2206	10.5
			102	2250	18.5

MDD* - Maximum dry density

3.4.6 Direct Shear tests

The presence of coarse-grained soils, difficulty in obtaining undisturbed samples, and low sample recoveries resulted in limited strength testing during the laboratory testing program. A total of four direct shear tests (ASTM D3080/D3080M-11) were conducted on the remoulded samples collected from borings. Direct shear tests were performed using the consolidated drained (CD) method. Failure was achieved by applying the shear rate (0.01 mm/min) under drained-loading conditions. The results of the direct shear testing are included in Appendix C and summarized in Table 9. The samples for coarse-grained soils (GP-GC and GC-GM) do not contain gravel particles higher than sieve 4 (4.76 mm), but some gravel particles are still present; whereas, for the fine-grained sample (CL), fine sand is also present in the sample. Apparent cohesion values for coarse grained soils, with average values around 30 kPa, is ignored in the design. Typical published values for the internal friction angle for inorganic clays, silty clays, sandy clays of low plasticity ranges between 25 and 35 degrees

Table 9 Summary of Direct Shear Testing Results

Borehole	Depth (m)	UCSC Classification	Cohesion (kPa)	Friction Angle [°]
100.6-1	2.3	GP-GC	32.8	34.6
100.6-1	4.6	GP-GC	13.9	35.0
100.6-1	7.6	GC-GM	38.5	35.9
100.6-2	2.3	CL	10.1	32.3

3.4.7 Consolidation Test

Three consolidation tests (ASTM D2435/D2435M-11) were conducted on the remoulded samples collected from borings. The result of consolidation testing is included in Appendix C and summarized in Table 10.

Table 10 Summary of Consolidation Test Result

Borehole	Depth (m)	UCSC Classification	Compression Index (C_c)	Pre-consolidation Pressure (P_p) (kPa)	Pre-consolidation Void Ratio (e)
100.6-1	7.6	GC-GM	0.12	0.0	-
100.6-2	4.6	CL	0.06	48.0	0.54
100.6-2	7.6	GP-GC	0.11	16.0	0.37

3.4.8 Chemical Tests

Three samples (sample depths ranging from 0.76 m to 4.6 m below existing ground surface) were tested for chemical content (chloride and sulphate) and pH. Soil pH ranged from 8.6 to 8.7, chloride content from 69.0 to 114.0 mg/L, and sulphate from 19.0 to 24.0 mg/L.

3.4.9 Organic Content Tests

The organic content test was performed on one sample obtained at a depth of 4.6 m below existing ground surface, in accordance with ASTM D2974 – 14, "Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils." Results indicated organic content was 0.6 percent.

3.5 Seismic Refraction Survey Results

The seismic refraction survey found that the hard soil depth ranges from 3.6 to 7.9 m below ground surface, with depth generally increasing towards the west. Modelled bedrock p-wave velocities range from 2,695 m/s to 2,830 m/s, and the modelled overburden velocities range between 550 m/s and 619 m/s.

4.0 Engineering Recommendations

4.1 General

Geotechnical recommendations provided in this report may require revision if the project details are altered at a later stage of the project design.

Fill soil containing organics with layer thickness up to 3.0 m was encountered at the project sites, especially at 100.6 km. The existing fill soils are understood to have been placed during the construction of the parking lot, thus allowing time for the majority of long-term settlement to occur. Barr has no records indicating that the any of the fill soils encountered at the project site were placed in a controlled manner with adequate compaction. It was observed, based on the test results obtained from the test program, the existing fill soils are non-uniform, stiff to hard, and at reasonable moisture contents. Therefore, none of the fill soils encountered at this site can be considered as engineered fill materials.

As the consistency of the fill soil is questionable, foundation bearing within the existing fill soils is not considered a viable option due to the risk associated with total and differential settlements. It is recommended that the foundation of the proposed culvert be placed directly on top of the competent soil.

All foundation design recommendations presented in this report are based on the assumption that an adequate level of field review will be provided during construction and that a suitably qualified contractor, experienced in foundation and earthworks construction, will carry out all construction. An adequate level of field review is considered to be full-time observation during foundation construction and full-time monitoring and compaction testing during backfill operations.

Design and construction recommendations for the geotechnical aspects of the project are presented in the subsections below.

4.2 Foundations

4.2.1 General

Due to the presence of inconsistent fill soil and fill containing organics at the project site, some precautions are required to select the appropriate foundation system for the proposed development. Although shallow foundation system is recommended, care should be taken due to the presence of uncontrolled fill with the potential of uneven future settlement.

Based on the subsurface conditions encountered in the boreholes and the results of the groundwater monitoring, groundwater infiltration is expected.

4.2.2 Geotechnical Resistance Factors

The geotechnical resistance factors required to calculate the factored foundation resistance to axial and horizontal loads in accordance with the 2005 National Building Code of Canada (NBCC) are provided below in Table 11.

Table 11 Geotechnical Resistance Factors for Deep Foundations

Description		Resistance Factor
Shallow Foundation		0.5
Deep Foundation		
Resistance to axial load	From semi-empirical analysis	0.4
	From static loading test results	0.6
	From dynamic monitoring results (i.e., pile driver analyzer [PDA] testing)	0.5
Uplift resistance	From semi-empirical analysis	0.3
	From loading test results	0.4
Horizontal load resistance		0.5

Under the Limit State Design (LSD) method, foundations are to be designed considering the factored Ultimate Limit State (ULS) and the Serviceability Limit State (SLS).

4.2.3 Shallow Foundations

A shallow foundation system consisting of spread footings and strip footings founded on competent native soil may be used to support the anticipated structural loads. Footings should not be placed on the existing uncontrolled/undocumented fill soils.

The LSD ultimate and factored bearing resistance for the design of strip and spread footings may be taken as the following (Table 12), subject to other recommendations in this report.

Table 12 Shallow Foundation Design Parameters

Location	Soil Type	Ultimate Bearing Resistance (kPa)	Factored Bearing Resistance (kPa)	Foundation Soil Coefficient of Friction (°)	Foundation Soil Unit Weight (kN/m^3)	Modulus of Subgrade Reaction (MPa/m)
Both sites	Coarse-grained soils	250	125	30	19.5	20

* From CFEM 2006 (Pg. 147, Table 9.3)

A geotechnical resistance factor of 0.5 was utilized to calculate the ULS factored values of bearing resistance presented in Table 12. The bearing resistance values in Table 12 are subject to change based on different serviceability criterion (i.e., settlements), footing sizes, and structural loading conditions that were not known by Barr at the time of this report. Thus, a qualified geotechnical engineer should carry out a detailed drawing review upon final design prior to construction, to ensure suitability. The bearing capacities provided should be verified and approved in the field during construction by qualified geotechnical personnel prior to the placement of concrete.

The bearing resistance corresponding to different serviceability criterion (i.e., settlements) and footing sizes can be computed once more information regarding the project is made available to Barr.

Differential settlements, rather than total settlements, are usually the governing factor in structural and architectural design. For footings, the degree of settlement is directly dependent on the quality of construction, as well as adherence to the recommendations of this report.

4.3 Modulus of Subgrade Reaction

Barr recommends that 20 MPa/m be used as spring constant for the soil.

4.4 Sliding Friction

The friction coefficient between the clayey soil of the site and concrete should be taken as 0.57, while that of the granular soils should be taken as 0.65 assuming a plain concrete surface.

4.5 Earth Pressure for Below-Grade Structures

The below-grade structures should be designed to resist lateral earth pressures, in the at-rest condition, and may be designed using the following expression, which assumes a triangular pressure distribution:

$$p_o = K_o(\gamma h + q)$$

Where:

p_o = Unfactored lateral earth pressure at a given depth (kPa).

K_o = Coefficient of earth pressure at-rest condition, assumes walls are rigidly supported; use 0.55 for backfill material, such as silts and clays, use 0.45 for sands and gravels.

γ = Bulk unit weight of soil for backfill; for fill, use 18.0 kN/m$^{3;}$ for sands and 21.0 kN/m^3 for gravel.

h = Depth below final grade (m).

q = Any surcharge pressure at ground level (kPa).

If foundation perimeter drainage is not provided, allowance should be made for hydrostatic pressures. Below the groundwater table, a value of the bulk unit weight of 8.0 kN/m^3 for fills should be used. In addition, the hydrostatic pressure due to water, as given in the following equation, should be applied.

$$p_w = \gamma_w h_w$$

Where:

p_w = Unfactored hydrostatic pressure (kPa).

γ_w = Unit weight of water (9.8 kN/m^3).

h_w = Depth below top of water table (m).

The above-noted expression assumes native material or backfill material compacted to approximately 98% SPDD and horizontal ground behind the basement wall. If the ground surface slopes upwards away from the wall, design wall pressures should be re-evaluated.

4.6 Frost Conditions

4.6.1 Frost Depth

The estimated frost penetration for the area is approximately 3.0 m (CFEM, 2006).

4.6.2 Frost Heave and Precautions

The soils on this project site, particularly the soils of low-medium plasticity, have the potential to exhibit moderate frost effects (heaving upon freezing and softening upon thawing). There will be a parking lot on top of the proposed culvert. The soil beneath and/or adjacent to the footings should be protected from freezing during and after construction to prevent the potential of heaving and cracking of the foundation elements.

Alternatively, rigid insulation may be used to provide frost protection below the pavement. A competent geotechnical engineer should be given the opportunity to review the final design details prior to construction.

With the data available from the fieldwork, it is difficult to calculate the amount of frost heave that can occur in the project area. However, due to the soil types present and the shallow groundwater table, some degree of frost heave is likely to occur.

Partial removal and replacement of the frost-susceptible soil and replacement with non-frost-susceptible soil, such as free-draining gravel, can also be undertaken. The level of risk reduction associated with frost heave is generally related to the amount of removal and replacement; greater depths of removal and replacement generally correlate to greater risk reduction. During final design, the civil engineer should discuss these risks with the owner to determine an acceptable design solution that balances project economics and site constraints with the level of risk that the owner is willing to accept.

Frost-susceptible soils typically exhibit fines content greater than 15% (Andersland and Ladanyi, 2004). Gravel or crushed stone drain surface water quickly and do not draw water from the water table. Coarse aggregate with uniform gradation is recommended. The replaced gravel fill should be free of fines which might fill voids and provide capillary channels around large particles. Although providing proper drainage reduces the extent of frost heave, it does not reduce the soil's moisture content enough to eliminate heaving entirely. Therefore, it is necessary to also prevent surface water from entering the base or subgrade. Using proper drainage measures will also reduce the movement of the surface water which can help in preventing frost heave.

4.7 Soil Chemical Content

Soluble sulphate concentrations were measured as between 19 mg/L to 203 mg/L. These results indicate the potential degree of a sulphate attack on the concrete as “moderate” per CSA guidelines; therefore, it is recommended to use sulphate-resistant (HS or HSb) cementing material.

Stricter recommendations may be required due to structural or other exposure considerations (A23.1-09; Table 1).

Imported fill to be placed in contact with concrete should be tested during project design for water-soluble sulphate content to determine its suitability for use as a backfill or foundation for concrete structures.

5.0 Construction Recommendations

General construction recommendations are presented in the following section.

5.1 Subgrade Preparation

5.1.1 Site Grading and Drainage

It is recommended that final site grading be provided to direct water to areas remote from the proposed structures. Minimum landscape gradients of 1.5% are recommended to reduce the risk of runoff ponding in localized areas. The parking area should be graded to drain away from the structures at a minimum gradient of 2%.

5.1.2 Excavations

Depending on construction conditions, excavations may have to be extended to remove wet, loose, soft, or otherwise unstable soils that become disturbed during the excavation process and lose strength. A geotechnical engineer should be present during excavation to observe and document that all excavations are extended to sufficient depths such that all unsuitable material is removed.

5.1.3 Construction Excavations

The composition and consistency of the fill soils encountered at the site are such that conventional hydraulic excavators should be able to remove these materials.

It is recommended that temporary cut slopes excavated in fill and above the water table be constructed no steeper than 1H:1V for a maximum slope height of 3 m. Unsupported excavations would be monitored on a daily basis for slope movements, such as slumping, bulging, etc. Such movements should be reported to the geotechnical engineer, and remedial measures should be undertaken immediately. Temporary surcharge loads, such as construction material or equipment, should not be allowed within 3 m of unsupported excavation face. The side slopes should be addressed at the time of construction. Occupational Health and Safety Standards (OH&S) must be adhered to.

Heavy equipment, in the vicinity of the excavation, should be utilized with care. Construction haul roads should avoid development areas prior to construction of suitable built-up subgrades. All construction haul routes should be carefully monitored for evidence of deep disturbance and, if such is noted, should be re-routed, re-constructed, or given time to stabilize.

Prior to allowing workers to enter, construction excavations should be carefully observed for evidence of instability, such as cracks, bulging, or soil loss from seepage areas. Evidence of excavation instability should be reported to the project engineer and corrected prior to allowing worker access. Any loose soil blocks, cobbles, and the like should be scaled from the excavation slopes prior to worker entry.

If sloping of the sides of the excavation is not feasible due to space limitations or other factors, then vertically sided excavations greater than 1.5 m deep will have to be shored. For relatively narrow utility trenches, excavations should be entered only in conjunction with an appropriate safety device utilized in accordance with the manufacturer's recommendations.

5.1.4 Groundwater Control

Groundwater levels in the vicinity of the project site are approximately between 2.6 m and 7.6 m below the existing ground surface. It is not expected that groundwater will be encountered at shallow depths (less than 1.5 m), considering the groundwater levels and soil types encountered across the site. Groundwater levels fluctuate over time, and higher or lower groundwater levels may be experienced during construction.

Dewatering will be required for the construction in some project areas. In low-permeability soils (clays and silts), a system of sloped trenches and sump pits are likely to be adequate to dewater shallow excavations on the site. Excavations into more permeable soils (sands and gravel) and below the water table will likely require more comprehensive dewatering methods (e.g., constructing a temporary coffer/diversion structure and use of silt fences, etc.).

5.1.5 Surface Water Control

In the case of a surface runoff, the water should be diverted away from the construction area. Similarly, in the case of working within the river limits, temporary cofferdams will need to be constructed to divert the river water and avoid any contamination.

5.1.6 Subgrade Construction

The surface of the bedrock can be levelled using sand and/or lean concrete. In case the foundation is to be placed in the soil, after the removal of unsuitable materials, the bottom of the excavation should be compacted to 98% SPDD to a depth of 500 mm.

If any soft or weak zones are identified during the compaction, the material should be sub-cut a minimum of 1 m and replaced with suitably compacted engineered fill material.

Backfill and fill placed over wet or submerged excavation bottoms should initially consist of sand with a maximum particle size of 35 mm, having less than 50 percent of the particles by weight passing a number 40 sieve, and less than 5 percent of the particles by weight passing a number 200 sieve. A geotextile should be placed between the sand and the native subgrade as a means of preventing migration of fines into the fill material. This material should be placed to an elevation at least 600 mm above the excavation bottoms or water surfaces prior to compaction and prior to using alternative backfill and fill materials.

5.1.7 Subgrade Stabilization

If the foundations are placed on the bedrock, then soil stabilization is not required. If the foundation is placed on the fill or existing soil, then stabilization may be required depending on whether large areas of subgrade are unsuitable; then subgrade stabilization is required, and one of the following methods can be utilized:

- **Removal and Replacement** – Inadequate materials can be removed and replaced with compacted granular fill. The use of a geotextile fabric or geogrid may potentially reduce removal and replacement requirements

- **Scarification and Recompaction** – It may be feasible to scarify, dry, and recompact the exposed soils. The success of this procedure would depend primarily on favorable weather and sufficient time to dry the soils. Even with adequate time and weather, however, stable subgrades may not be achievable if the thickness of the soft soil is greater than 500 mm.

- **Soil Stabilization** – The use of cement, lime, or fly ash as a soil-stabilizing agent can be considered in lieu of removal and replacement or scarification and recompaction. The type and quantity of materials used to stabilize the soils will be dependent upon soil type. Typically lime stabilization is used for higher moisture content silty clay to clayey silt soils similar to those encountered at the site. Fat clay soils may be particularly susceptible to softening, and disturbance from rain events and construction traffic. Fat clay soils are not expected to be found on the site; however, if encountered below the proposed roadways, soil stabilization may be beneficial. The design of a soil stabilization program should be performed by a geotechnical engineer in conjunction with laboratory testing to provide the proper stabilizing agent, application rate, and depth of soils stabilized.

5.1.8 Placement and Compaction of Fill

It is recommended that engineered fill should be placed in 200-mm maximum compacted lift thickness, provided standard compaction equipment is used (note that small units such as "jumping jacks" are not recommended for compaction).

5.2 Cold Weather Construction

If site grading and construction are anticipated during cold weather, all snow and ice should be removed from cut-and-fill areas prior to additional grading. No fill should be placed on frozen subgrades. No frozen soils should be used as fill.

The soils on this project site, particularly the clay till of low-medium plasticity, have the potential to exhibit moderate frost effects (heaving upon freezing and softening upon thawing). The soil beneath and/or adjacent to the highway foundation should be protected from freezing during and after construction to prevent the potential of heaving and cracking.

5.3 Buried Utilities

The results of the geotechnical investigation indicate that utilities, if any, are likely to be placed in the fill material. These soils should generally be suitable for support of underground utilities. Within the zone of frost-susceptible soils (up to 3 m below the existing ground surface), insulation may be required. Soils from trench excavations may be used as backfill, provided they are free of debris. Groundwater seepage may be encountered in the shallow excavations (up to 0.6 m).

As noted above, groundwater seepage may be encountered during deep excavations.

It is expected that the native soils encountered on the site will have some potential for sloughing in steep-sided trenches. Utility trenches will either have to be sloped back or entered only when an appropriate safety cage or trench box, used in accordance with the manufacturer's specifications, is utilized.

5.4 Bedrock Rippibility

No bedrock was encountered during the field investigation. Based on the geophysics results (Appendix A), the interpreted hard soil ranges from 3.6 to 7.9 m below ground surface, with depth generally increasing to the west. Modelled bedrock p-wave velocities range from 2,688 m/s to 3,568 m/s, and the modelled overburden velocities range between 550 m/s and 704 m/s.

5.5 Construction Material Testing

In-place density testing should be performed on the compacted backfill material. Density tests should be performed where the construction observer is concerned regarding the adequacy of compaction or at a frequency of one test per lift for every 100 square m of fill placed. Material samples should be submitted to a qualified laboratory for standard Proctor maximum dry density testing in advance of any in-place density testing.

5.6 General Construction Recommendations

Some general construction recommendations are as follows:

1. The foundations should be placed on competent native soil.
2. Suitably qualified persons, independent of the contractor, should carry out all such field reviews. It should be noted that failure to provide an adequate level of foundation review may be in contravention of the Building Code requirements.
3. Groundwater levels were measured at depths varying from 2.3 m to 7.6 m below the existing ground surface. Based on the groundwater-level measurements, temporary and permanent dewatering measures may be required. Groundwater seepage during footing excavation is anticipated in the project area. Therefore, dewatering the soil in advance of the excavation may be necessary for excavation stability and seepage control.
4. It is recommended that a smooth edge-trimming bucket or grade-all be used for final excavation to the foundation subgrade elevation to minimize disturbance of exposed bearing soils.
5. Footing excavations must be protected at all times from freezing temperatures, the ingress of free water, disturbance by construction traffic, and excessive drying. It is recommended that exposed bearing surfaces be protected with mud slab if foundations are not constructed promptly after excavation and not founded on bedrock.
6. Recommendations for minimum depth of cover for footings are discussed elsewhere in this report for frost considerations.
7. Based on the results for moisture-density relationship tests, a minimum dry density of 1,950 kg/m^3 or 95% of maximum dry density based on standard Proctor dry testing is

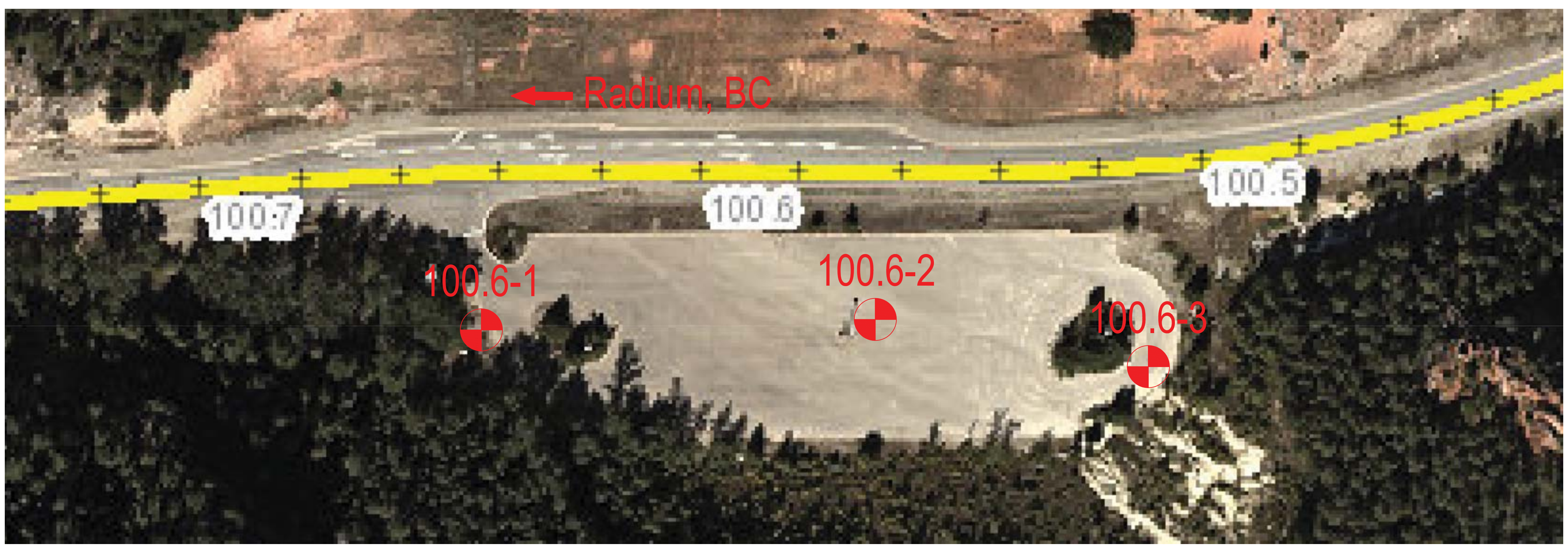
recommended for backfill, whichever is greater. In some cases, additional compaction effort beyond 95 percent of the standard Proctor dry density may be necessary to obtain a minimum dry density of at least 1,950 kg/m^3.

6.0 References

Andersland, O.B., and Ladanyi, B., 2004. Frozen Ground Engineering. Second Edition. John Wiley & Sons Inc.

Figure

1 95.9 Culvert



2 100.6 Radium Hotspring Overflow Parking Lot

N

Borehole	UTM N (m)	UTM E (m)	Elevation (m)	Depth (m)
95.9-1	572803	5610964	1251.6	7.6
95.9-2	572697	5610912	1251.3	6.1
100.6-1	568342	5609705	1026.7	15.2
100.6-2	568417	5609707	1031.3	9.1
100.6-3	568469	5609698	1035.9	9.1

0 20 30 40
SCALE IN METERS

FIGURE 1

BOREHOLE LOCATIONS
100.6 & 95.9 Culvert Replacement
Kootney National Park, BC

LEGEND

BOREHOLE

BARR
Barr Engineering & Environmental Science Ltd
808–4 Ave 700
Calgary AB T2P–3E8
Ph: 1–403–592–8300
Fax: (952) 832–2601
www.barr.com

CADD USER: Mitchell Prince FILE: G:\MGP3\61021019\RADIUM\REPORT RES\LOCATION FIGURE.DWG PLOT SCALE: 1:1 PLOT DATE: 12/5/2017 1:44 PM

Appendix A

Seismic Refraction Survey

SHALLOW EARTH TECHNOLOGIES INC.

PROJECT 17-14

PARKS CANADA
SITES Km 95.9 AND Km 100.6
KOOTENAY NATIONAL PARK, BRITISH COLUMBIA
GEOPHYSICAL SURVEYS

Barr Engineering and Environmental Science Canada Ltd.
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November 12th, 2017

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www.shallowearthtechnologies.com

1.0 INTRODUCTION

Shallow Earth Technologies Inc. (SETI) conducted seismic refraction and ground penetrating radar surveys at Site Km 95.9, and Site Km 100.6 along Highway 93 in Kootenay National Park, British Columbia for Barr Engineering and Environmental Science Canada Ltd. on October 25th and 26th, 2017. The objectives of the surveys were to:

- determine bedrock depth
- determine the seismic velocity of the competent (*i.e.*, unweathered) bedrock
- determine depth below ground surface to existing culverts

The bedrock investigation surveys were designed to investigate to a maximum depth of 10 metres below ground surface. The culvert investigation surveys were designed to investigate to a maximum depth of approximately 4 metres below ground surface.

2.0 SCOPE OF SERVICES

The proposed Scope of Services for each of the two sites were as follows:

- Conduct seismic refraction surveys at two sites in Kootenay National Park, B.C. to determine depth to, and seismic velocity of, unweathered bedrock material.
- Conduct GPR surveys along a minimum of four transects at each of two sites to determine the lateral location and depth to existing buried culverts.
- Prepare an interpreted two-dimensional seismic depth section for each seismic refraction transect and determine seismic (compression-wave (or, p-wave)) velocities within the shallow bedrock.
- Prepare an interpreted GPR depth section for each GPR transect to determine location and depth of burial of existing culverts.
- Prepare a report that discusses the geophysical survey results and summarizes the survey methods used.
- SETI was required to supply all necessary equipment and personnel to carry out the Scope of Services.

SETI will supplied all personnel and necessary equipment to carry out the Scope of Services. In addition, the surveys were conducted under the supervision of a professional geophysicist registered with the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC).

3.0 METHOD DESCRIPTION

Seismic refraction and ground penetrating radar surveys were conducted to address the survey objectives.

3.1 Seismic Refraction Survey Method

The seismic refraction survey was conducted to determine depth to the top of unweathered (competent) bedrock and the seismic velocity of the earth materials.

For the seismic refraction method, an acoustic wave is typically generated at ground surface which propagates into the subsurface soil and rock. Upon encountering boundaries having contrasting mechanical properties (*i.e.*, density, elasticity and, consequently, seismic wave propagation speed) the acoustic wave pulse is partially refracted and partially transmitted into underlying strata. The ray-path of the incident-transmitted pulse is bent, or refracted, at the boundary in accordance with Snell's law (Figure 1).

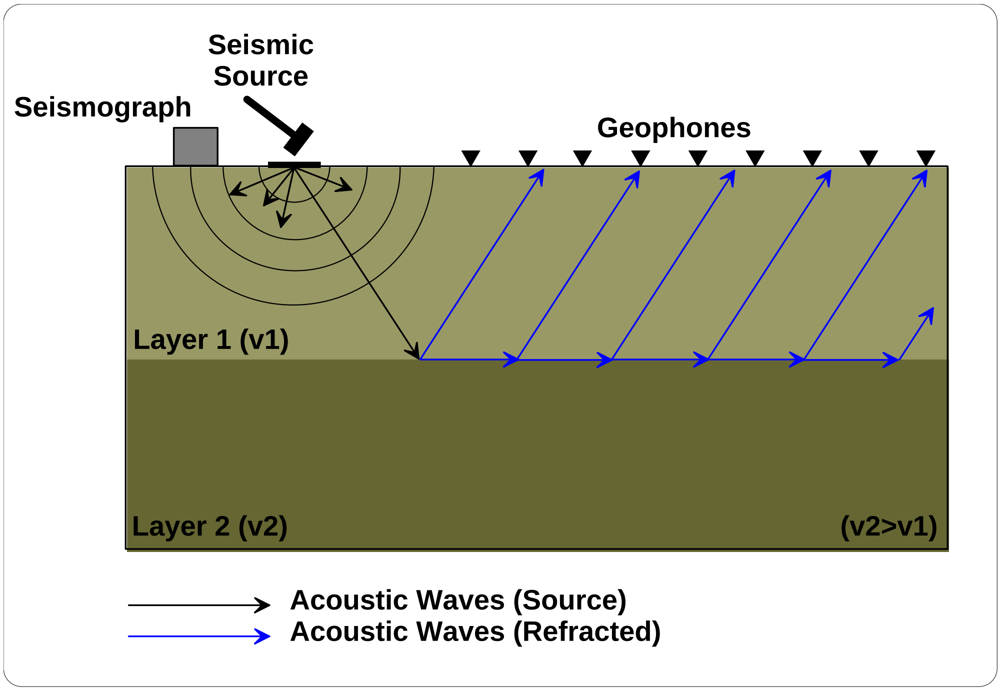


Figure 1: Seismic refraction method (two-layer model)

By measuring the elapsed time between initial pulse generation at the shot-point and the arrival of the refracted waves at surface, layer speed and thicknesses can be determined.

The initial pulse was generated using a truck-mounted accelerated weight-drop and, in areas that were not truck-accessible, a sledge hammer. The arrival of the refracted waves at varying distance from the input source were measured by small microphones, or geophones, and recorded by a digital seismograph (Figure 2).

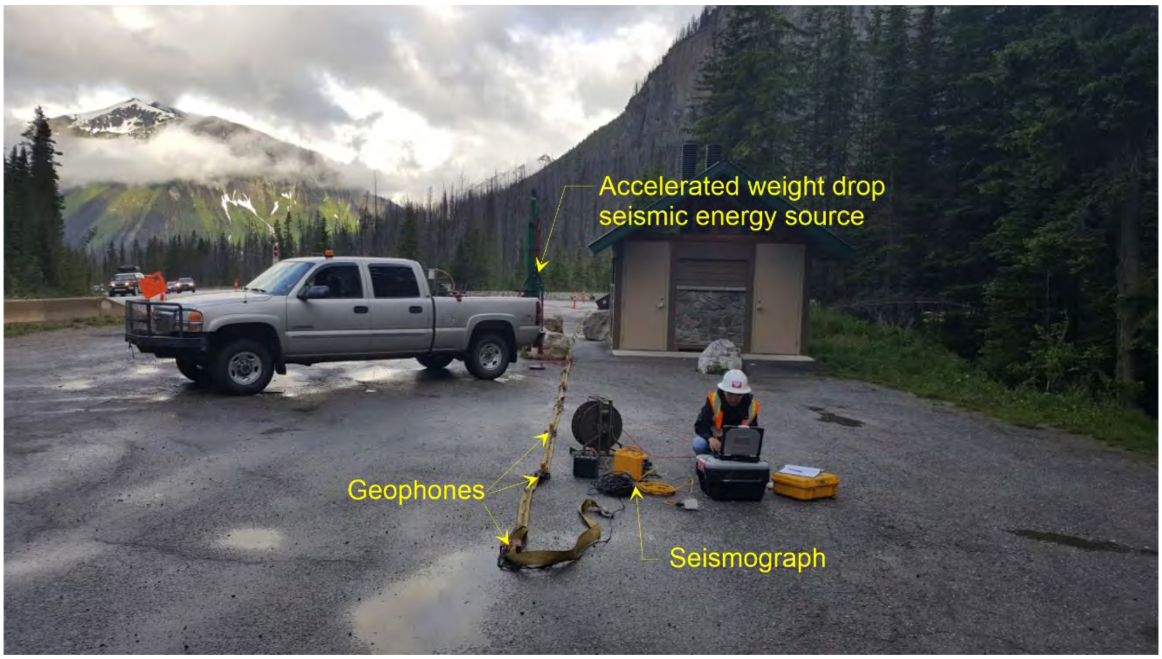


Figure 2: Seismic refraction instrumentation setup

Seismic refraction data were collected using a Geometrics Inc. Geode seismograph and an array of twelve 4.5 Hz. land geophones. Acoustic energy was imparted at multiple locations (shot points) along the geophone arrays.

The following seismic refraction survey acquisition parameters were used:

- Geophone spacing: 2.0 and 3.0 metres
- Offset shot distance: 20 to 45 metres
- Sampling interval: 0.125 milliseconds
- Time window: 1000 milliseconds
- Filters: none

A Trimble GeoXT GPS receiver was used to collect real-time Wide Area Augmentation System (WAAS) differentially corrected positional data at all geophone and shotpoint locations along each seismic survey lines.

Seismic refraction data processing consisted of digitizing the refracted arrival travel times which were then directly inverted to a subsurface model using wavefront-inversion modelling. The wavefront-inversion method, using Sandmeier Geophysical Research Reflexw software, allows interactive back propagation of the seismic wavefronts by finite differences approximation of the eikonal equation.

Seismic refraction data were collected along two survey lines at each of the two sites as illustrated by Figures 3 and 4.

3.1 Ground Penetrating Radar (GPR) Survey Method

GPR surveys were conducted to determine the lateral location and depth to existing buried culverts.

The GPR method provides high vertical and horizontal resolution data that can be quickly acquired while towing the instrumentation behind a vehicle or pulled along the ground while walking. Data are normally acquired at one second time intervals, allowing compilation of continuous depth profiles along survey lines.

A GPR transmitter antenna emits electromagnetic waves into the ground which are partially reflected at subsurface interfaces and detected by a receiver antenna. Reflections result from contrasts in the dielectric constant of subsurface materials and stratigraphic layering. Given an estimate of radar velocity, corresponding reflector depths may be determined. Depth analysis can be further enhanced by intrusive methods, such as test pits and bore holes.

Maximum GPR penetration depth is mostly controlled by antenna frequency and the by electrical conductivity of subsurface materials; GPR depth penetration decreases with antenna frequency and ground conductivity. Increased ground conductivity resulting from clay-rich soils and/or dissolved salts can significantly reduce the effective range of GPR signals to sub-metre depths.

GPR data were collected along four survey lines at Site Km 95.9 and along seven lines at Site Km 100.6 (Figures 3 and 4). Data were collected at 20 traces/metre within a 135 nanosecond time window and stacked 10 times using a Geophysical Survey Systems, Inc. (GSSI) SIR-3000 with 200 MHz shielded antennas.

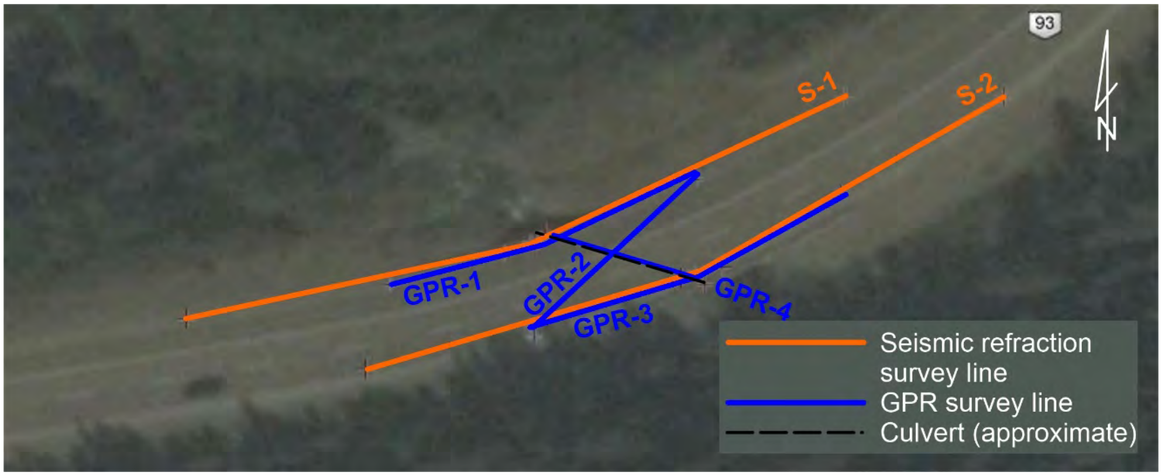


Figure 3: Site Km 95.9 geophysical survey line location map

Figure 4: Site Km 100.6 geophysical survey line location map

4.0 RESULTS

Seismic refraction survey data were collected along two individual lines at Site 95.9 and two lines at Site 100.6; GPR data were collected along four survey lines at Site Km 95.9 and along seven lines at Site Km 100.6.

4.1 Site Km 95.5

Results of the seismic refraction survey at Site Km 95.5 are illustrated as interpreted depth sections (Figures 5 and 6) and as an interpreted bedrock depth isopach (Figure 7). GPR survey results are presented as interpreted depth sections on Figure 8a and as an interpreted depth to top of culvert map on Figure 8b.

As illustrated on Figures 5 to 7, interpreted bedrock depth at Site Km 95.5 ranges from approximately 4.0 to 7.7 metres below ground surface. Modelled bedrock p-wave velocity is 2688 metres/second along Line S-1 and 3568 metres/second along Line S-2; modelled overburden velocity is 704 metres/second along Line S-1 and 668 metres/second along Line S-2.

Interpreted top of culvert depth ranges from 1.0 m to 2.0 m below ground surface (Figures 8a and 8b).

4.2 Site Km 100.6

Results of the seismic refraction survey at Site Km 100.6 are illustrated as interpreted depth sections (Figures 9 and 10) and as an interpreted bedrock depth isopach (Figure 11). GPR survey results are presented as interpreted depth sections on Figure 12a and as an interpreted depth to top of culvert map on Figure 12b.

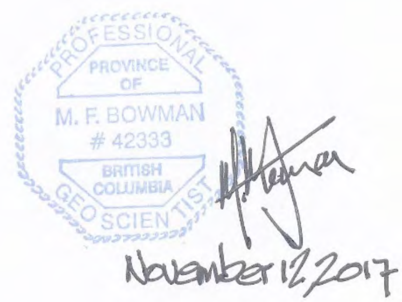
Interpreted bedrock depth at Site Km 100.6 ranges from approximately 3.6 to 7.9 metres below ground surface (Figures 9 to 11). Modelled bedrock p-wave velocity is 2830 metres/second along Line S-3 and 2695 metres/second along Line S-4; modelled overburden velocity is 619 metres/second along Line S-3 and 550 metres/second along Line S-4.

GPR response to the buried culvert at Site Km 100.6 was only evident along lines GPR-5, GPR-6 and GPR-7 where the interpreted depth is 2.2 m, 2.6 m and 2.4 m, respectively. The lack of response along lines GPR-8, GPR-9, GPR-10 and GPR-11 may be due to an increased burial depth and/or a difference in soil type (*i.e.*, higher clay content within the overburden soil).

5.0 CLOSURE

We trust that this report meets your present requirements. If you have any questions, or if additional information is required, please contact the undersigned.

SHALLOW EARTH TECHNOLOGIES INC.



Joe Gouthro
President

Mark Bowman, P.Geo.
Senior Geophysicist

STATEMENT OF LIMITATIONS

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The investigation undertaken by Shallow Earth Technologies Inc. with respect to this report and any conclusions or recommendations made in this report reflect Shallow Earth Technologies Inc.’s judgment based on the site conditions observed at the time of the site inspection on the date set out in this report, and on information available at the time of preparation of this report. This report has been prepared for specific application to this site and it is based, in part, upon visual observation of the site and subsurface investigation at discrete locations and depths, all as described in this report. Unless otherwise stated, the findings cannot be extended to previous or future site conditions, portions of the site which were unavailable for direct investigation or subsurface locations which were not investigated directly.

If site conditions or applicable standards change or if any additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this report may be necessary.

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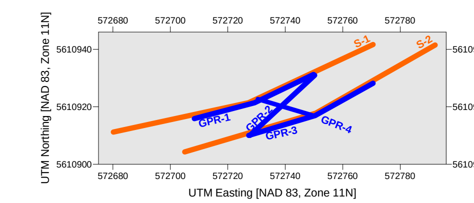
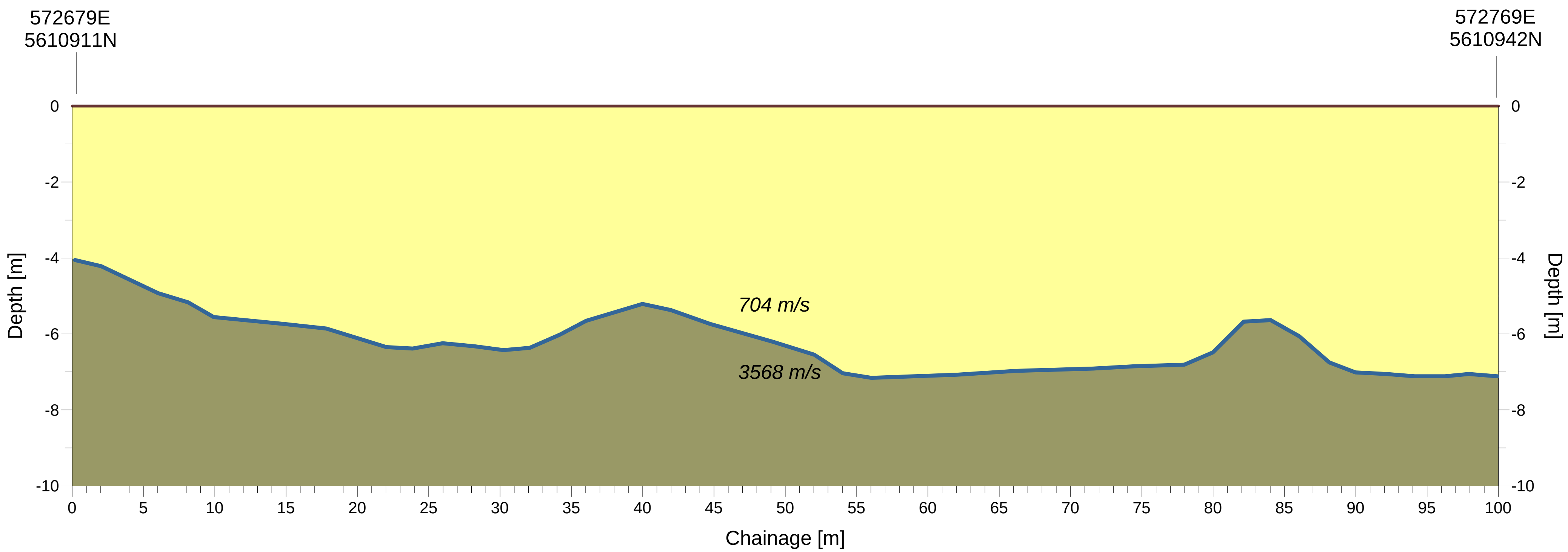
FIGURES

Line Location Map





Horizontal Scale: 1 cm = 4 m
Vertical Scale: 1 cm = 1.5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

LEGEND

- Interpreted bedrock surface
- Interpreted overburden
- Interpreted bedrock
- *1000 m/s* Modelled speed of seismic wave propagation (metres/second)

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 95.9
Kootenay National Park, B.C.

TITLE

Seismic Refraction Survey
Interpreted Depth Section
Seismic Line S-1

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	5	

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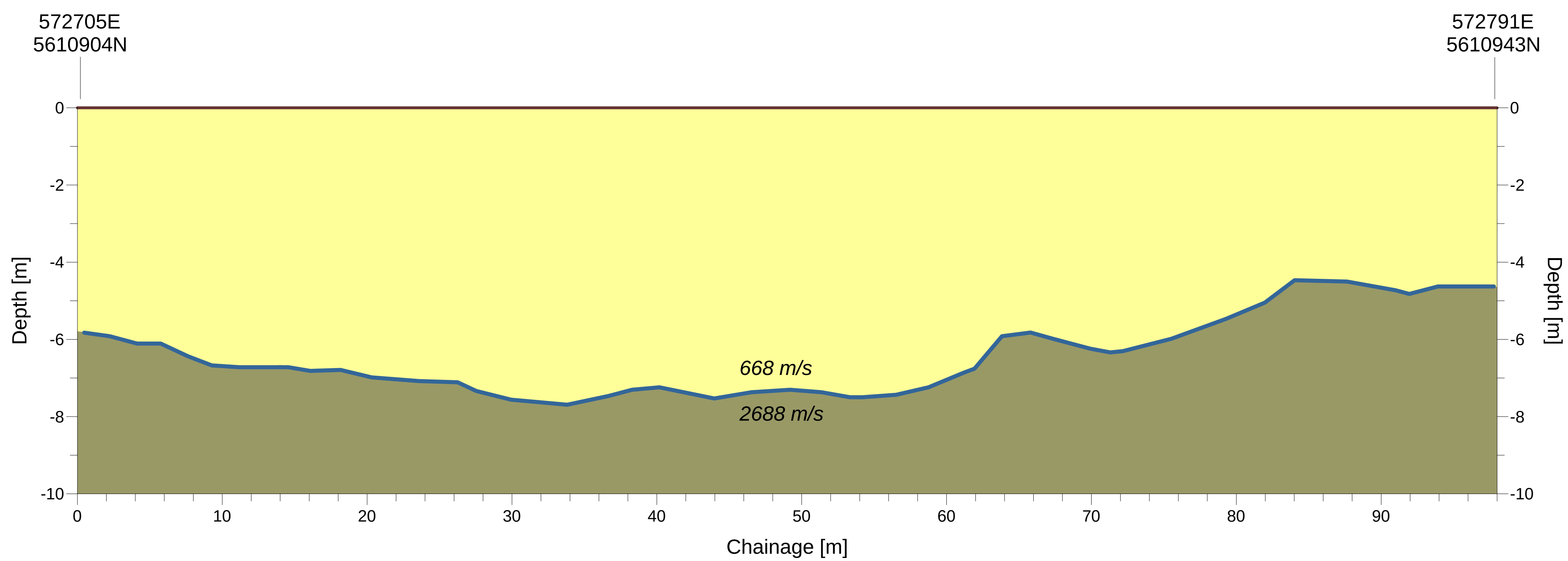
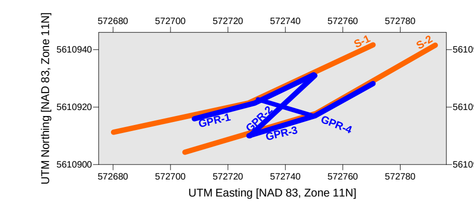


Horizontal Scale: 1 cm = 4 m
Vertical Scale: 1 cm = 1.5 m

Line Location Map



LEGEND

Interpreted bedrock surface

Interpreted overburden

Interpreted bedrock

1000 m/s Modelled speed of seismic wave propagation (metres/second)

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Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 95.9
Kootenay National Park, B.C.

TITLE

Seismic Refraction Survey
Interpreted Depth Section
Seismic Line S-2

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	6	

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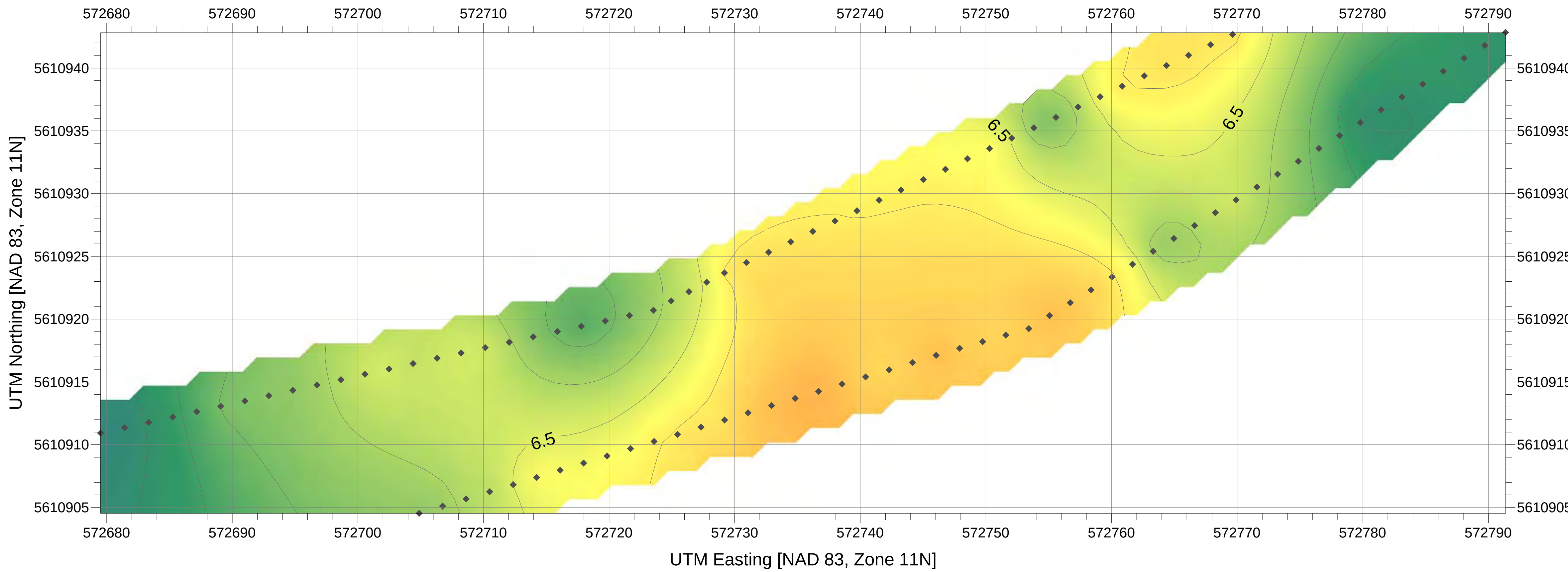

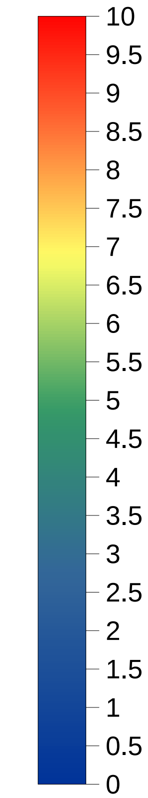

Interpreted Depth to Bedrock
[metres]

LEGEND

◆ ◆ ◆ ◆ ◆ Seismic Geophone Location

CLIENT

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Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 95.9
Kootenay National Park, B.C.

TITLE

Seismic Refraction Survey
Interpreted Bedrock Depth Isopach

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	7	

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Scale: 1 cm = 4 m

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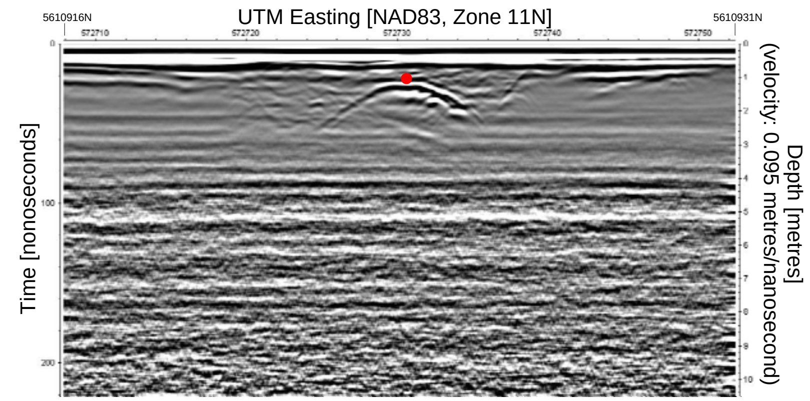
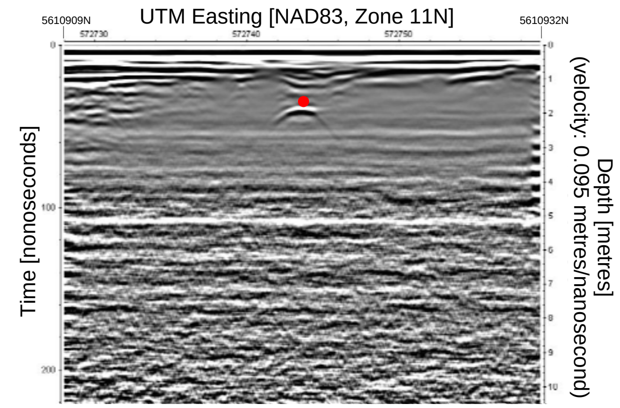
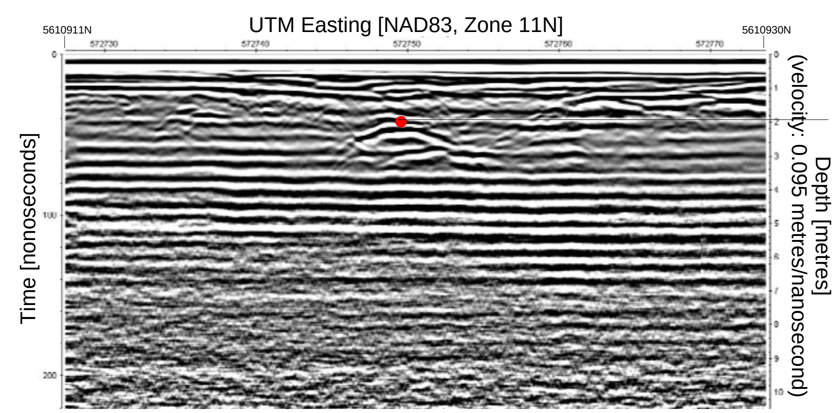
GPR-1



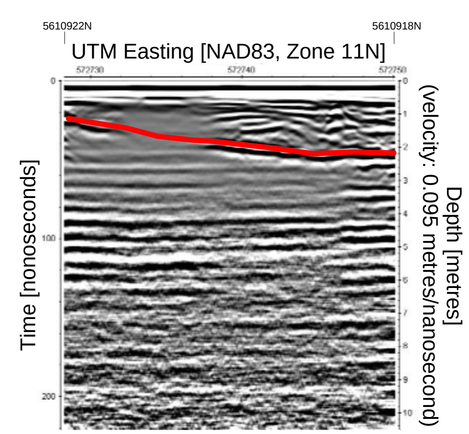
GPR-2



GPR-3



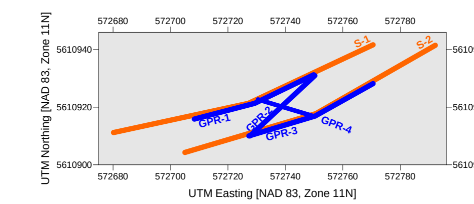
GPR-4



Horizontal Scale: 1 cm = 5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

Line Location Map



LEGEND

● Interpreted top of culvert (GPR-1, GPR-2 and GPR-3)

— Interpreted top of culvert (GPR-4 along top of culvert)

CLIENT

Barr Engineering and Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

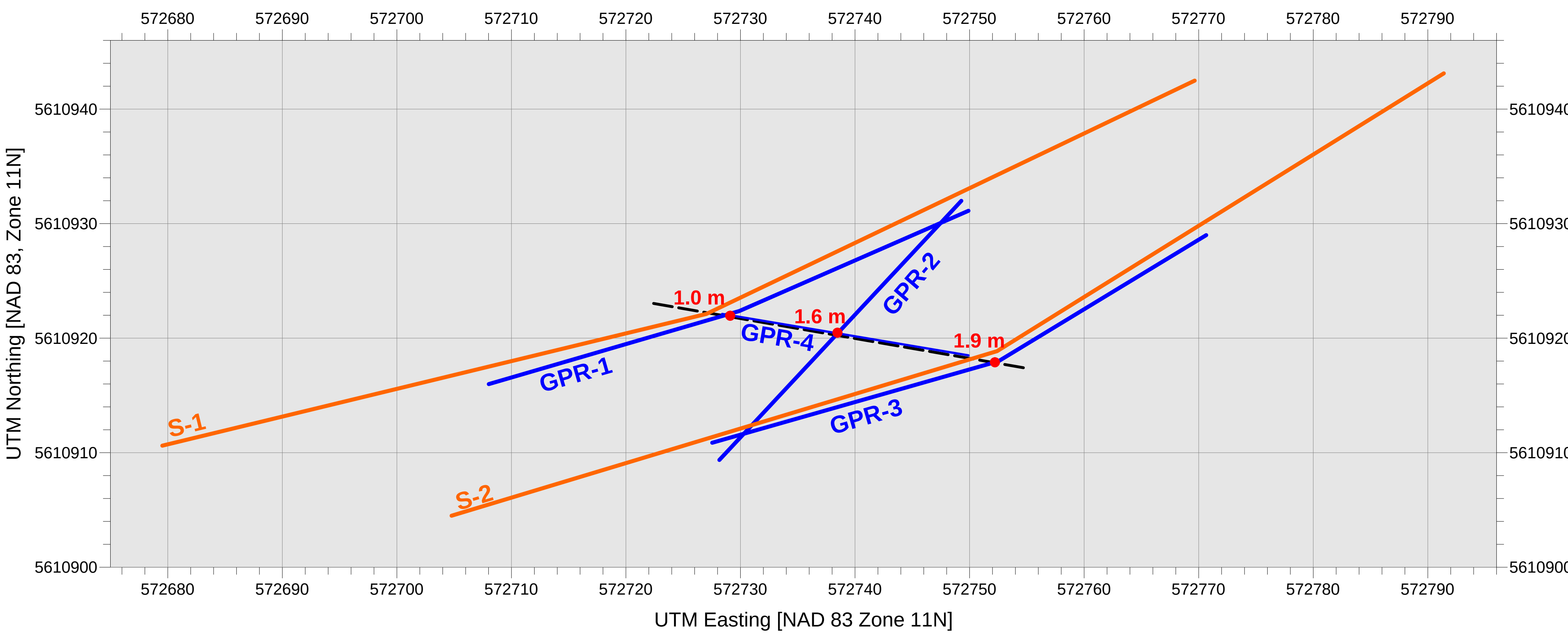
Parks Canada
Site Km 95.9
Kootenay National Park, B.C.

TITLE

Ground Penetrating Radar (GPR) Survey
Interpreted Depth Sections

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	8a	

SHALLOW EARTH TECHNOLOGIES INC.



Horizontal Scale: 1 cm = 5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

LEGEND

1.0 m — Interpreted top of culvert depth

— — — Approximate culvert alignment

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 95.9
Kootenay National Park, B.C.

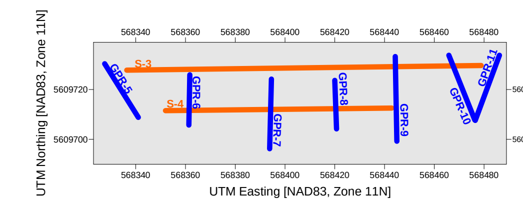
TITLE

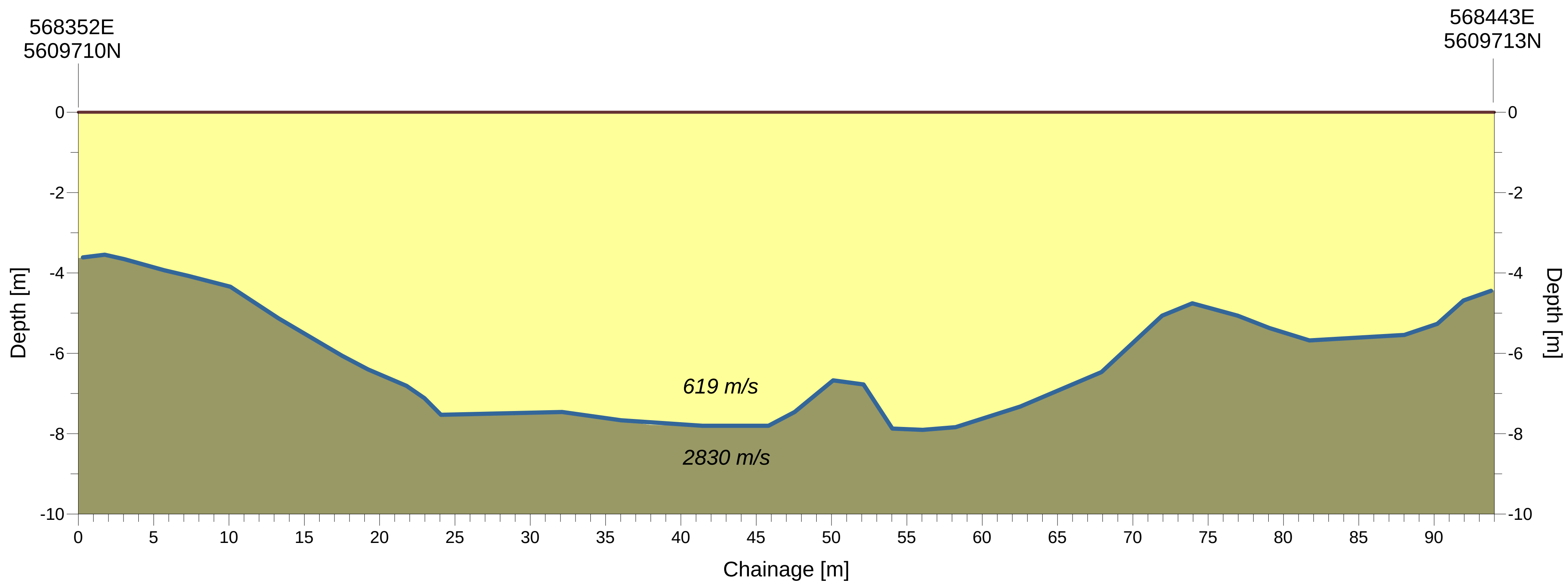
Ground Penetrating Radar (GPR) Survey
Interpreted Depth to Top of Culvert

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	8b	

SHALLOW EARTH TECHNOLOGIES INC.

Line Location Map





LEGEND

Interpreted bedrock surface

Interpreted overburden

Interpreted bedrock

1000 m/s Modelled speed of seismic wave propagation (metres/second)

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 100.6
Kootenay National Park, B.C.

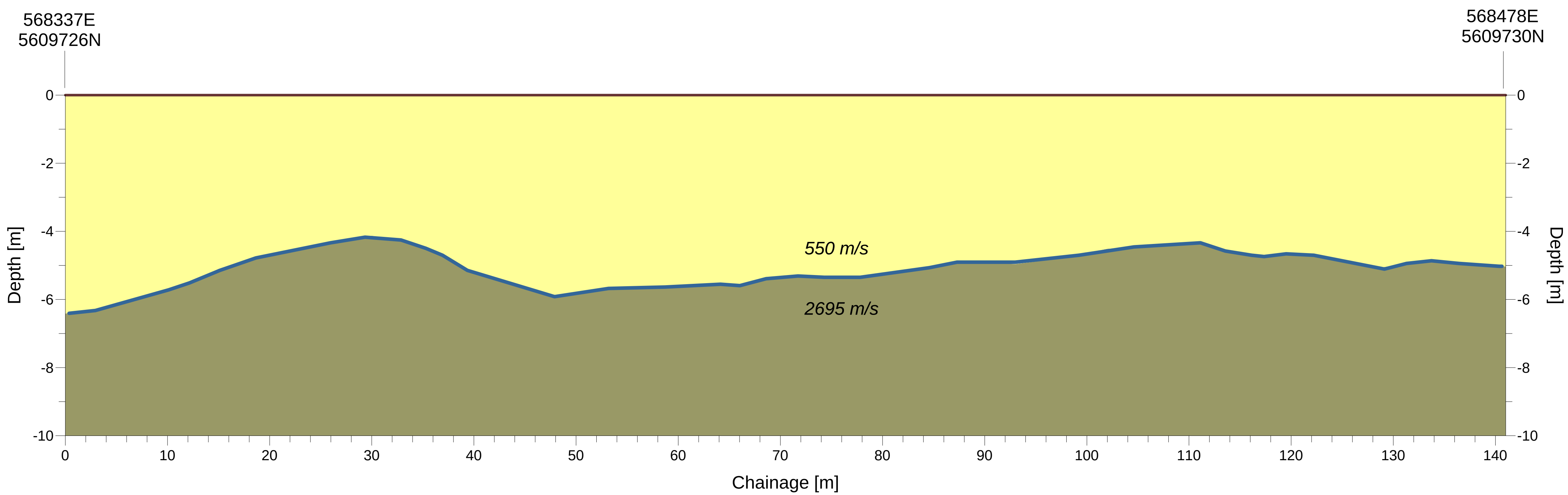
TITLE

Seismic Refraction Survey
Interpreted Depth Section
Seismic Line S-3

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	9	

SHALLOW EARTH TECHNOLOGIES INC.

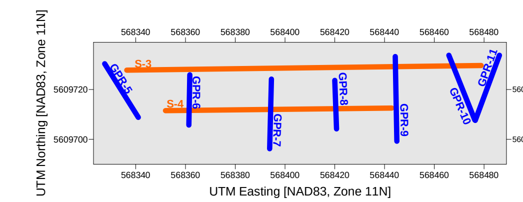
Horizontal Scale: 1 cm = 4 m
Vertical Scale: 1 cm = 1.5 m



Horizontal Scale: 1 cm = 5 m
Vertical Scale: 1 cm = 1.5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

Line Location Map



LEGEND

- Interpreted bedrock surface
- Interpreted overburden
- Interpreted bedrock
- *1000 m/s* Modelled speed of seismic wave propagation (metres/second)

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

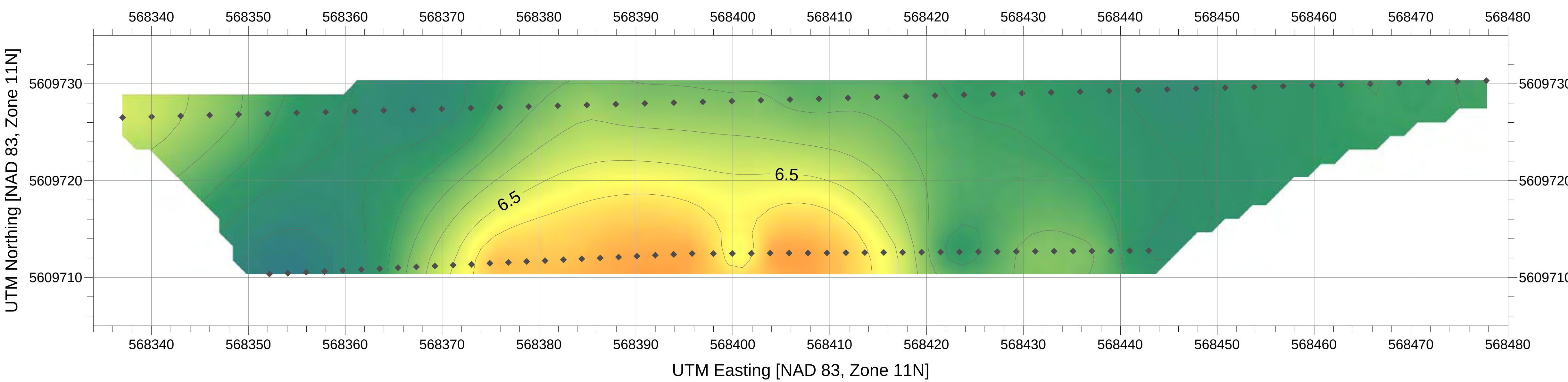
Parks Canada
Site Km 100.6
Kootenay National Park, B.C.

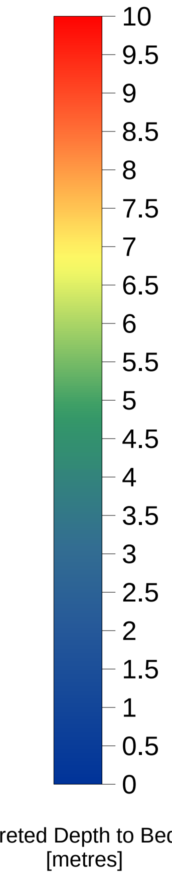
TITLE

Seismic Refraction Survey
Interpreted Depth Section
Seismic Line S-4

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	10	

SHALLOW EARTH TECHNOLOGIES INC.





LEGEND

◆ ◆ ◆ ◆ ◆ Seismic Geophone Location

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 100.6
Kootenay National Park, B.C.

TITLE

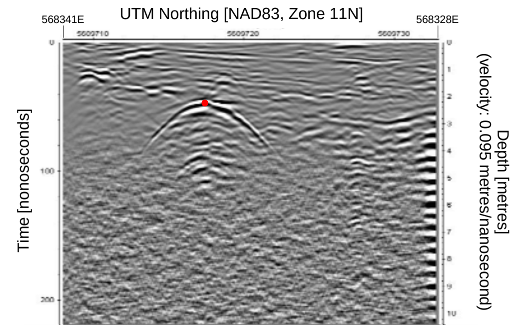
Seismic Refraction Survey
Interpreted Bedrock Depth Isopach

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	11	

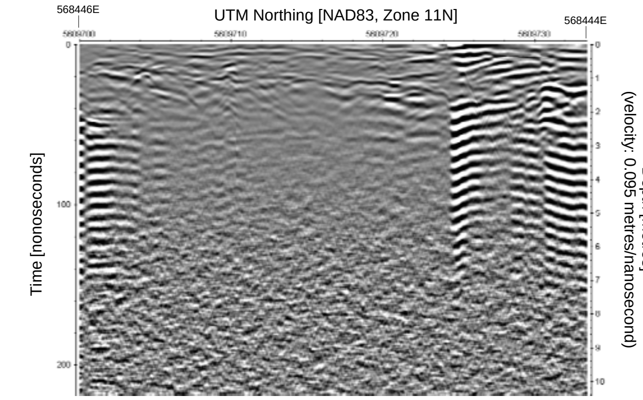
SHALLOW EARTH TECHNOLOGIES INC.

Scale: 1 cm = 5 m

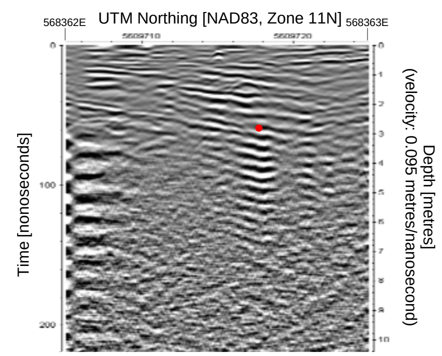
GPR-5



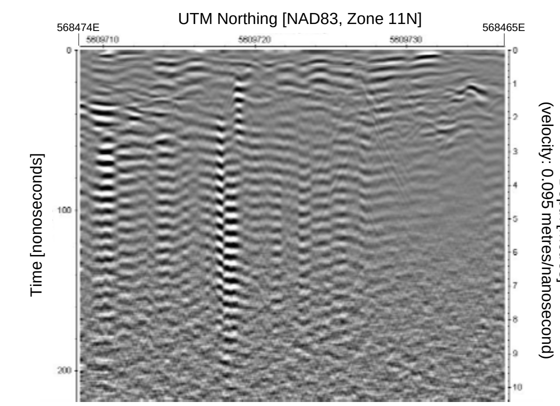
GPR-9



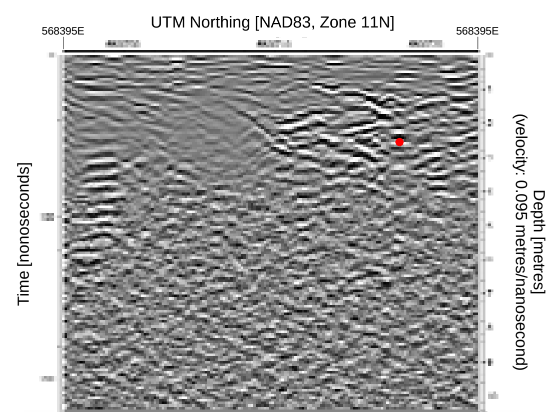
GPR-6



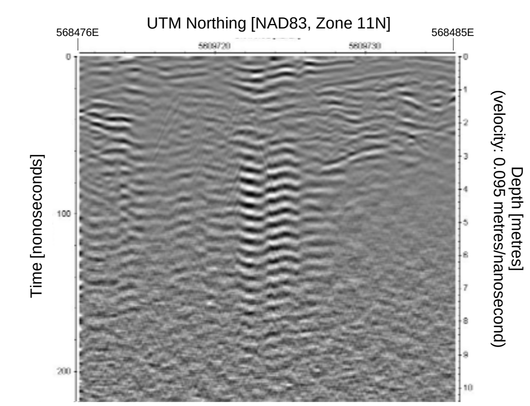
GPR-10



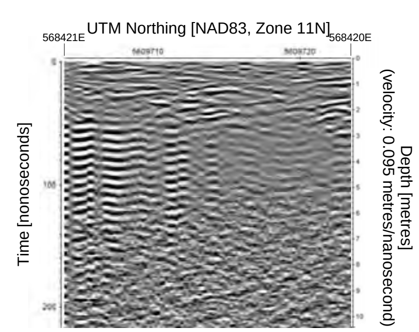
GPR-7



GPR-11



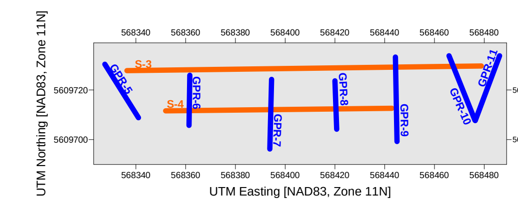
GPR-8



Horizontal Scale: 1 cm = 5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

Line Location Map



LEGEND

● Interpreted top of culvert

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

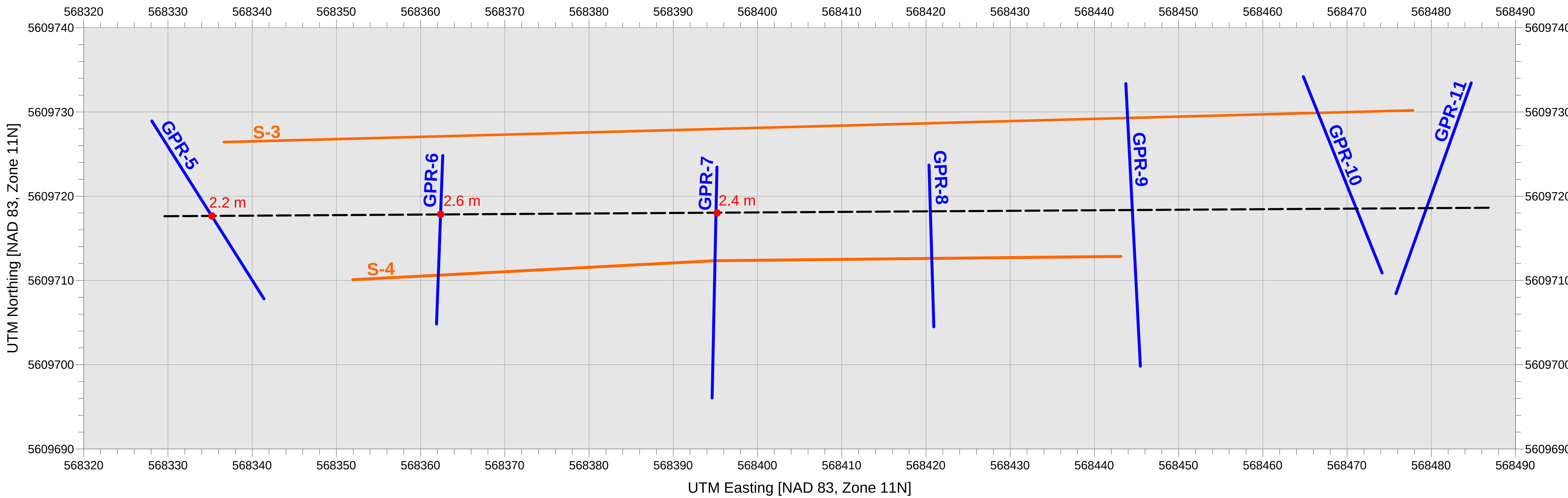
Parks Canada
Site Km 100.6
Kootenay National Park, B.C.

TITLE

Ground Penetrating Radar (GPR) Survey
Interpreted Depth Sections

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	12a	

SHALLOW EARTH TECHNOLOGIES INC.



Horizontal Scale: 1 cm = 7.5 m

The information contained on this figure must be used only in the context of the original report with which it was associated. This figure is subject to the limitations of that report.

LEGEND

1.0 m ● Interpreted top of culvert depth

— — — Approximate culvert alignment

CLIENT

Barr Engineering and
Environmental Science Canada Ltd.
808 - 4 Ave S.W.,
Calgary Alberta T2P 3E8

PROJECT

Parks Canada
Site Km 100.6
Kootenay National Park, B.C.

TITLE

Ground Penetrating Radar (GPR) Survey
Interpreted Depth to Top of Culvert

PROJECT No:	17-14	
DRAWN BY:	JG	03NOV2017
CHECKED BY:	MB	09NOV2017
REVIEWED BY:	MB	09NOV2017
FIGURE No:	12b	

SHALLOW EARTH TECHNOLOGIES INC.

Appendix B

Soil Boring Logs

P:\CALGARY\61 CANADA\02\61021019 PARKS CANADA MARBLE CANYON\WORKFILES\04 2 CULVERT SITES\DATA\GINT LOGS NOV 21-24 2017\61021019 NOV 21-24-2017.GPJ BARR\LIBRARY_JFB.GLB

BARR

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 100.6-1

Project: Highway 93S Culvert Replacement at 95.6 km & 100.6 km

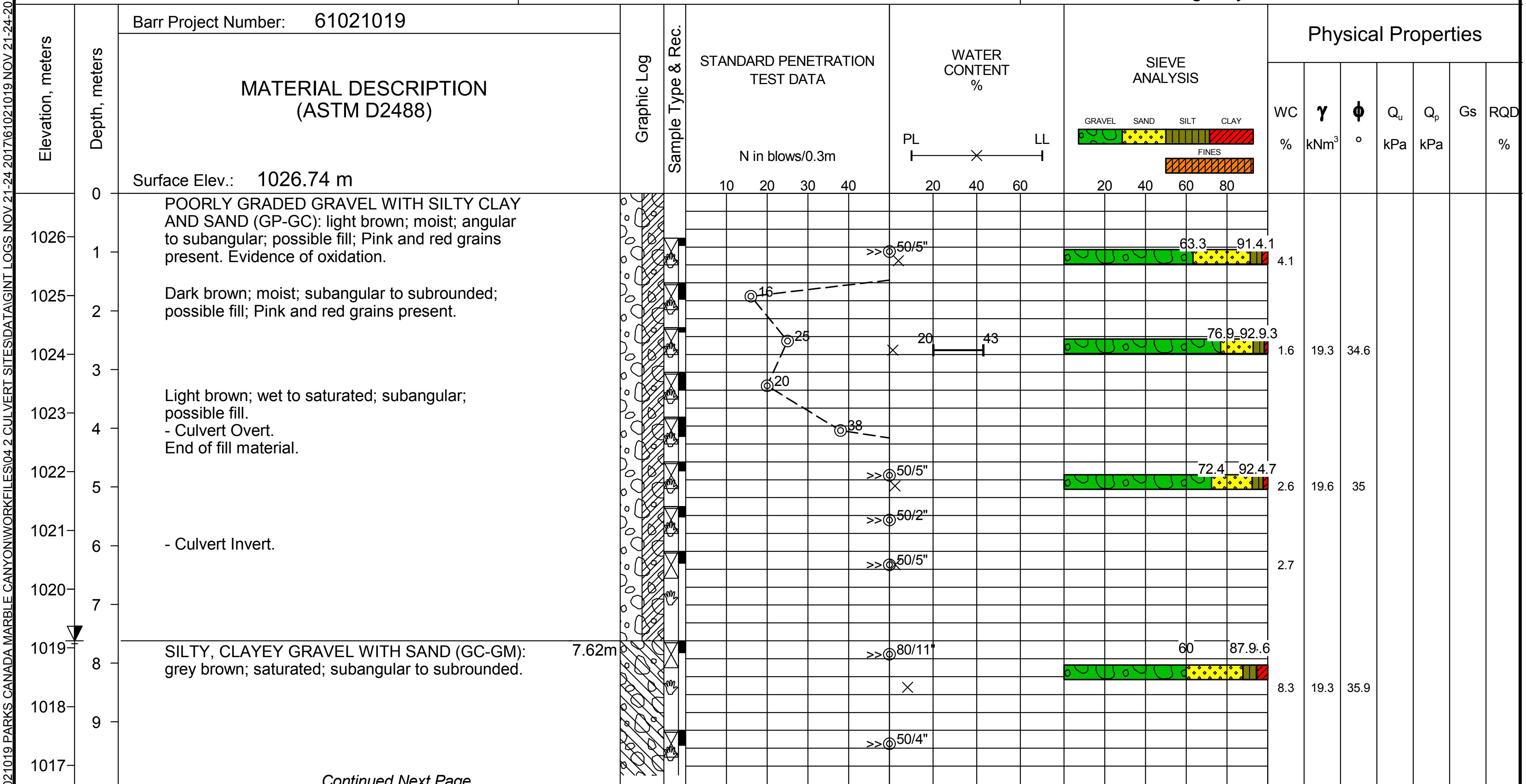
Location: Highway 93S, BC

Client: Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1026.74 m



Completion Depth:	15.2
Date Boring Started:	21/11/17
Date Boring Completed:	23/11/17
Logged By:	MGP3
Drilling Contractor:	Mobile Augers
Drilling Method:	SONIC
Ground Surface Elevation:	1026.7
Coordinates:	UTM 11 N:568342m, E:5609705m
Datum:	1022

Remarks:

SAMPLE TYPES

SPT | Grab Sample

WATER LEVELS (m)

At Time of Drilling 7.62

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 100.6-1

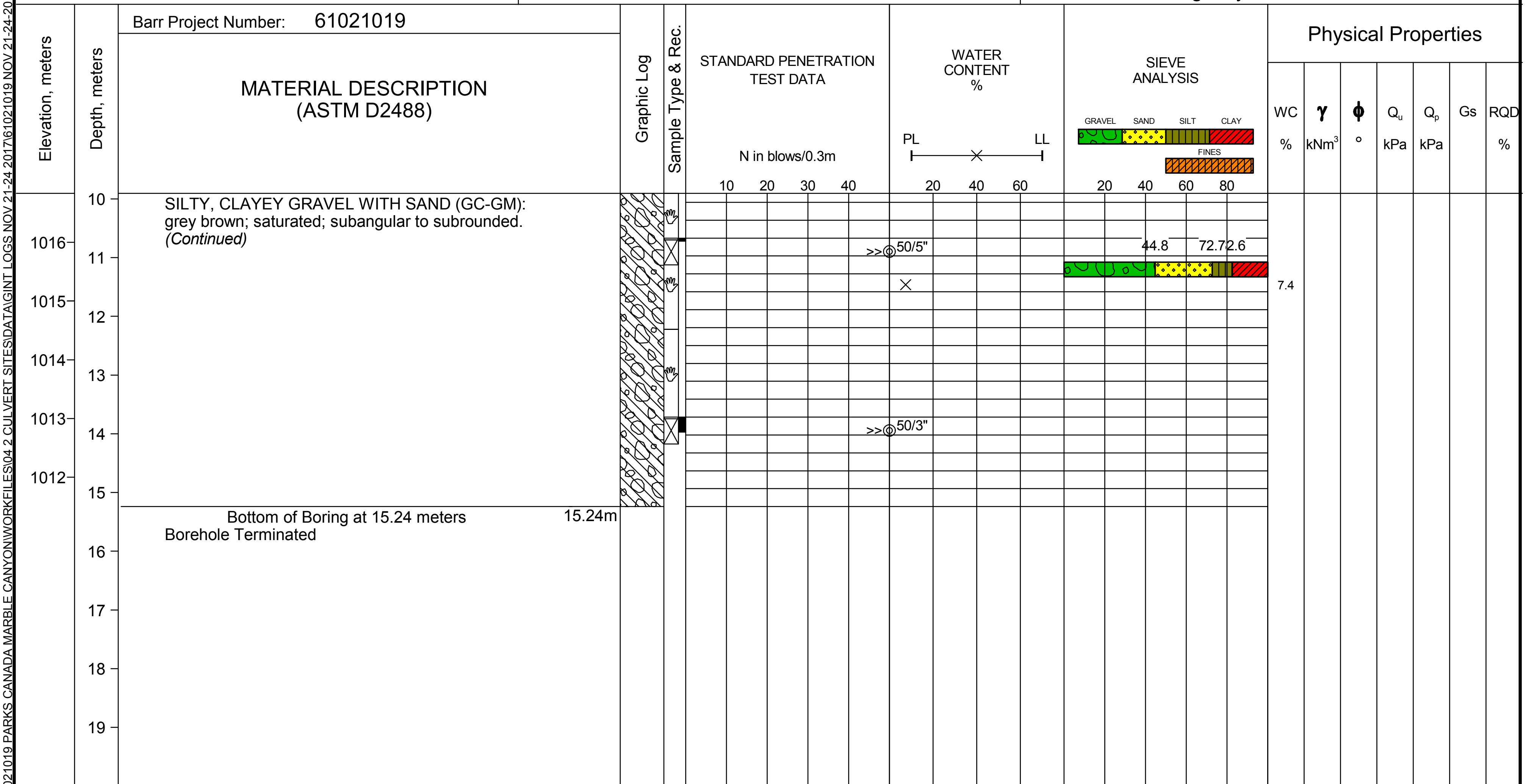
Project: Highway 93S Culvert Replacement at 95.6 km & 100.6 km

Location: Highway 93S, BC

Client: Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

MATERIAL DESCRIPTION (ASTM D2488)



SILTY, CLAYEY GRAVEL WITH SAND (GC-GM): grey brown; saturated; subangular to subrounded. *(Continued)*

Bottom of Boring at 15.24 meters
Borehole Terminated

Completion Depth:	15.2
Date Boring Started:	21/11/17
Date Boring Completed:	23/11/17
Logged By:	MGP3
Drilling Contractor:	Mobile Augers
Drilling Method:	SONIC
Ground Surface Elevation:	1026.7
Coordinates:	UTM 11 N:568342m, E:5609705m
Datum:	1022

Remarks:

SAMPLE TYPES

SPT   Grab Sample

WATER LEVELS (m)

At Time of Drilling 7.62

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 100.6-2

Project: Highway 93S Culvert Replacement at 95.6 km & 100.6 km

Location: Highway 93S, BC

Client: Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1031.31 m

Depth, meters	Material Description	Boundary depth
0	POORLY GRADED GRAVEL WITH SILTY CLAY AND SAND (GP-GC): dark brown; moist; subangular; possible fill; Organic chunks present.	
1.52	GRAVILY SILT WITH SAND AND ORGANICS (GC-GM): brown; wet to saturated; angular; End of fill material.	1.52m
2.29	LEAN CLAY WITH SAND (CL): brown; wet to saturated; sub-plastic. - Culvert Overt. Large chunks of bark and trees. - Culvert Invert.	2.29m
7.62	POORLY GRADED GRAVEL WITH SILTY CLAY AND SAND (GP-GC): light brown; saturated; subangular.	7.62m
9.14	SILTY, CLAYEY SAND WITH GRAVEL (SC-SM): light brown; saturated; subangular.	9.14m
	Bottom of Boring at 9.14 meters Borehole Terminated	

Elevation, meters: 1031, 1030, 1029, 1028, 1027, 1026, 1025, 1024, 1023

Depth, meters: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Graphic Log | Sample Type & Rec.

STANDARD PENETRATION TEST DATA — N in blows/0.3m (10, 20, 30, 40)

WATER CONTENT % — PL, LL (20, 40, 60)

SIEVE ANALYSIS — GRAVEL, SAND, SILT, CLAY, FINES (20, 40, 60, 80)

Physical Properties: WC %, γ kNm³, ϕ °, Q_u kPa, Q_p kPa, Gs, RQD %

Depth (approx.)	SPT N	PL	LL	Sieve analysis	WC %	γ kNm³	ϕ °
~1.0 m	27			74.4, 94.6	3.2		
~1.8 m	20			33.4, 66, 86.1	7.8		
~2.5 m	11	17	33	11.9, 28.2, 61.7	16.9	17.7	32.3
~3.2 m	8						
~4.9 m		18	35		22.7	17.7	
~7.7 m	>>50/5"			53.4, 82, 94.5	8.2		
~9.2 m	>>50/4"			39.1, 81.3	8.8		

Completion Depth:	9.1
Date Boring Started:	23/11/17
Date Boring Completed:	23/11/17
Logged By:	MGP3
Drilling Contractor:	Mobile Augers
Drilling Method:	SONIC
Ground Surface Elevation:	1031.3
Coordinates:	UTM 11 N:568417m, E:5609707m
Datum:	1022

Remarks:

SAMPLE TYPES: SPT; Grab Sample; 3-inch Shelby Tube

WATER LEVELS (m): At Time of Drilling 7.62

LEGEND:
MC Moisture Content
γ Dry Unit Weight
ϕ Friction Angle
Q_u Unconfined Compression
Q_p Hand Penetrometer UC
Gs Specific Gravity
RQD Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 100.6-3

Project: Highway 93S Culvert Replacement at 95.6 km & 100.6 km

Location: Highway 93S, BC

Client: Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

Surface Elev.: 1035.89 m

Elevation, meters	Depth, meters	MATERIAL DESCRIPTION (ASTM D2488)	Standard Penetration Test Data (N in blows/0.3m)	WC %
	0	POORLY GRADED GRAVEL WITH SILTY CLAY AND SAND (GP-GC): brown/light brown; moist; subangular; possible fill; Pink and red grains present. Evidence of oxidation.		
1035	1		>>50/5"	3.9
1034	2		>>50/1"	
		End of fill material.	>>50/5"	5.4
1033	3		>>50/1"	
1032	4	- Culvert Overt.		
1031	5	4.57m SILTY, CLAYEY GRAVEL WITH SAND (GC-GM): brown/light brown; saturated; subangular.	>>50/5"	8.5
1030	6	- Culvert Invert.	>>50/4"	
1029	7			
1028	8		>>69	7.5
1027	9			
		9.14m Bottom of Boring at 9.14 meters Borehole Terminated	>>50/5"	

Column headings: Graphic Log; Sample Type & Rec.; STANDARD PENETRATION TEST DATA (N in blows/0.3m: 10, 20, 30, 40); WATER CONTENT % (PL, LL: 20, 40, 60); SIEVE ANALYSIS (GRAVEL, SAND, SILT, CLAY, FINES: 20, 40, 60, 80); Physical Properties: WC %, γ kNm³, ϕ °, Q_u kPa, Q_p kPa, Gs, RQD %

Completion Depth: 9.1
Date Boring Started: 23/11/17
Date Boring Completed: 24/11/17
Logged By: MGP3
Drilling Contractor: Mobile Augers
Drilling Method: SONIC
Ground Surface Elevation: 1035.9
Coordinates: UTM 11 N:568469m, E:5609698m
Datum: 1022

Remarks:

SAMPLE TYPES
SPT
Grab Sample

WATER LEVELS (m)
At Time of Drilling 4.57

LEGEND
MC Moisture Content
γ Dry Unit Weight
ϕ Friction Angle
Q_u Unconfined Compression
Q_p Hand Penetrometer UC
Gs Specific Gravity
RQD Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 95.6-1

Sheet 1 of 1

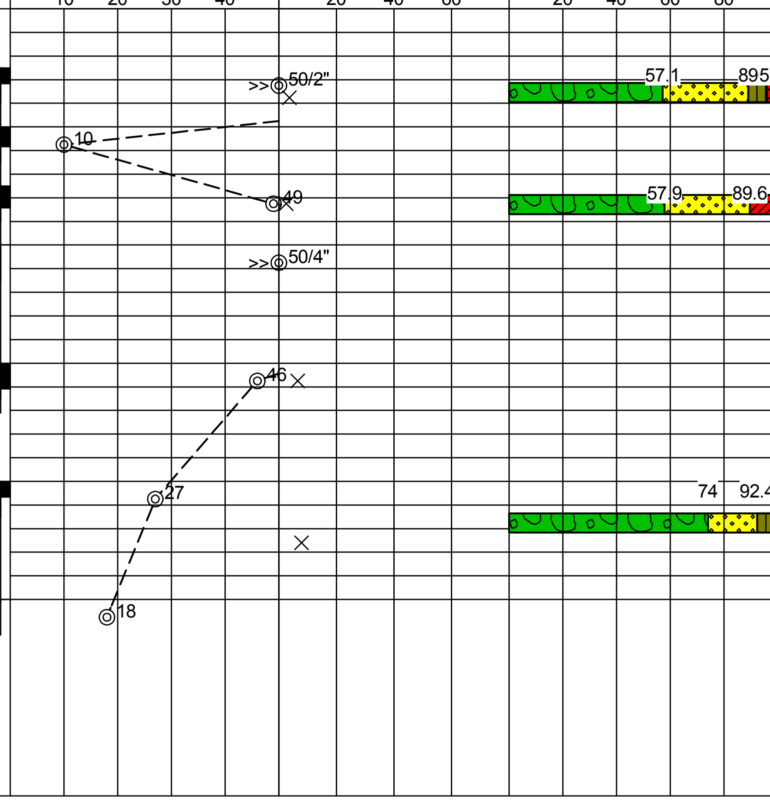
Project:	Highway 93S Culvert Replacement at 95.6 km & 100.6 km	Location:	Highway 93S, BC	Client:	Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

Surface Elev.: 1251.55 m

Elevation, meters	Depth, meters	MATERIAL DESCRIPTION (ASTM D2488)		WC %	γ kNm³	ϕ °	Q_u kPa	Q_p kPa	Gs	RQD %
	0	WELL-GRADED GRAVEL WITH SILTY CLAY AND SAND (GW-GC): light grey to brown; moist; angular to subangular; possible fill; Evidence of oxidation.								
1251	1			3.7	19	37.5				
1250	2									
1249				2.5						
	3	End of fill material.								
1248	4	- Culvert Overt.								
1247		POORLY GRADED GRAVEL WITH SILTY CLAY AND SAND (GP-GC): brown-light brown; moist to wet; angular to subangular. - Culvert Invert.	4.57m	6.6						
1246	5									
1245	6									
1244	7			7.9						
	8	Bottom of Boring at 7.62 meters Borehole Terminated	7.62m							
	9									

Graphic Log | Sample Type & Rec.



Completion Depth:	7.6
Date Boring Started:	24/11/17
Date Boring Completed:	24/11/17
Logged By:	MGP3
Drilling Contractor:	Mobile Augers
Drilling Method:	SONIC
Ground Surface Elevation:	1251.6
Coordinates:	UTM 11 N:572803m, E:5610964m
Datum:	1022

Remarks:

SAMPLE TYPES

SPT   Grab Sample

WATER LEVELS (m)

At Time of Drilling 4.57

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Barr Engineering and Environmental Science Canada Ltd.
808 4th Ave SW Suite 700
Calgary, AB T2P 3E8
Telephone: 403-592-8300

LOG OF BORING 95.6-2

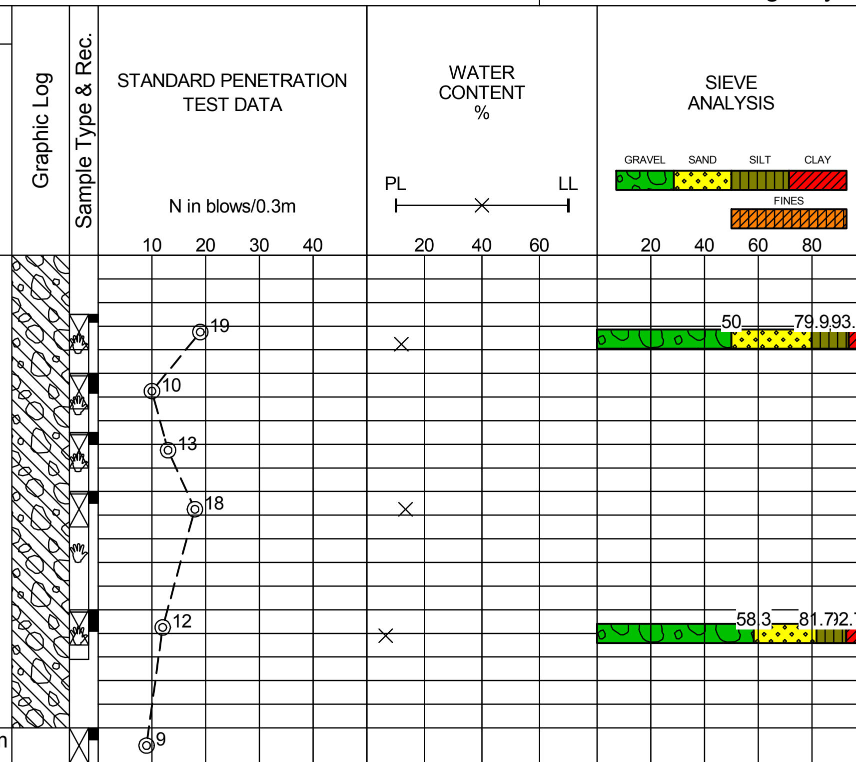
Project: Highway 93S Culvert Replacement at 95.6 km & 100.6 km | Location: Highway 93S, BC | Client: Highway Engineering Services - Parks Canada Agency

Barr Project Number: 61021019

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1251.30 m

Elevation, meters	Depth, meters	Material Description
1251	0	SILTY, CLAYEY GRAVEL WITH SAND (GC-GM): brown; moist; subangular to subrounded; possible fill; Evidence of oxidation.
1250	1	End of fill material.
1249	2	Saturated. - Culvert Overt.
1248	3	Grass and black organics present.
1247	4	Boulder from 3.7 m to 4.4 m. - Culvert Invert.
1246	5	
	6	Bottom of Boring at 6.10 meters 6.10m Borehole Terminated
	7	
	8	
	9	



Physical Properties						
WC %	γ kNm³	ϕ °	Q_u kPa	Q_p kPa	Gs	RQD %
12						
13.5						
6.5						

Completion Depth:	6.1
Date Boring Started:	24/11/17
Date Boring Completed:	24/11/17
Logged By:	MGP3
Drilling Contractor:	Mobile Augers
Drilling Method:	SONIC
Ground Surface Elevation:	1251.3
Coordinates:	UTM 11 N:572697m, E:5610912m
Datum:	1022

Remarks:

SAMPLE TYPES

SPT Grab Sample

WATER LEVELS (m)

At Time of Drilling 2.29

LEGEND

MC Moisture Content
γ Dry Unit Weight
ϕ Friction Angle
Q_u Unconfined Compression
Q_p Hand Penetrometer UC
Gs Specific Gravity
RQD Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Appendix C

Laboratory Test Summary and Results

Test Result Summary for borings at km95.6

Boring	Sample #	Top of Sample (ft)	Sample Length (ft)	Bottom of Sample (ft)	Top of Sample (m)	Sample Length (m)	Bottom of Sample (m)	Recovery (in)	Type	SPT Data	USCS Classification	Bulk Density (Kg/m^3)	Dry Density (Kg/m^3)	Bulk Unit Weight (kN/m^3)	Dry Unit Weight (kN/m^3)	Moisture (%)	Atterbergs %			Sieve Data										Consolidation Test			UCS		Cohesion (kPa)	Angle of internal Friction, ϕ (deg)	Tan(ϕ)	pH	ER (ohms-meter)	SO$_4$ mg/L	Cl mg/L	Organic Content (%)	Max Dry Density (kg/m3)	Opt WC (%)
										N Value							PL	LL	PI	Gravel	Sand	Silt	Clay	Fines	D10	D30	D60	Cu	Cc	Compression Index,Cc (kpa)	Pp (kpa)	Pp (e)	Corrected Stength (Mpa)	Corrected Stength (tsf)										
	28	2.5	1.5	4.0	0.8	0.5	1.2	8	SS	50/2"	GW-GC																																	
	28A	2.5	5.0	7.5	0.8	1.5	2.3	30	SONIC		GW-GC	2012	1940.2	19.7	19.0	3.7				57.10	31.90	6.90	4.10	11.00	0.06	1.48	18.52	336.64	2.14						20.0	37.5	0.77						2335	5.1
	29	5.0	1.5	6.5	1.5	0.5	2.0	10	SS	10	GW-GC																																	
	30	7.5	1.5	9.0	2.3	0.5	2.7	11	SS	49	GW-GC					2.5				57.90	31.70		10.40	10.40	--	1.97	8.57																	
95.6-1	31	10.0	1.5	11.5	3.0	0.5	3.5	0	SS	50/4"	GW-GC																																	
	32	15.0	1.5	16.5	4.6	0.5	5.0	13	SS	46	GP-GC					6.6																												
	33	20.0	1.5	21.5	6.1	0.5	6.6	8	SS	27	GP-GC																																	
	33A	20.0	5.0	25.0	6.1	1.5	7.6	60	SONIC		GP-GC					7.9				74.00	18.40	5.30	2.30	7.60	0.23	6.57	20.62	89.65	9.10															
	34	25.0	1.5	26.5	7.6	0.5	8.1	0	SS	18	GP-GC																																	
	35	2.5	1.5	4.0	0.8	0.5	1.2	4	SS	19	GC-GM																																	
	35A	2.5	5.0	7.5	0.8	1.5	2.3	60	GRAB		GC-GM					12.0				50.00	29.90	13.80	6.30	20.10	0.01	0.55	9.27	1041.57	3.67														2137	7.7
	36	5.0	1.5	6.5	1.5	0.5	2.0	10	SS	10	GC-GM																																	
	37	7.5	1.5	9.0	2.3	0.5	2.7	6	SS	13	GC-GM																																	
95.6-2	38	10.0	1.5	11.5	3.0	0.5	3.5	6	SS	18	GC-GM					13.5																						7.76		203.00	1371.00	1.7		
	39	15.0	1.5	16.5	4.6	0.5	5.0	11	SS	12	GC-GM																																	
	39A	15.0	5.0	20.0	4.6	1.5	6.1	60	SONIC		GC-GM					6.5				58.30	23.40	11.00	7.30	18.30	0.01	2.20	8.37	837.00	57.83	0.13	81.0	0.274											2107	7.9
	40	20.0	1.5	21.5	6.1	0.5	6.6	6	SS	9	GC-GM																																	

Test Result Summary for borings at 100.6km

	1	2.5	1.5	4.0	0.8	0.5	1.2	5	SS	50/5"	GP-GC																																	
	1B	2.5	2.5	5.0	0.8	0.8	1.5	30	GRAB		GP-GC					4.1				63.30	28.10	5.70	2.90	8.60	0.13	3.03	17.91	142.14	4.07														2358	5.5
	2	5.0	1.5	6.5	1.5	0.5	2.0	11	SS	16	GP-GC																																	
	3	7.5	1.5	9.0	2.3	0.5	2.7	3	SS	25	GP-GC																																	
	3A	7.5	2.5	10.0	2.3	0.8	3.0	30	SONIC		GP-GC	2002	1970.5	19.6	19.3	1.6	20	43	23	76.90	16.00	5.40	1.70	7.10	0.20	8.05	26.11	127.99	12.17						32.8	34.6	0.69	8.65		21.00	114.00			
	4	10.0	1.5	11.5	3.0	0.5	3.5	12	SS	20	GP-GC																																	
	5	12.5	1.5	14.0	3.8	0.5	4.3	13	SS	38	GP-GC																																	
	6	15.0	1.5	16.5	4.6	0.5	5.0	6	SS	50/5"	GP-GC																																	
100.6-1	6A	15.0	2.5	17.5	4.6	0.8	5.3	30	SONIC		GP-GC	2047	1995.1	20.1	19.6	2.6				72.40	20.00	5.30	2.30	7.60	0.22	5.86	24.40	110.91	6.40						13.9	35.0	0.70							
	7	17.5	1.5	19.0	5.3	0.5	5.8	7	SS	50/2"	GP-GC																																	
	8	20.0	1.5	21.5	6.1	0.5	6.6	8	SS	50/5"	GP-GC					2.7																												
	9	25.0	1.5	26.5	7.6	0.5	8.1	8	SS	80/11"	GP-GC																																	
	9A	25.0	5.0	30.0	7.6	1.5	9.1	60	SONIC		GC-GM	2130	1966.8	20.9	19.3	8.3				60.00	27.90	6.70	5.40	12.10	0.04	1.32	14.25	407.14	3.49	0.12	0.0				39.5	35.9	0.72						2389	4.9
	10	30.0	1.5	31.5	9.1	0.5	9.6	10	SS	50/4"	GC-GM																																	
	11	35.0	1.5	36.5	10.7	0.5	11.1	2	SS	50/5"	GC-GM																																	
	11A	35.0	5.0	40.0	10.7	1.5	12.2	60	SONIC		GC-GM					7.4				44.80	27.90	9.90	17.40	27.30	--	0.19	6.38																	
	12	45.0	1.5	46.5	13.7	0.5	14.2	10	SS	50/3"	GC-GM																																	
	13	2.5	1.5	4.0	0.8	0.5	1.2	12	SS	27	GP-GC																																	
	13A	2.5	2.5	5.0	0.8	0.8	1.5	30	SONIC		GP-GC					3.2				74.40	20.20			5.40	0.38	6.52	26.17	69.79	4.33															
	14	5.0	1.5	6.5	1.5	0.5	2.0	11	SS	20	GP-GC																																	
	14A	5.0	2.5	7.5	1.5	0.8	2.3	30	SONIC		GC-GM					7.8				33.40	32.60	20.10	13.90	34.00	0.00	0.04	2.76	920.00	0.19															
	15	7.5	1.5	9.0	2.3	0.5	2.7	8	SS	11	GC-GM																																	
100.6-2	15A	7.5	2.5	10.0	2.3	0.8	3.0	30	SONIC		CL	2114	1808.4	20.7	17.7	16.9	17	33	16	11.90	16.30	33.50	38.30	71.80	--	0.00	0.03								10.1	32.3	0.63	8.72		24.00	85.00			
	16	10.0	1.5	11.5	3.0	0.5	3.5	7	SS	8	CL																																	
	17	15.0	2.0	17.0	4.6	0.6	5.2	14	3T		CL	2127	1733.5	20.9	17.0	22.7	18	35	17											0.06	48.0	0.542										0.6		
	18	25.0	1.5	26.5	7.6	0.5	8.1	3	SS	50/5"	GP-GC																																	
	18A	25.0	5.0	30.0	7.6	1.5	9.1	60	SONIC		GP-GC					8.2				53.40	28.60	12.50	5.50	18.00	0.02	1.02	8.20	546.67	8.46	0.11	16.0	0.371											2169	8.3
	19	30.0	1.5	31.5	9.1	0.5	9.6	11	SS	50/4"	SC-SM					8.8				39.10	42.20			18.70	--	0.48	4.53																	
	20	2.5	1.5	4.0	0.8	0.5	1.2	6	SS	50/5"	GP-GC					3.9																												
	21	5.0	1.5	6.5	1.5	0.5	2.0	0	SS	50/1"	GP-GC																																	
	22	7.5	1.5	9.0	2.3	0.5	2.7	11	SS	50/5"	GP-GC					5.4																												
100.6-3	23	10.0	1.5	11.5	3.0	0.5	3.5	0	SS	50/1"	GP-GC																																	
	24	15.0	1.5	16.5	4.6	0.5	5.0	12	SS	50/5"	GC-GM					8.5																						8.62		19.00	8.00			
	25	20.0	1.5	21.5	6.1	0.5	6.6	4	SS	50/4"	GC-GM																																	
	26	25.0	1.5	26.5	7.6	0.5	8.1	10	SS	69	GC-GM					7.5																												
	27	30.0	1.5	31.5	9.1	0.5	9.6	6	SS	50/5"	GC-GM																																	

SOLUM
CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo-Lab Report

December 20, 2017

Barr Eng.
808 4th Ave. SW, Suite 700
Calgary, AB T2P 3E8

Attention: **Imran Shah**
Project No.: **61021019.00**
Project Name: **Geo. Inv. For Culvert Sites**
Solum Job No.: **08201171201(196)**

Sample Received on: December 1, 2017
# of Sample Rec'd: 8 pails, 1 ST

Test	Quantity	ASTM Designation
Moisture Content	23	D2216
Atterberg Limits	3	D4318
Particle-Size Analysis (Full Gradation)	12	D422(withdrawn 2016)
Greater Than No. 200 Sieve Analysis	3	C136
Standard Proctor - Method C	6	D698
Bulk Density	1	D2937
1-D Consolidation	4	D2435
CD Direct Shear Test (Coarse)	5	D3080
CBR (Soaked)	3	D1883
pH	4	G51
Water Soluble Sulphates & Chlorides	4	N/A
Organic Content (method C)	2	D2974

Saad A.M. Farag
Principal

9, 3620-29 Street NE,Calgary, AB T1Y 5Z8
ph:(403)250-3035 Fax:(403)250-3021 Email: solum@mymts.net

Laboratory Analysis Summary

SOLUM CONSULTANTS LTD.

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Project Number:	61021019.00
Client:	Barr Eng.
Project Name:	Geo. Inv. For Culvert Sites
Location:	Kootenay National Park
Tested By:	KC/SF
Reviewed By:	
Date Reviewed:	20-Dec-17 (dd-mm-yy)
Solum Job No.:	08201171201(196)

Results (Page 1)

Borehole ID	Sample ID	Organic Content(%)	Atterberg Limits				Particle Size Analysis					Soil Classification** Group Symbols	Bulk Density (kg/m^3)
			Liquid Limit(%)	Plastic Limit(%)	Plastic Index(%)	Classification* (USCS)	Cobble Size (%) (75-300mm)	Gravel Size (%) (4.75-75mm)	Sand Size (%) (0.075-4.5mm)	Silt Size (%) (0.005-0.075 mm)	Clay Size (%) (<0.005mm)		
100.6-1	1B	---	---	---	---	---	0.0	63.3	28.1	5.7	2.9	---	---
100.6-1	3A	---	43	20	23	CL	0.0	76.9	16.0	5.4	1.7	GC	---
100.6-1	6A	---	---	---	---	---	0.0	72.4	20.0	5.3	2.3	---	---
100.6-1	9A	---	---	---	---	---	0.0	60.0	27.9	6.7	5.4	---	---
100.6-1	11A	---	---	---	---	---	0.0	44.8	27.9	9.9	17.4	---	---
100.6-2	13A	---	---	---	---	---	0.0	74.4	20.2	5.4		---	---
100.6-2	14A	---	---	---	---	---	0.0	33.4	32.6	20.1	13.9	---	---
100.6-2	15A	---	33	17	16	CL	0.0	11.9	16.3	33.5	38.3	CL	---
100.6-2	17	0.6	35	18	17	CL	---	---	---	---	---	---	2127
100.6-2	18A	---	---	---	---	---	0.0	53.4	28.6	12.5	5.5	---	---

* Note: Soil classification is for material less than 0.425 mm (material used for Atterberg Limits), this includes the fine sand, silt and clay fraction of the sample.

** Note: Soil classification is for the whole sample. Soil classification uses the Atterberg Limits results and the percent fines, percent sand and percent gravel as described in ASTM D2487.

Laboratory Analysis Summary

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

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Project Number:	61021019.00
Client:	Barr Eng.
Project Name:	Geo. Inv. For Culvert Sites
Location:	Kootenay National Park
Tested By:	KC/SF
Reviewed By:	
Date Reviewed:	20-Dec-17 (dd-mm-yy)
Solum Job No.:	08201171201(196)

Results (Page 2)

Borehole ID	Sample ID	Organic Content(%)	Atterberg Limits				Particle Size Analysis					Soil Classification** Group Symbols
			Liquid Limit(%)	Plastic Limit(%)	Plastic Index(%)	Classification* (USCS)	Cobble Size (%) (75-300mm)	Gravel Size (%) (4.75-75mm)	Sand Size (%) (0.075-4.5mm)	Silt Size (%) (0.005-0.075 mm)	Clay Size (%) (<0.005mm)	
100.6-2	19	---	---	---	---	---	0.0	39.1	42.2	18.7		---
95.6-1	28A	---	---	---	---	---	0.0	57.1	31.9	6.9	4.1	---
95.6-1	30	---	---	---	---	---	0.0	57.9	31.7	10.4		---
95.6-1	33A	---	---	---	---	---	0.0	74.0	18.4	5.3	2.3	---
95.6-2	35A	---	---	---	---	---	0.0	50.0	29.9	13.8	6.3	---
95.6-2	38	1.7	---	---	---	---	---	---	---	---	---	---
95.6-2	39A	---	---	---	---	---	0.0	58.3	23.4	11.0	7.3	---

* Note: Soil classification is for material less than 0.425 mm (material used for Atterberg Limits), this includes the fine sand, silt and clay fraction of the sample.

** Note: Soil classification is for the whole sample. Soil classification uses the Atterberg Limits results and the percent fines, percent sand and percent gravel as described in ASTM D2487.

WSH Labs (1992) Ltd.

3851B – 21 Street NE • Calgary, Alberta, Canada • T2E 6T5

Phone: (403) 250-9164 • Fax: (403) 291-4597 • www.wshlabs.com

SOLUM Consultants Ltd.	**Phone:**	(403) 250-3035	**File Number:**	121417
#9, 3620 - 29 Street NE	**Fax:**	(403) 250-3021		
Calgary, AB T1Y 5Z8	**E-Mail:**	solum@mymts.net	**PO Number:**	

Project:	61021019.00	**Date Sampled:**	
	Solum #196	**Date Received:**	12/14/2017
Attention:	Saad A.M. Farag	**Date Reported:**	12/18/2011

RESULTS OF SOIL ANALYSIS

Lab Number	Sample ID	Sulphate (%)	Chloride (%)	pH (1:1)
R7796	100.6-1 3A 7.5'	0.0021	0.0114	8.65
R7797	100.6-2 15A 7.5'	0.0024	0.0085	8.72
R7798	100.6-3 24 15'	0.0019	0.0008	8.62
R7799	95.6-2 38 10'	0.0203	0.1371	7.76

WSH Labs (1992) Ltd. as per: KBW

The analysis is based on a 1:1 water/soil ratio unless otherwise noted. The results above are related only to the items analyzed.

Water (Moisture) Content (ASTM D2216)

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Tested By:	KC/SF	Reviewed By:	SF
Date Tested:	19-Dec-17	(dd-mmm-yy)	
Solum Job No.:	08201171201(196)		

Sample Information

Borehole ID	100.6-1	100.6-1	100.6-1	100.6-1	100.6-1	100.6-1
Sample ID	1B	3A	6A	8	9A	11A
Container ID	1	2	3	4	5	6
Wet Sample Weight +Tare (g)	274.78	189.58	235.40	181.17	173.91	329.97
Dry Sample Weight +Tare (g)	264.87	187.07	229.97	177.31	162.60	309.16
Weight of Water (g)	9.91	2.51	5.43	3.86	11.31	20.81
Tare (g)	23.70	26.84	24.95	36.34	26.88	27.10
Weight of Dry Soil (g)	241.17	160.23	205.02	140.97	135.72	282.06
Water Content (%)	4.1	1.6	2.6	2.7	8.3	7.4

Borehole ID	100.6-2	100.6-2	100.6-2	100.6-2	100.6-2	100.6-2
Sample ID	13A	14A	15A	17	18A	19
Container ID	7	8	9	10	11	12
Wet Sample Weight +Tare (g)	203.42	237.32	117.75	249.65	128.91	184.00
Dry Sample Weight +Tare (g)	197.87	222.18	104.70	213.53	120.92	171.22
Weight of Water (g)	5.55	15.14	13.05	36.12	7.99	12.78
Tare (g)	26.90	27.39	27.35	54.44	23.56	25.21
Weight of Dry Soil (g)	170.97	194.79	77.35	159.09	97.36	146.01
Water Content (%)	3.2	7.8	16.9	22.7	8.2	8.8

Borehole ID	100.6-3	100.6-3	100.6-3	100.6-3	95.6-1	95.6-1
Sample ID	20	22	24	26	28A	30
Container ID	13	14	15	16	17	18
Wet Sample Weight +Tare (g)	164.74	246.95	138.25	178.73	246.25	148.90
Dry Sample Weight +Tare (g)	159.54	235.67	129.47	167.92	238.49	146.01
Weight of Water (g)	5.20	11.28	8.78	10.81	7.76	2.89
Tare (g)	26.81	27.12	26.24	23.71	26.91	28.23
Weight of Dry Soil (g)	132.73	208.55	103.23	144.21	211.58	117.78
Water Content (%)	3.9	5.4	8.5	7.5	3.7	2.5

Borehole ID	95.6-1	95.6-1	95.6-2	95.6-2	95.6-2	
Sample ID	32	33A	35A	38	39A	
Container ID	19	20	21	22	23	
Wet Sample Weight +Tare (g)	214.85	123.77	191.00	199.12	132.59	
Dry Sample Weight +Tare (g)	203.17	116.72	173.45	178.42	126.12	
Weight of Water (g)	11.68	7.05	17.55	20.70	6.47	
Tare (g)	26.35	27.78	27.13	25.37	26.63	
Weight of Dry Soil (g)	176.82	88.94	146.32	153.05	99.49	
Water Content (%)	6.6	7.9	12.0	13.5	6.5	

Atterberg Limits (ASTM D4318) - Method A

SOLUM™ CONSULTANTS LTD.

GEOTECHNICAL & MATERIAL TESTING LABORATORY

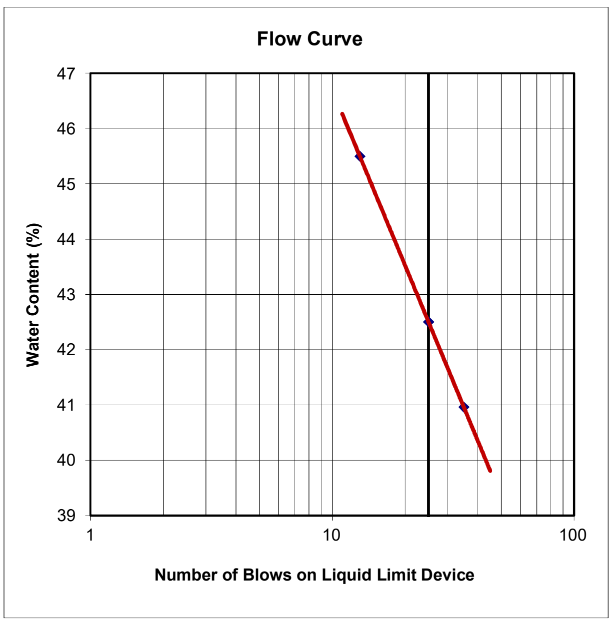
Project Number:	61021019.00
Project Name:	Geo. Inv. For Culvert Sites
Location:	Kootenay National Park
Borehole ID:	100.6-1
Sample ID	3A
Depth:	7.5'
Tested By:	KC
Reviewed By:	SF
Date Tested:	19-Dec-17 (dd-mmm-yy)
Solum Job No.:	08201171201(196)

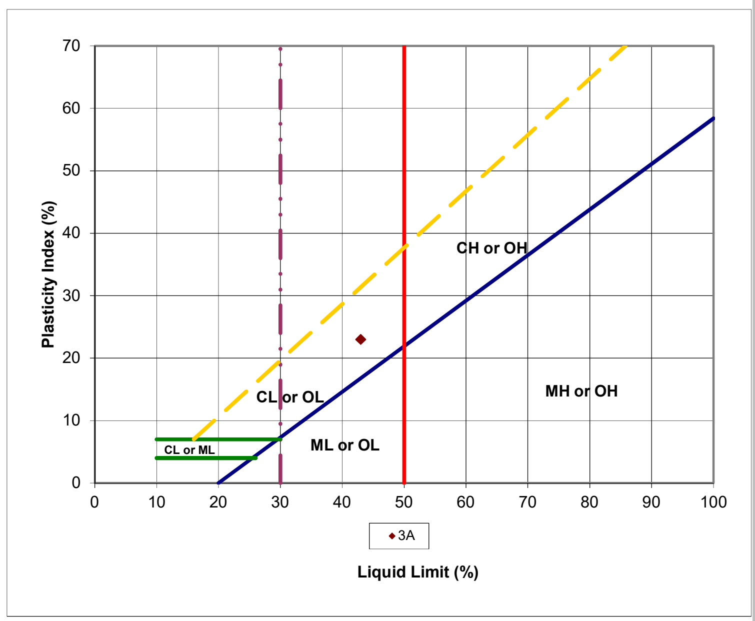
Sample Information

	Liquid Limit (Air Dried) - Multipoint Method			Liquid Limit (Oven Dried)	
Container ID	1	2	3		
Number of Blows	13	25	35		
Wet Sample Weight +Tare (g)	28.92	29.25	30.47		
Dry Sample Weight +Tare (g)	23.16	24.29	25.01		
Weight of Water (g)	5.76	4.96	5.46		
Tare (g)	10.50	12.62	11.68		
Weight of Dry Soil (g)	12.66	11.67	13.33		
Water Content (%)	45.5	42.5	41.0		

	Plastic Limit	
Container ID	4	5
Wet Sample Weight +Tare (g)	25.04	26.04
Dry Sample Weight +Tare (g)	23.26	23.91
Weight of Water (g)	1.78	2.13
Tare (g)	14.41	13.26
Weight of Dry Soil (g)	8.85	10.65
Water Content (%)	20.1%	20.0%
Average Water Content (%)	20.1	

Results	
Liquid Limit (Air Dried) (%)	43
Liquid Limit (Oven Dried) (%)	---
LL % Difference	---
Plastic Limit (%)	20
Plasticity Index (%)	23
-40 Mesh Sieve (y/n)	y
Unified Soil Classification System	CL





Atterberg Limits (ASTM D4318) - Method A

SOLUM™ CONSULTANTS LTD.

GEOTECHNICAL & MATERIAL TESTING LABORATORY

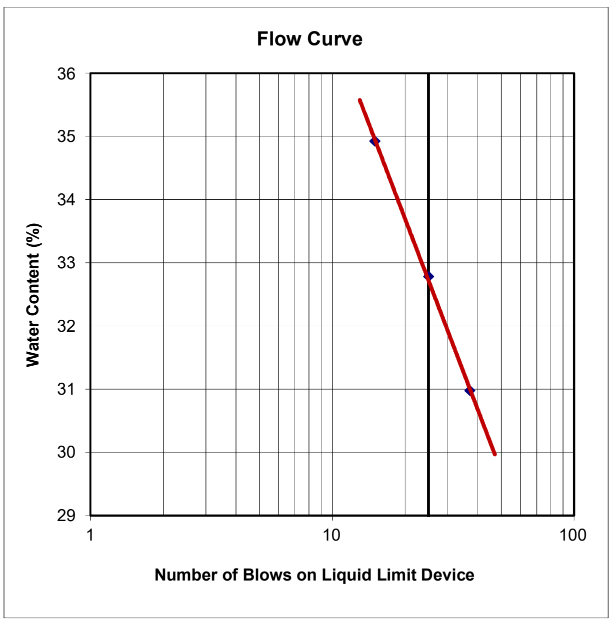
Project Number:	61021019.00		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Borehole ID:	100.6-2		
Sample ID	15A	Depth:	7.5'
Tested By:	KC	Reviewed By:	SF
Date Tested:	19-Dec-17	(dd-mmm-yy)	
Solum Job No.:	08201171201(196)		

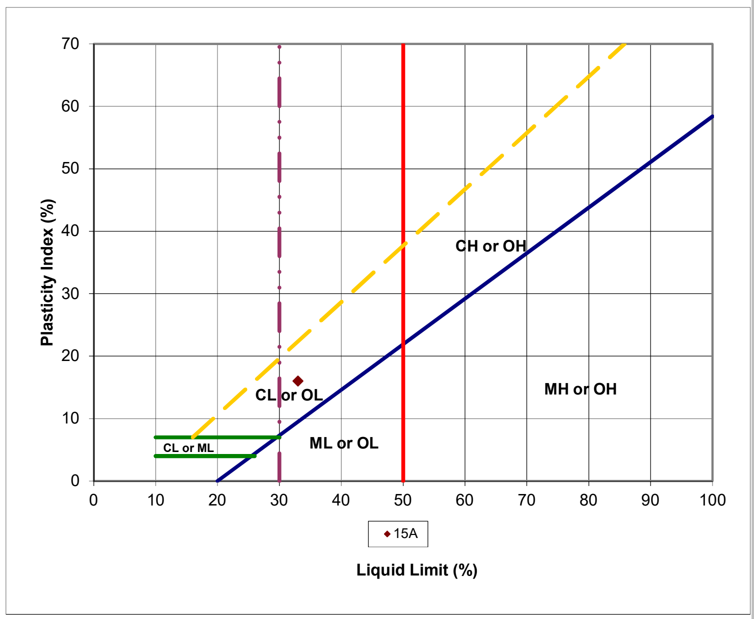
Sample Information

	Liquid Limit (Air Dried) - Multipoint Method			Liquid Limit (Oven Dried)	
Container ID	1	2	3		
Number of Blows	15	25	37		
Wet Sample Weight +Tare (g)	33.49	31.98	32.92		
Dry Sample Weight +Tare (g)	27.85	27.20	28.10		
Weight of Water (g)	5.64	4.78	4.82		
Tare (g)	11.70	12.62	12.54		
Weight of Dry Soil (g)	16.15	14.58	15.56		
Water Content (%)	34.9	32.8	31.0		

	Plastic Limit	
Container ID	4	5
Wet Sample Weight +Tare (g)	24.69	28.51
Dry Sample Weight +Tare (g)	23.27	26.30
Weight of Water (g)	1.42	2.21
Tare (g)	14.92	13.26
Weight of Dry Soil (g)	8.35	13.04
Water Content (%)	17.0%	16.9%
Average Water Content (%)	17.0	

Results	
Liquid Limit (Air Dried) (%)	33
Liquid Limit (Oven Dried) (%)	---
LL % Difference	---
Plastic Limit (%)	17
Plasticity Index (%)	16
-40 Mesh Sieve (y/n)	y
Unified Soil Classification System	CL





Atterberg Limits (ASTM D4318) - Method A

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

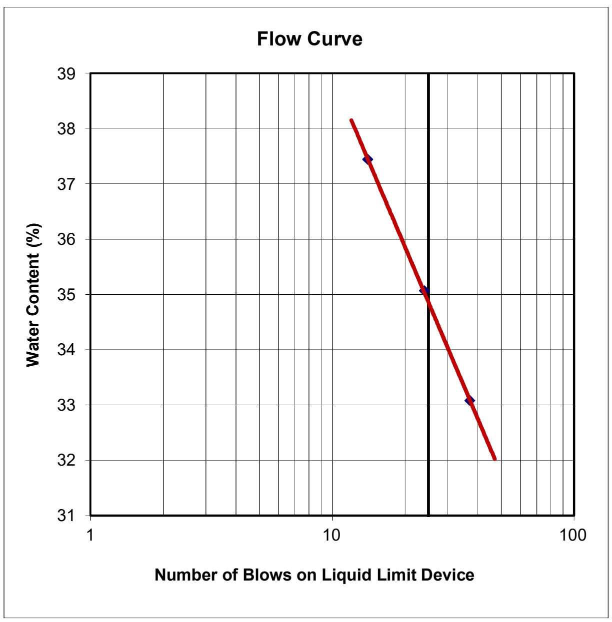
Project Number:	61021019.00		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Borehole ID:	100.6-2		
Sample ID	17	Depth:	15'
Tested By:	KC	Reviewed By:	SF
Date Tested:	19-Dec-17	(dd-mmm-yy)	
Solum Job No.:	08201171201(196)		

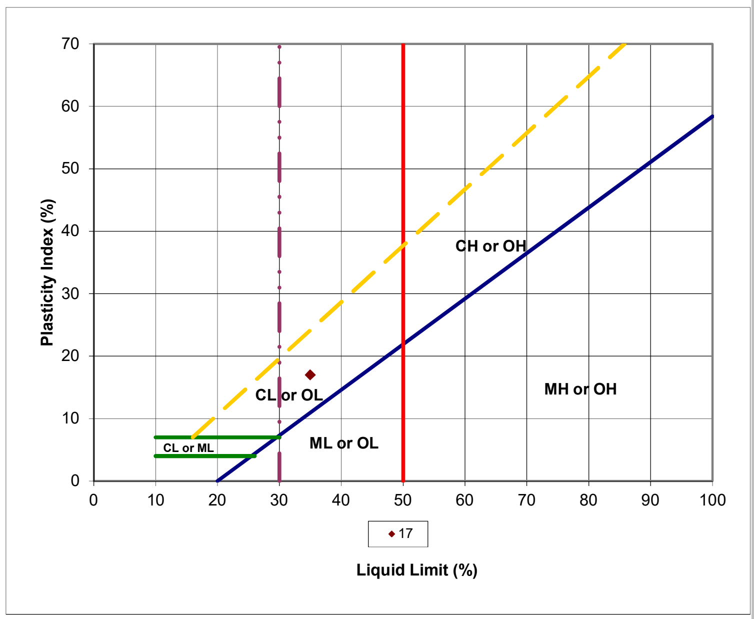
Sample Information

	Liquid Limit (Air Dried) - Multipoint Method			Liquid Limit (Oven Dried)	
Container ID	1	2	3		
Number of Blows	14	24	37		
Wet Sample Weight +Tare (g)	29.97	30.43	29.95		
Dry Sample Weight +Tare (g)	25.11	26.05	25.15		
Weight of Water (g)	4.86	4.38	4.80		
Tare (g)	12.13	13.56	10.64		
Weight of Dry Soil (g)	12.98	12.49	14.51		
Water Content (%)	37.4	35.1	33.1		

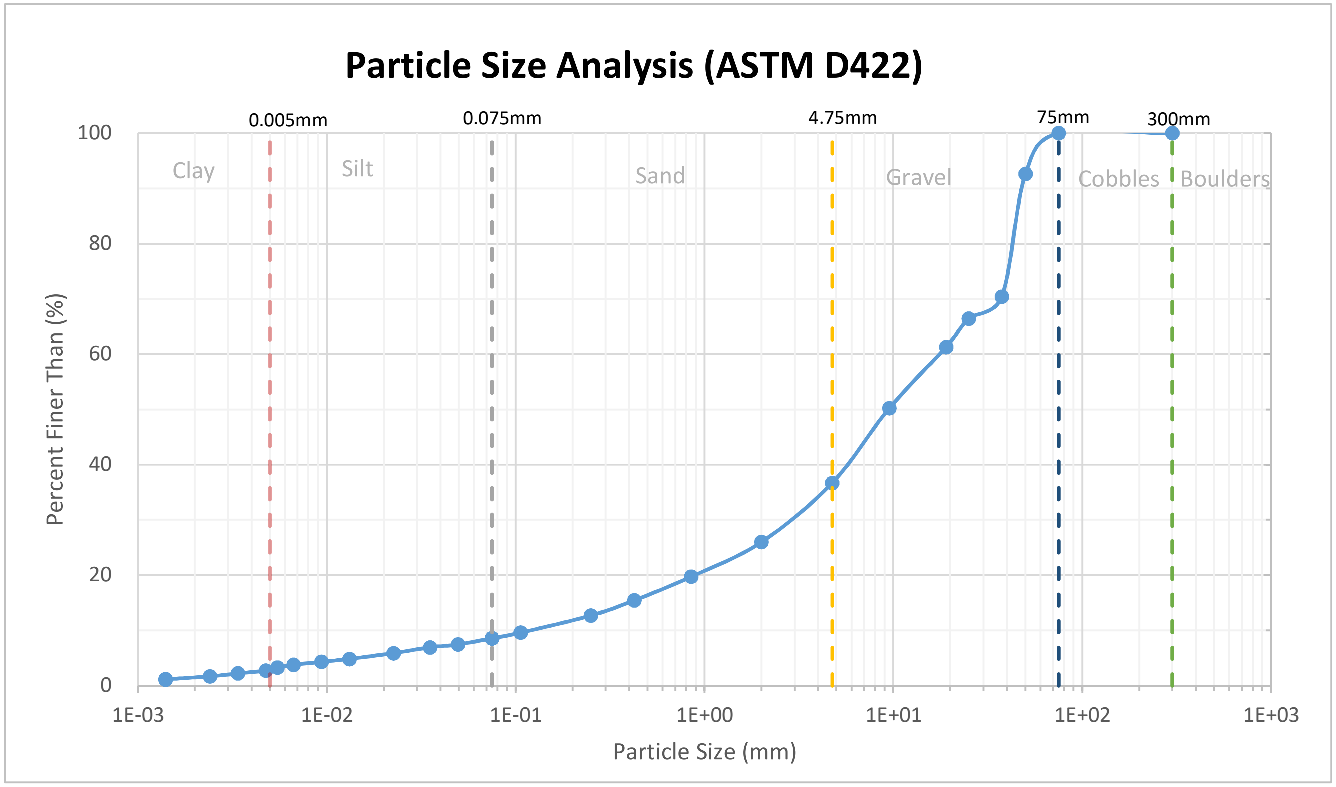
	Plastic Limit	
Container ID	4	5
Wet Sample Weight +Tare (g)	24.60	26.81
Dry Sample Weight +Tare (g)	23.11	24.73
Weight of Water (g)	1.49	2.08
Tare (g)	14.81	13.23
Weight of Dry Soil (g)	8.30	11.50
Water Content (%)	18.0%	18.1%
Average Water Content (%)	18.0	

Results	
Liquid Limit (Air Dried) (%)	35
Liquid Limit (Oven Dried) (%)	---
LL % Difference	---
Plastic Limit (%)	18
Plasticity Index (%)	17
-40 Mesh Sieve (y/n)	y
Unified Soil Classification System	CL





SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	92.63
1.5"	37.500	70.41
1"	25.000	66.44
0.75"	19.000	61.27
0.375"	9.500	50.19
No. 4	4.750	36.70
No. 10	2.000	25.98
No. 20	0.850	19.71
No. 40	0.425	15.44
No. 60	0.250	12.67
No. 140	0.106	9.57
No. 200	0.075	8.56
HYDROMETER	0.0495	7.45
	0.0352	6.92
	0.0225	5.87
	0.0132	4.82
	0.0094	4.30
	0.0067	3.77
	0.0055	3.25
	0.0048	2.72
	0.0034	2.19
	0.0024	1.67
	0.0014	1.14



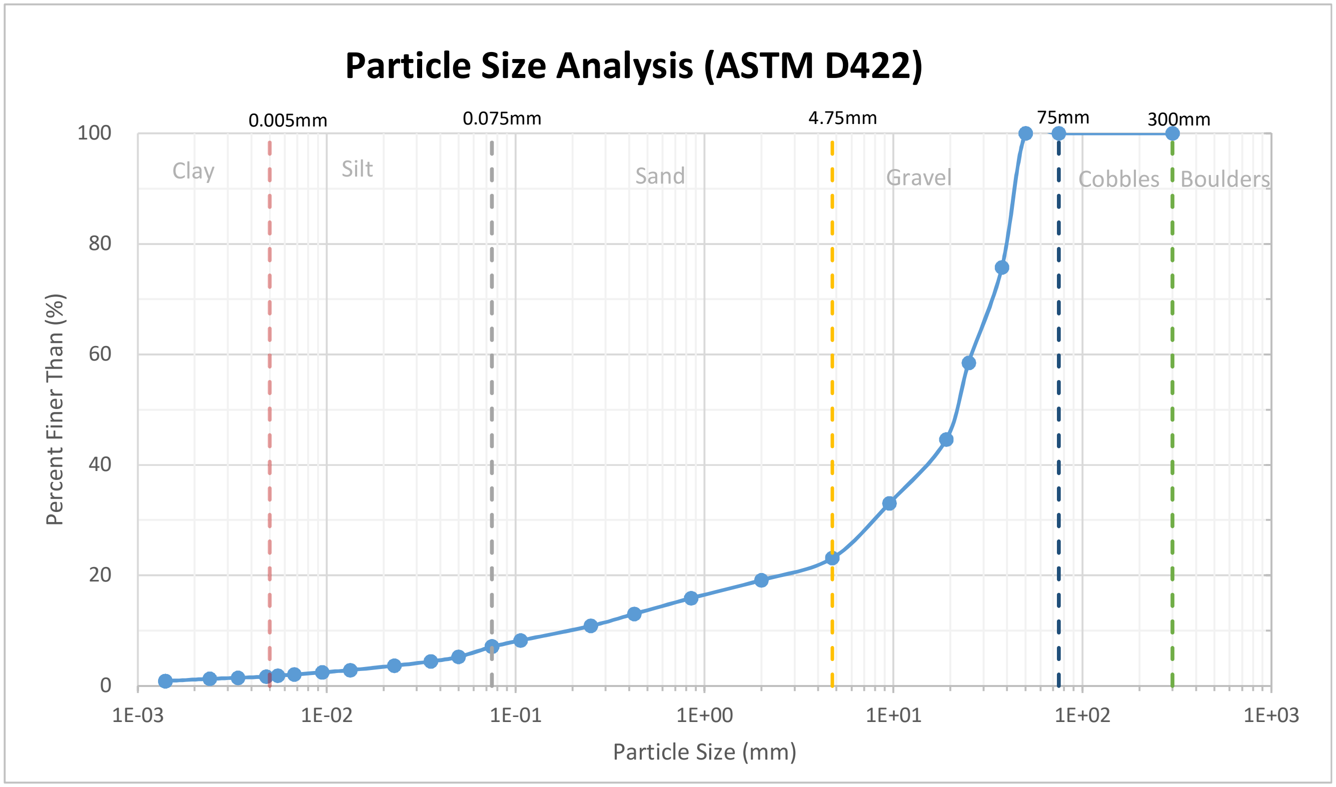
SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-1***
Sample ID:	***1B***
Depth:	***2.5'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	63.3
Sand:	28.1
Silt:	5.7
Clay:	2.9

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	75.73
1"	25.000	58.47
0.75"	19.000	44.58
0.375"	9.500	33.03
No. 4	4.750	23.11
No. 10	2.000	19.12
No. 20	0.850	15.87
No. 40	0.425	13.03
No. 60	0.250	10.84
No. 140	0.106	8.21
No. 200	0.075	7.12
HYDROMETER	0.0498	5.23
	0.0356	4.43
	0.0228	3.64
	0.0133	2.85
	0.0095	2.45
	0.0067	2.05
	0.0055	1.86
	0.0048	1.66
	0.0034	1.46
	0.0024	1.26
	0.0014	0.86



Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-1***
Sample ID:	***3A***
Depth:	***7.5'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	76.9
Sand:	16.0
Silt:	5.4
Clay:	1.7

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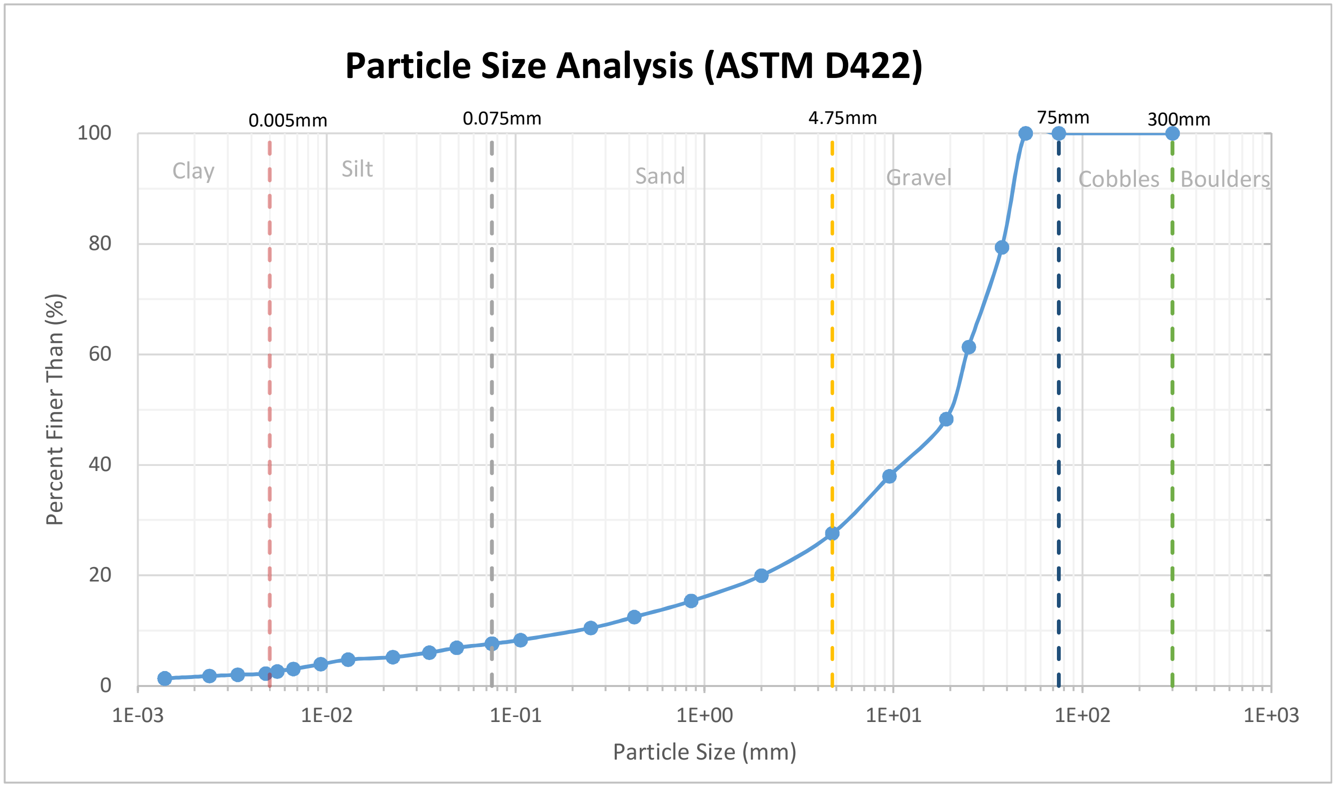
SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	79.38
1"	25.000	61.31
0.75"	19.000	48.29
0.375"	9.500	37.93
No. 4	4.750	27.58
No. 10	2.000	19.96
No. 20	0.850	15.36
No. 40	0.425	12.47
No. 60	0.250	10.46
No. 140	0.106	8.30
No. 200	0.075	7.63
HYDROMETER	0.0488	6.88
	0.0350	6.03
	0.0224	5.18
	0.0130	4.75
	0.0093	3.90
	0.0067	3.05
	0.0055	2.63
	0.0048	2.20
	0.0034	1.99
	0.0024	1.78
	0.0014	1.35



Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-1***
Sample ID:	***6A***
Depth:	***15.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	72.4
Sand:	20.0
Silt:	5.3
Clay:	2.3

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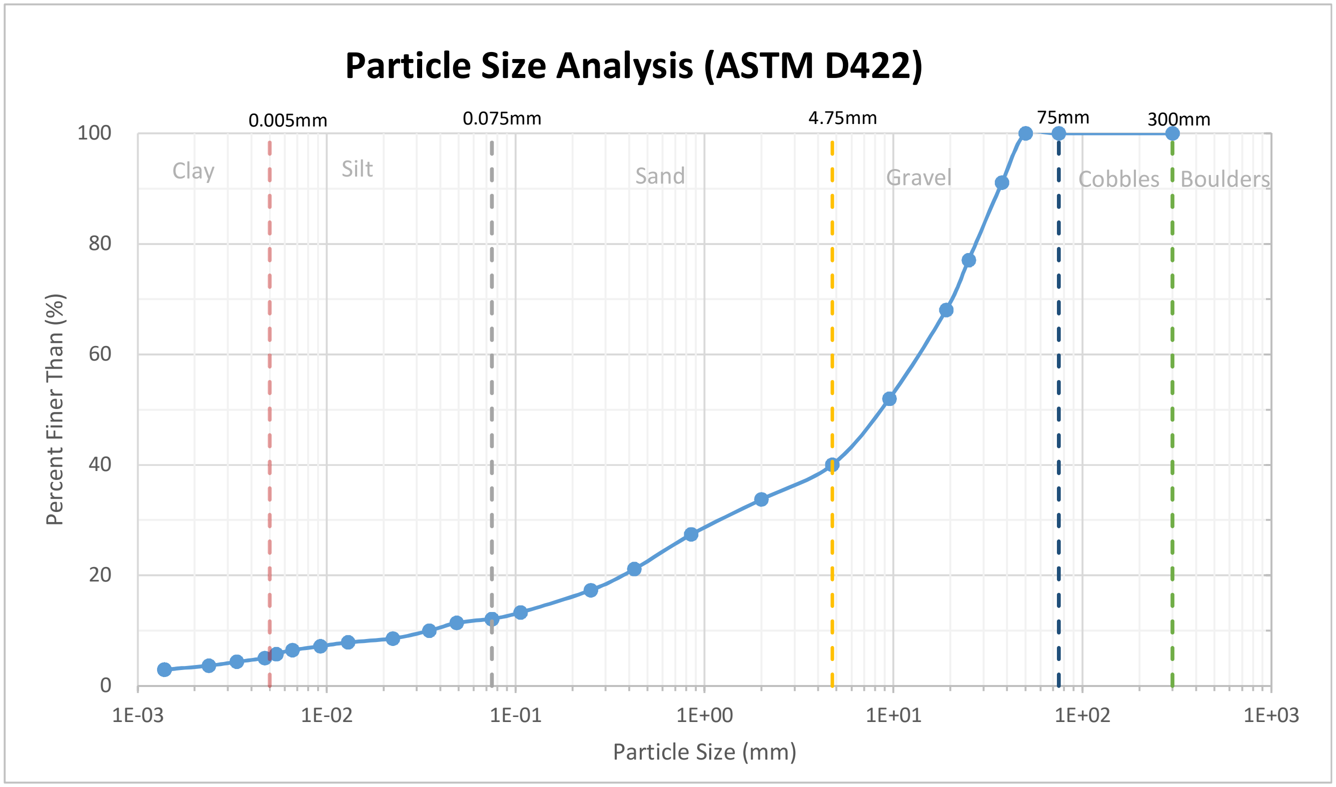
SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	91.08
1"	25.000	77.08
0.75"	19.000	68.05
0.375"	9.500	51.95
No. 4	4.750	40.04
No. 10	2.000	33.74
No. 20	0.850	27.40
No. 40	0.425	21.13
No. 60	0.250	17.31
No. 140	0.106	13.27
No. 200	0.075	12.09
HYDROMETER	0.0488	11.39
	0.0350	9.98
	0.0224	8.58
	0.0130	7.87
	0.0093	7.17
	0.0066	6.46
	0.0054	5.76
	0.0047	5.05
	0.0033	4.35
	0.0024	3.65
	0.0014	2.94



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GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-1***
Sample ID:	***9A***
Depth:	***25.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	60.0
Sand:	27.9
Silt:	6.7
Clay:	5.4

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	100.00
1"	25.000	92.16
0.75"	19.000	80.28
0.375"	9.500	69.18
No. 4	4.750	55.21
No. 10	2.000	47.24
No. 20	0.850	39.17
No. 40	0.425	34.26
No. 60	0.250	31.27
No. 140	0.106	28.19
No. 200	0.075	27.27
HYDROMETER	0.0460	25.66
	0.0327	24.65
	0.0208	23.63
	0.0121	22.61
	0.0087	20.57
	0.0062	18.53
	0.0051	17.51
	0.0045	16.49
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	0.0013	10.37

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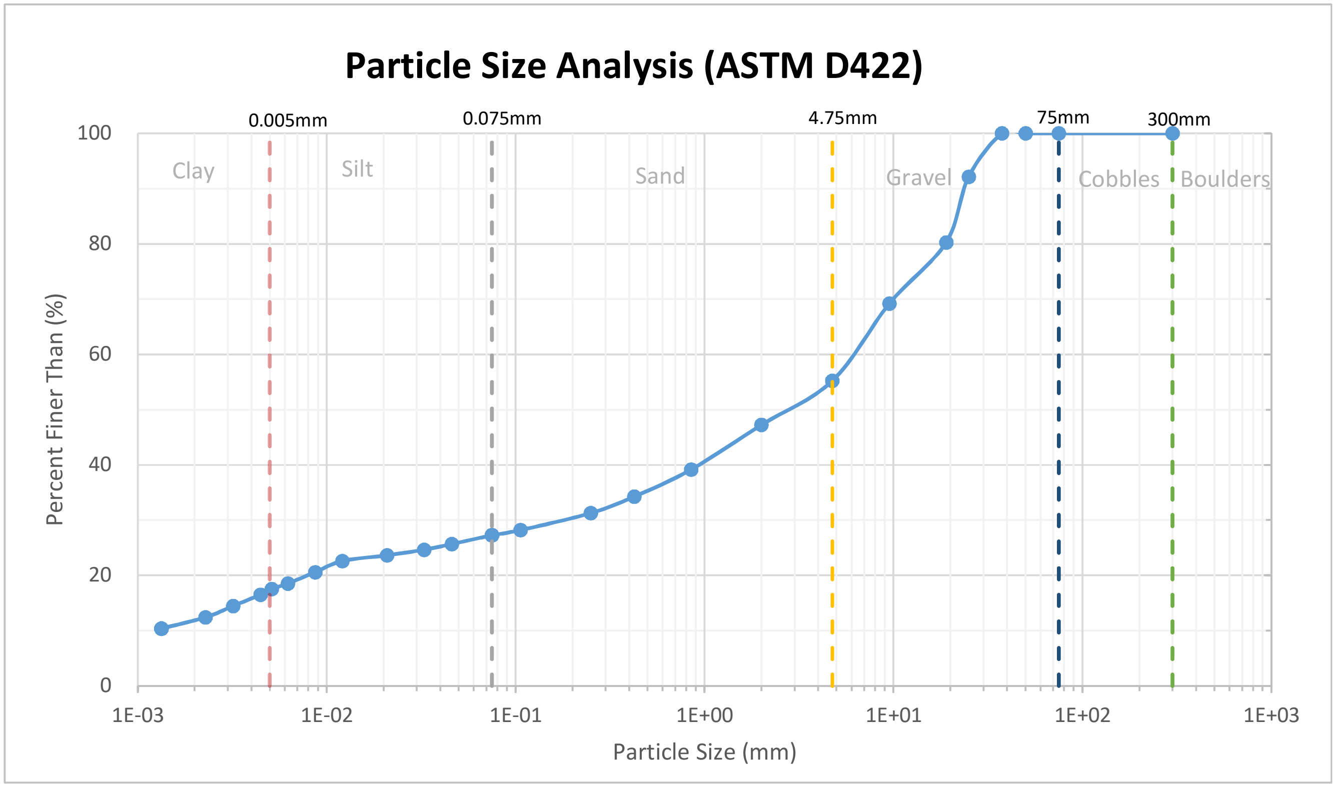
GEOTECHNICAL & MATERIAL TESTING LABORATORY



Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-1***
Sample ID:	***11A***
Depth:	***35.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	44.8
Sand:	27.9
Silt:	9.9
Clay:	17.4

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	100.00
1"	25.000	100.00
0.75"	19.000	87.65
0.375"	9.500	74.94
No. 4	4.750	66.61
No. 10	2.000	57.48
No. 20	0.850	49.69
No. 40	0.425	44.23
No. 60	0.250	40.29
No. 140	0.106	35.81
No. 200	0.075	33.99
HYDROMETER	0.0463	31.22
	0.0332	28.64
	0.0213	26.05
	0.0125	22.18
	0.0090	18.31
	0.0065	15.72
	0.0053	14.43
	0.0046	13.14
	0.0033	10.56
	0.0024	7.97
	0.0014	6.68

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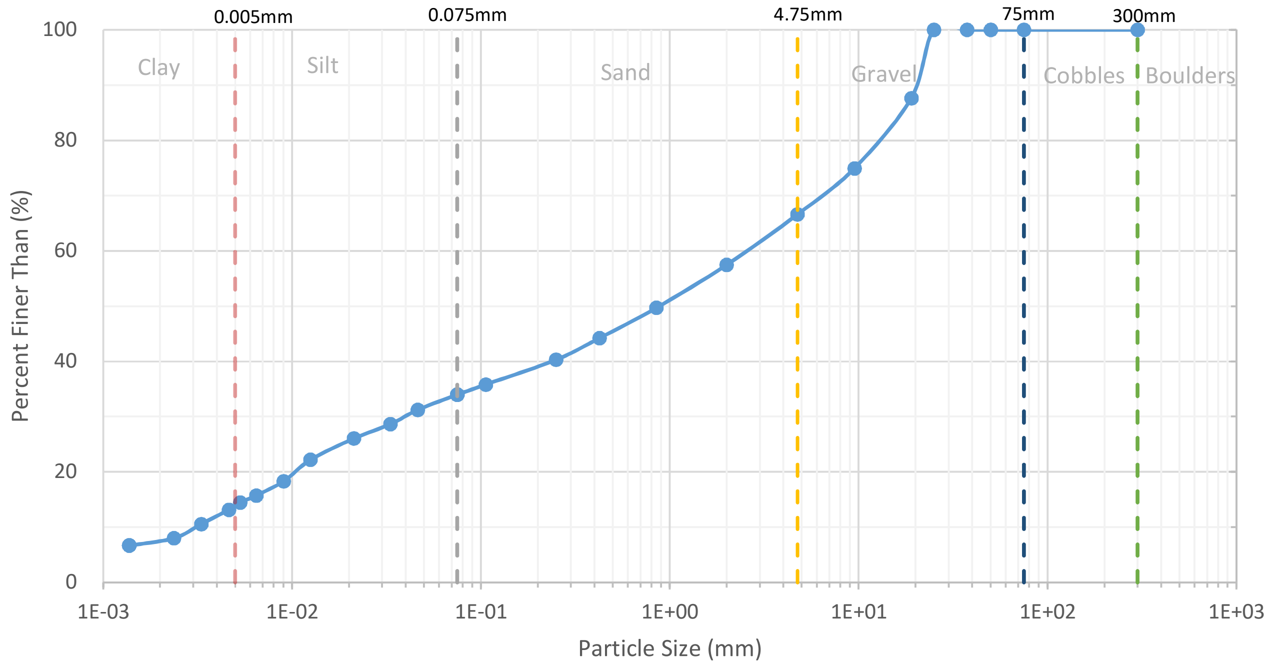
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Particle Size Analysis (ASTM D422)

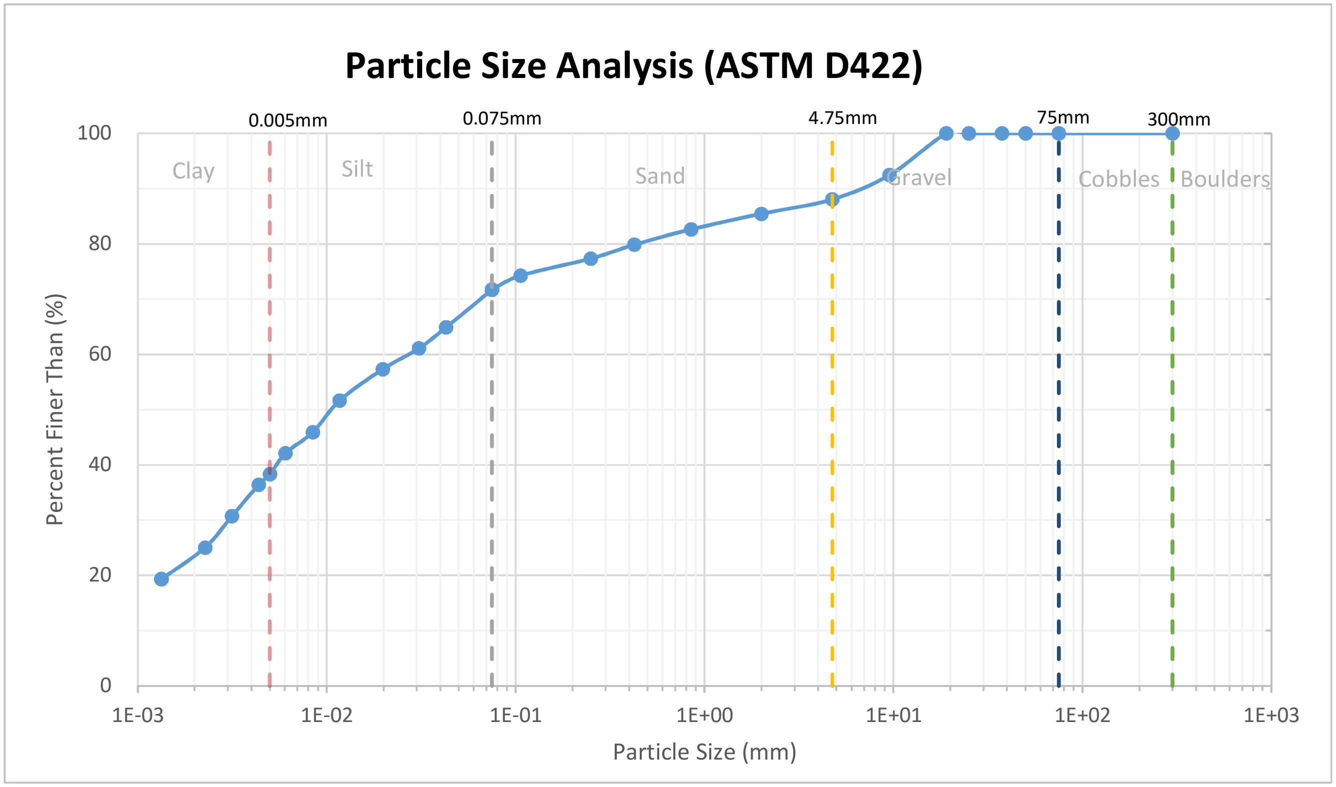


Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-2***
Sample ID:	***14A***
Depth:	***5.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	33.4
Sand:	32.6
Silt:	20.1
Clay:	13.9

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	100.00
1"	25.000	100.00
0.75"	19.000	100.00
0.375"	9.500	92.45
No. 4	4.750	88.07
No. 10	2.000	85.46
No. 20	0.850	82.65
No. 40	0.425	79.86
No. 60	0.250	77.35
No. 140	0.106	74.25
No. 200	0.075	71.73
HYDROMETER	0.0429	64.92
	0.0308	61.12
	0.0198	57.32
	0.0117	51.62
	0.0085	45.92
	0.0061	42.12
	0.0050	38.32
	0.0044	36.42
	0.0032	30.72
	0.0023	25.03
	0.0013	19.33



SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-2***
Sample ID:	***15A***
Depth:	***7.5'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	11.9
Sand:	16.3
Silt:	33.5
Clay:	38.3

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	100.00
1"	25.000	89.00
0.75"	19.000	85.50
0.375"	9.500	65.05
No. 4	4.750	46.55
No. 10	2.000	35.66
No. 20	0.850	29.02
No. 40	0.425	24.48
No. 60	0.250	21.73
No. 140	0.106	18.93
No. 200	0.075	17.98
HYDROMETER	0.0469	15.97
	0.0339	13.81
	0.0218	11.65
	0.0128	9.49
	0.0092	8.05
	0.0066	6.61
	0.0054	5.89
	0.0047	5.17
	0.0033	4.45
	0.0024	3.73
	0.0014	3.01

SOLUM CONSULTANTS LTD.
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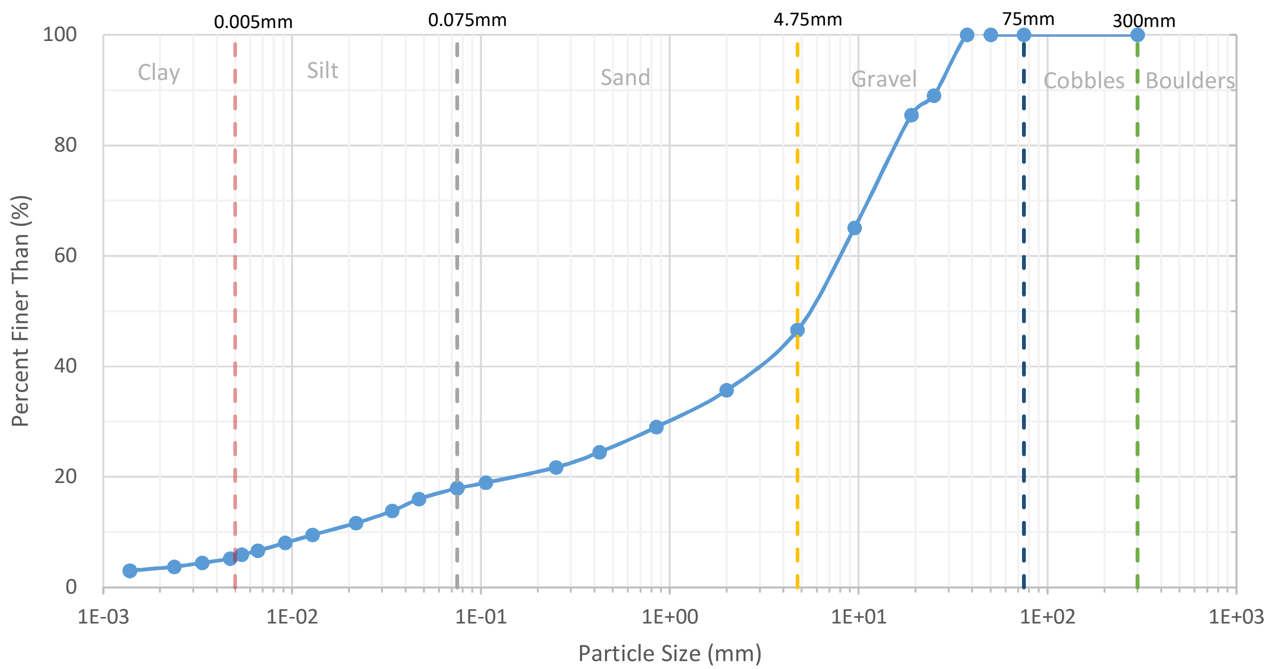
Particle Size Analysis (ASTM D422)



Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***100.6-2***
Sample ID:	***18A***
Depth:	***25.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	53.4
Sand:	28.6
Silt:	12.5
Clay:	5.5

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	74.23
1.5"	37.500	65.86
1"	25.000	63.60
0.75"	19.000	60.44
0.375"	9.500	51.81
No. 4	4.750	42.87
No. 10	2.000	35.20
No. 20	0.850	23.79
No. 40	0.425	17.98
No. 60	0.250	15.01
No. 140	0.106	11.97
No. 200	0.075	10.95
HYDROMETER	0.0498	9.71
	0.0355	8.61
	0.0227	7.50
	0.0132	6.76
	0.0094	6.03
	0.0067	5.29
	0.0055	4.55
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	0.0034	3.08
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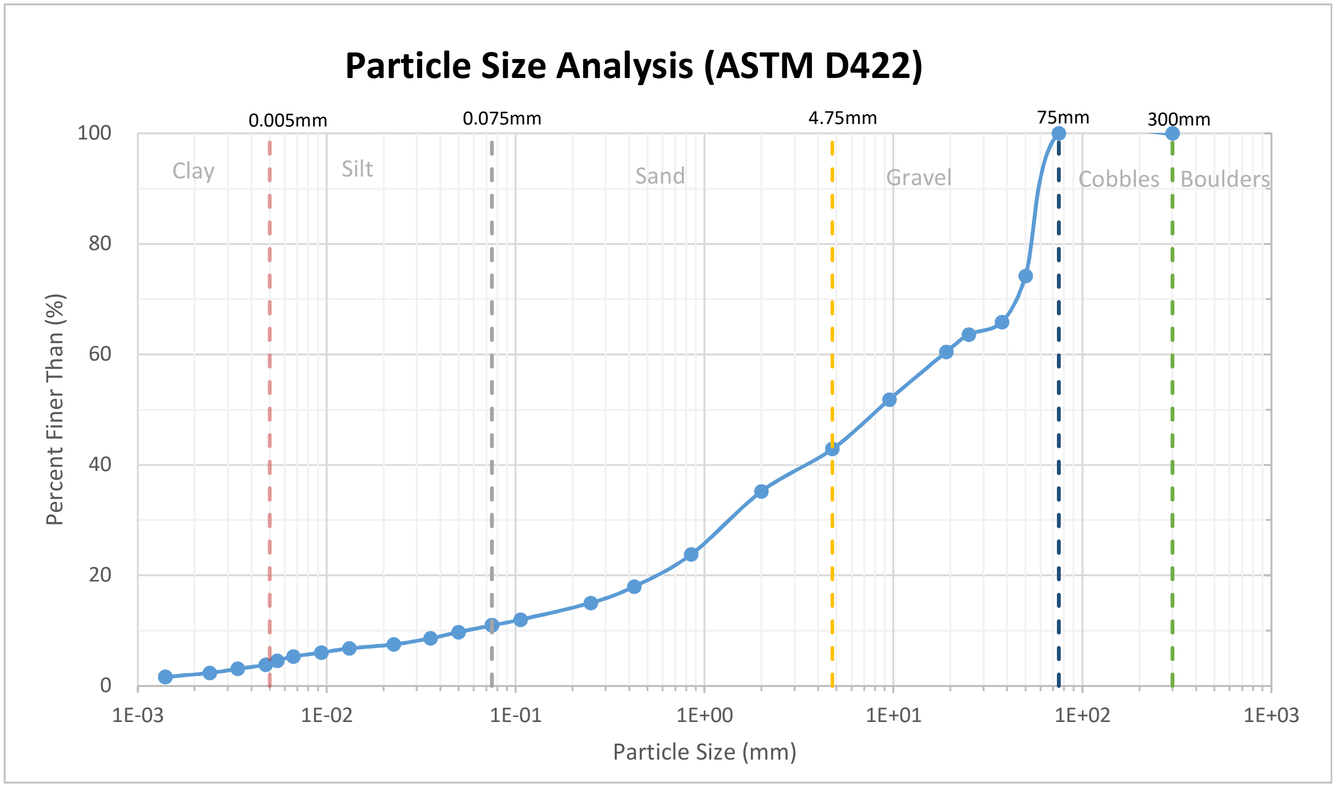

Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***95.6-1***
Sample ID:	***28A***
Depth:	***2.5'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	57.1
Sand:	31.9
Silt:	6.9
Clay:	4.1

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GEOTECHNICAL & MATERIAL TESTING LABORATORY

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	79.73
1"	25.000	66.67
0.75"	19.000	57.54
0.375"	9.500	36.41
No. 4	4.750	26.01
No. 10	2.000	20.58
No. 20	0.850	15.00
No. 40	0.425	11.87
No. 60	0.250	10.23
No. 140	0.106	8.51
No. 200	0.075	7.57
HYDROMETER	0.0498	5.61
	0.0356	4.76
	0.0228	3.91
	0.0132	3.48
	0.0094	3.05
	0.0067	2.63
	0.0055	2.42
	0.0048	2.20
	0.0034	1.78
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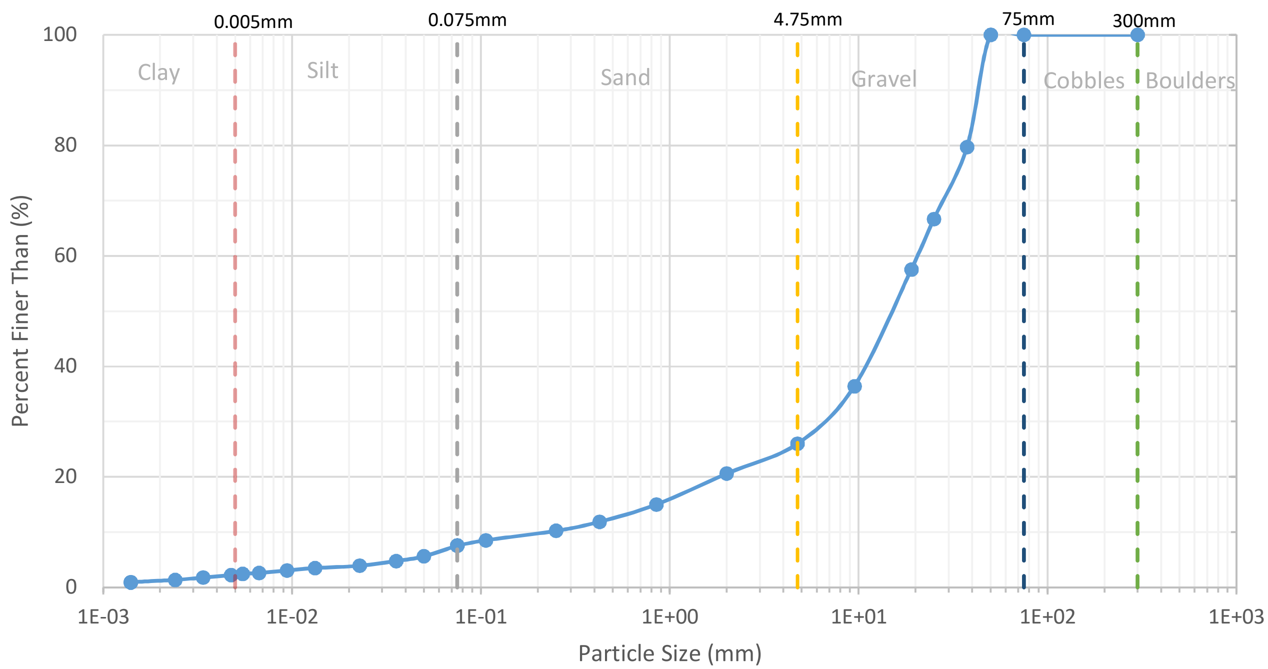
SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Particle Size Analysis (ASTM D422)

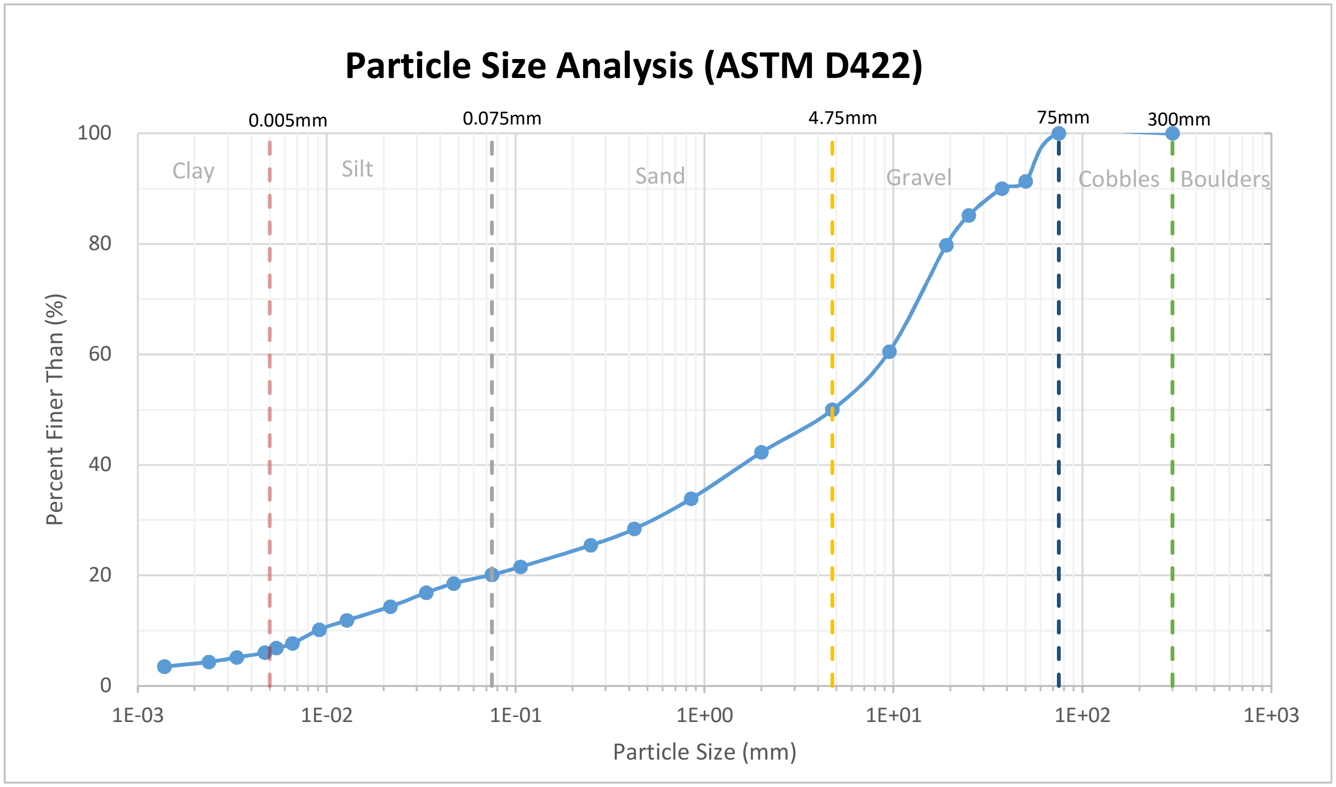


Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***95.6-1***
Sample ID:	***33A***
Depth:	***20.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	74.0
Sand:	18.4
Silt:	5.3
Clay:	2.3

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	91.30
1.5"	37.500	90.02
1"	25.000	85.14
0.75"	19.000	79.74
0.375"	9.500	60.50
No. 4	4.750	49.96
No. 10	2.000	42.26
No. 20	0.850	33.87
No. 40	0.425	28.41
No. 60	0.250	25.46
No. 140	0.106	21.53
No. 200	0.075	20.11
HYDROMETER	0.0469	18.52
	0.0336	16.85
	0.0217	14.35
	0.0128	11.84
	0.0091	10.17
	0.0066	7.66
	0.0054	6.83
	0.0047	5.99
	0.0033	5.16
	0.0024	4.32
	0.0014	3.49



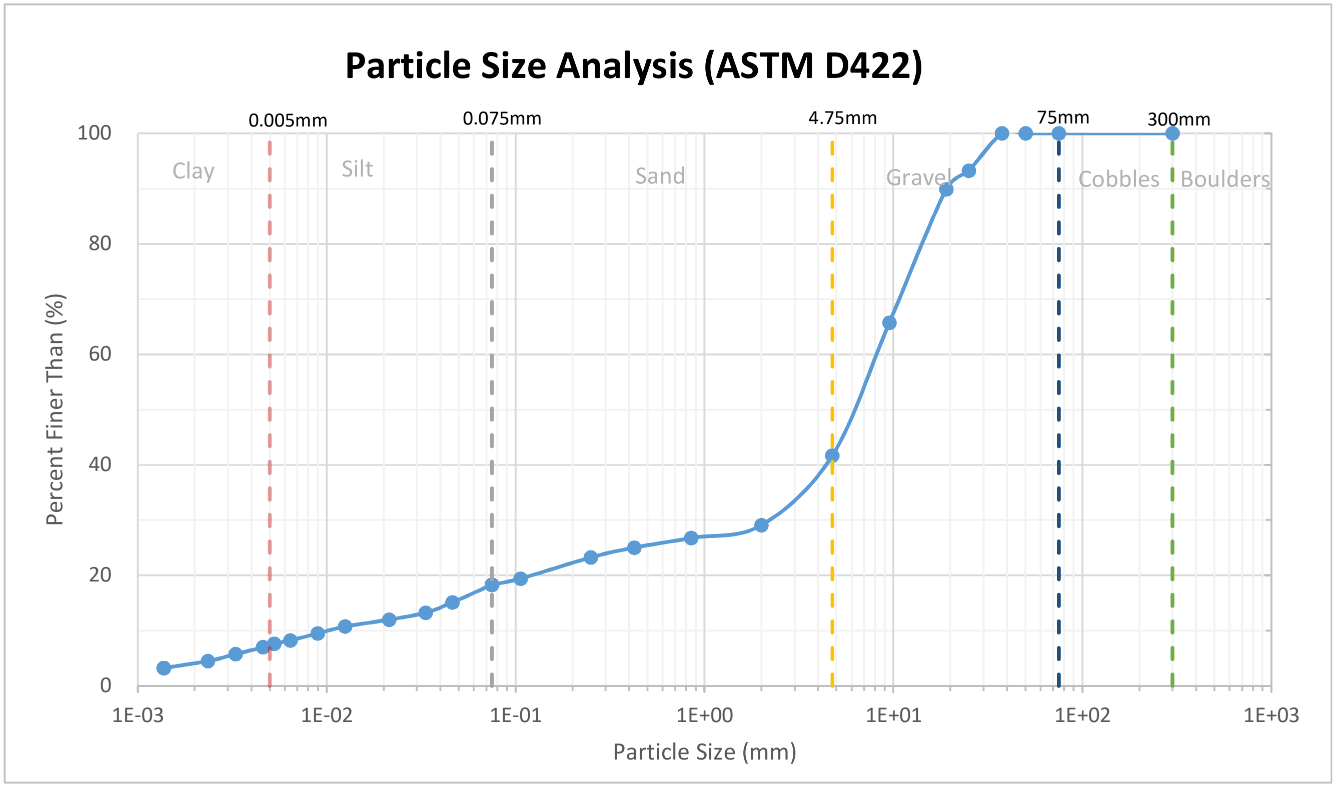
Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***95.6-2***
Sample ID:	***35A***
Depth:	***2.5'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	50.0
Sand:	29.9
Silt:	13.8
Clay:	6.3

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
2"	50.000	100.00
1.5"	37.500	100.00
1"	25.000	93.27
0.75"	19.000	89.87
0.375"	9.500	65.73
No. 4	4.750	41.69
No. 10	2.000	29.09
No. 20	0.850	26.77
No. 40	0.425	25.03
No. 60	0.250	23.24
No. 140	0.106	19.40
No. 200	0.075	18.32
HYDROMETER	0.0463	15.11
	0.0334	13.24
	0.0214	11.99
	0.0125	10.74
	0.0090	9.49
	0.0064	8.24
	0.0053	7.61
	0.0046	6.99
	0.0033	5.74
	0.0024	4.49
	0.0014	3.24



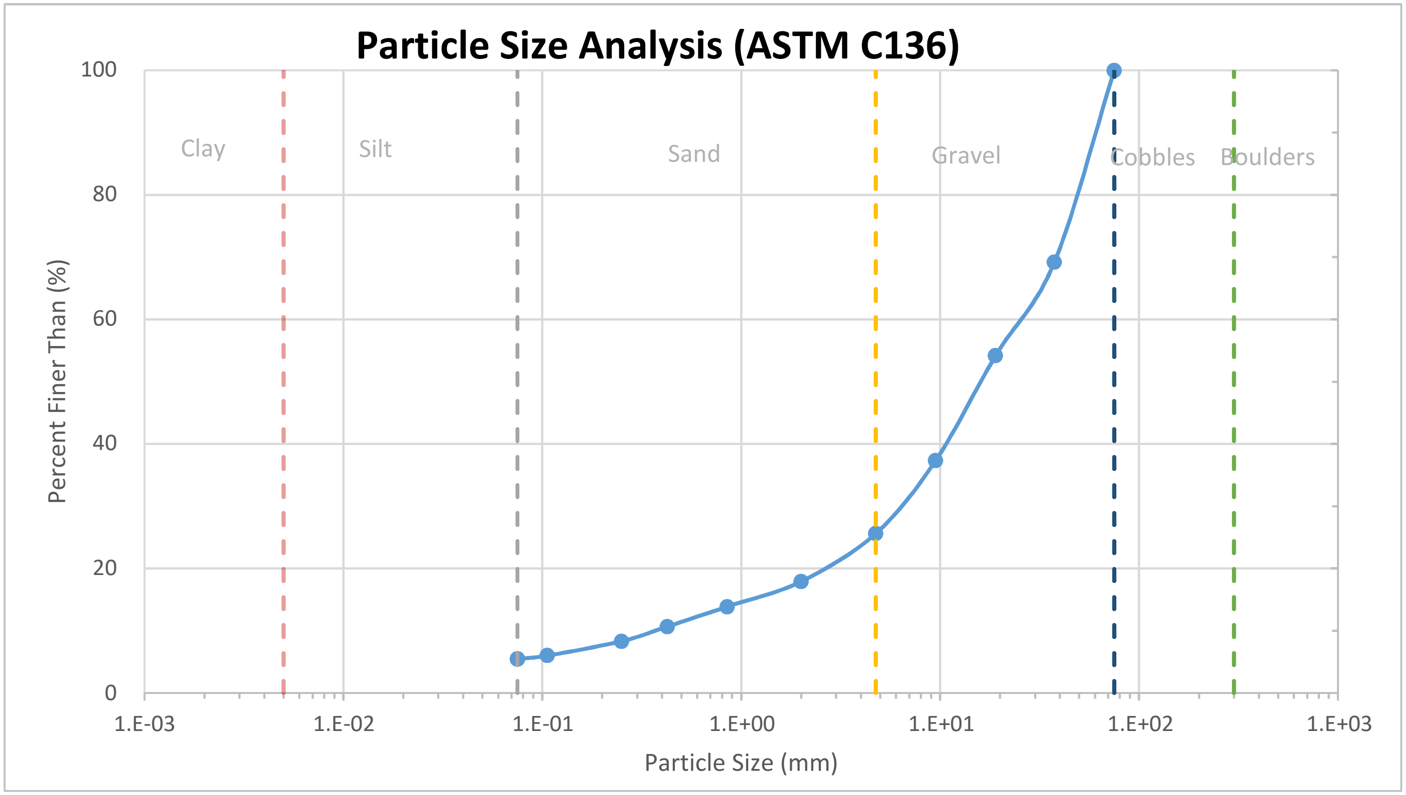
SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.:	***61021019.00***
Location:	***Kootenay National Park***
Solum Job No.:	***08201171201(196)***
Borehole ID:	***95.6-2***
Sample ID:	***39A***
Depth:	***15.0'***
Date Tested:	***19-Dec-17***

Particle Size (%)	
Cobbles:	0.0
Gravel:	58.3
Sand:	23.4
Silt:	11.0
Clay:	7.3

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
1.5"	37.500	69.18
0.75"	19.000	54.19
0.375"	9.500	37.36
No. 4	4.750	25.63
No. 10	2.000	17.92
No. 20	0.850	13.88
No. 40	0.425	10.67
No. 60	0.250	8.32
No. 140	0.106	6.02
No. 200	0.075	5.48



Geo. Inv. For Culvert Sites

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Project No.: 61021019.00

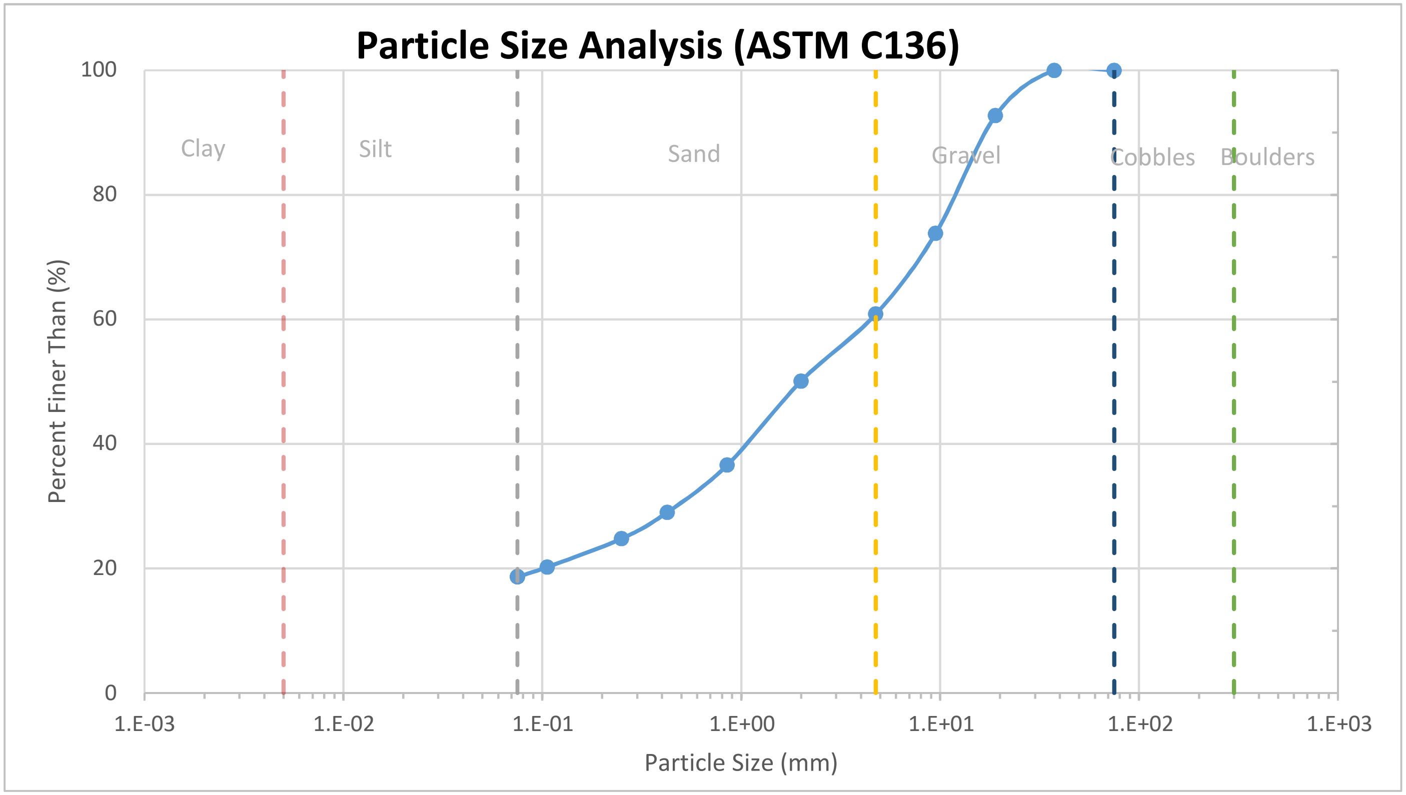
Solum Job No.: 08201171201(196)

Sample ID: 100.6-2 13A

Depth: 2.5'

Particle Size (%)	
Cobbles:	0.0
Gravel:	74.4
Sand:	20.2
Fines:	5.4

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
1.5"	37.500	100.00
0.75"	19.000	92.74
0.375"	9.500	73.84
No. 4	4.750	60.86
No. 10	2.000	50.10
No. 20	0.850	36.61
No. 40	0.425	29.03
No. 60	0.250	24.79
No. 140	0.106	20.23
No. 200	0.075	18.68



Geo. Inv. For Culvert Sites

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Project No.: 61021019.00

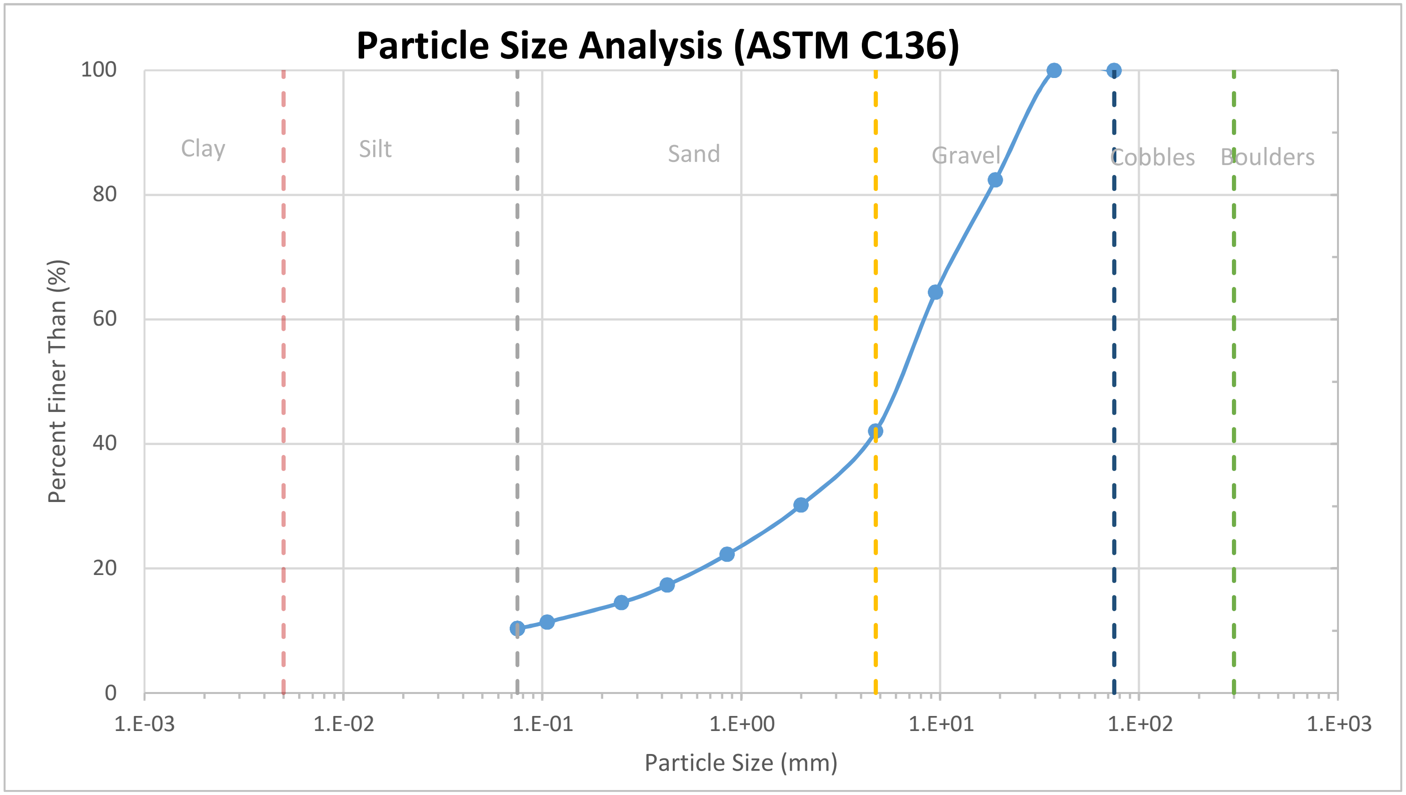
Solum Job No.: 08201171201(196)

Sample ID: 100.6-2 19

Depth: 30.0'

Particle Size (%)	
Cobbles:	0.0
Gravel:	39.1
Sand:	42.2
Fines:	18.7

SIEVE SIZE	PARTICLE-SIZE (mm)	PERCENT FINER (%)
3"	75.000	100.00
1.5"	37.500	100.00
0.75"	19.000	82.43
0.375"	9.500	64.36
No. 4	4.750	42.05
No. 10	2.000	30.20
No. 20	0.850	22.27
No. 40	0.425	17.37
No. 60	0.250	14.54
No. 140	0.106	11.40
No. 200	0.075	10.36



Geo. Inv. For Culvert Sites

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Project No.: 61021019.00

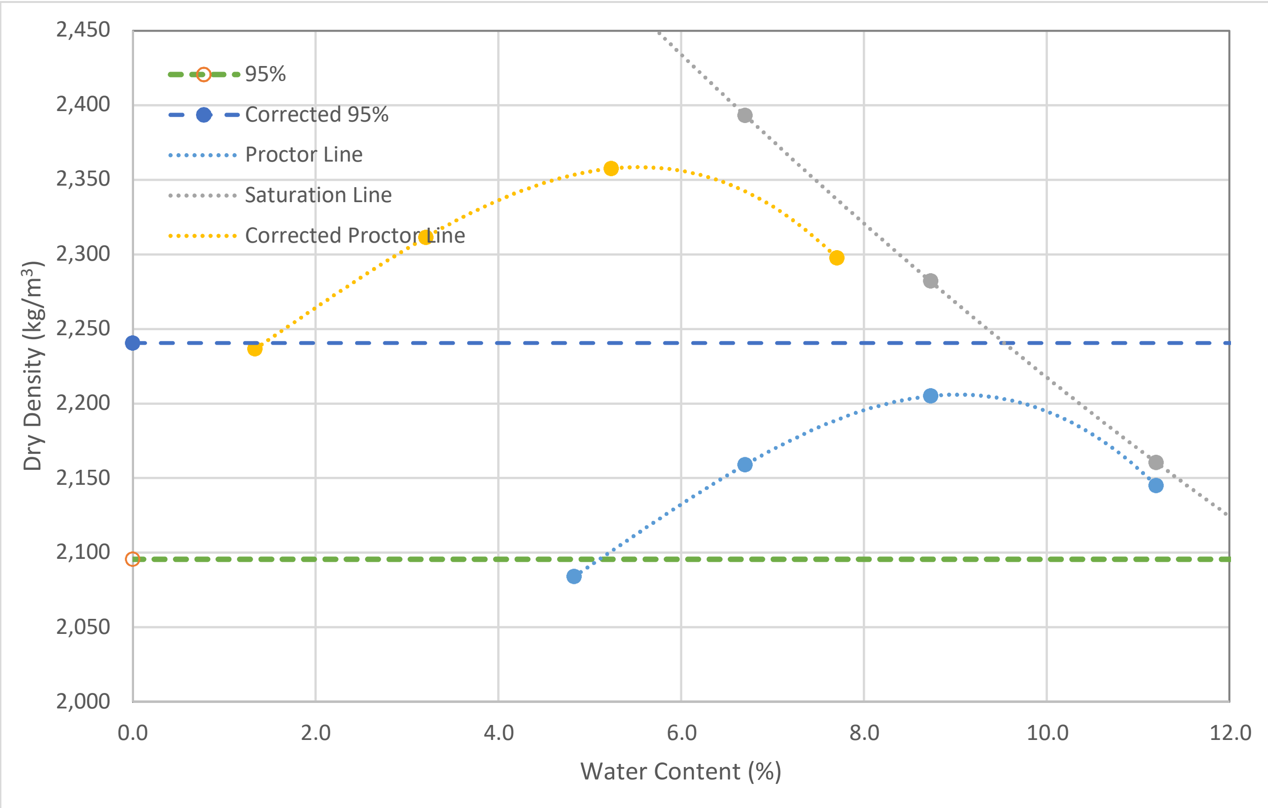
Solum Job No.: 08201171201(196)

Sample ID: 95.6-1 30

Depth: 7.5'

Particle Size (%)	
Cobbles:	0.0
Gravel:	57.9
Sand:	31.7
Fines:	10.4

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**100.6-1 1B**
Depth:	**2.5'**
Natural MC (%):	**4.1**

Optimum MC (%):	**9.0**
Max. Dry Density (kg/m^3):	**2206**
95% of MDD (kg/m^3)	**2096**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**38.7**
Corrected Optimum MC (%):	**5.5**	
Corrected Dry Density (kg/m^3):	**2358**	
Corrected 95% of MDD (kg/m^3)	**2241**	

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GEOTECHNICAL & MATERIAL TESTING LABORATORY

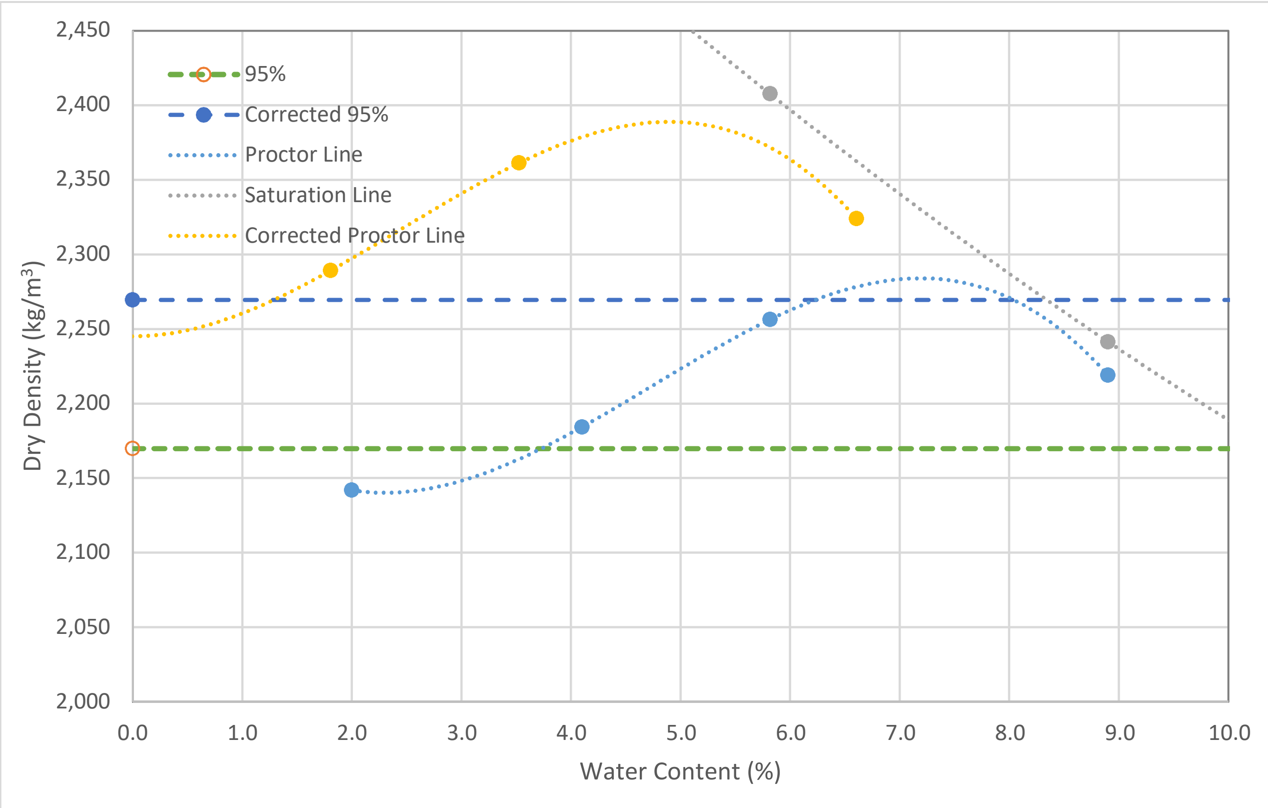
Geo. Inv. For Culvert Sites

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Use ASTM D4718 for oversize correction with deviation of particle remain on 3/4">30%.

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**100.6-1 9A**
Depth:	**25.0'**
Natural MC (%):	**8.3**

Optimum MC (%):	**7.2**
Max. Dry Density (kg/m^3):	**2284**
95% of MDD (kg/m^3)	**2170**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**31.9**
Corrected Optimum MC (%):	**4.9**	
Corrected Dry Density (kg/m^3):	**2389**	
Corrected 95% of MDD (kg/m^3)	**2269**	

Use ASTM D4718 for oversize correction with deviation of particle remain on 3/4">30%.

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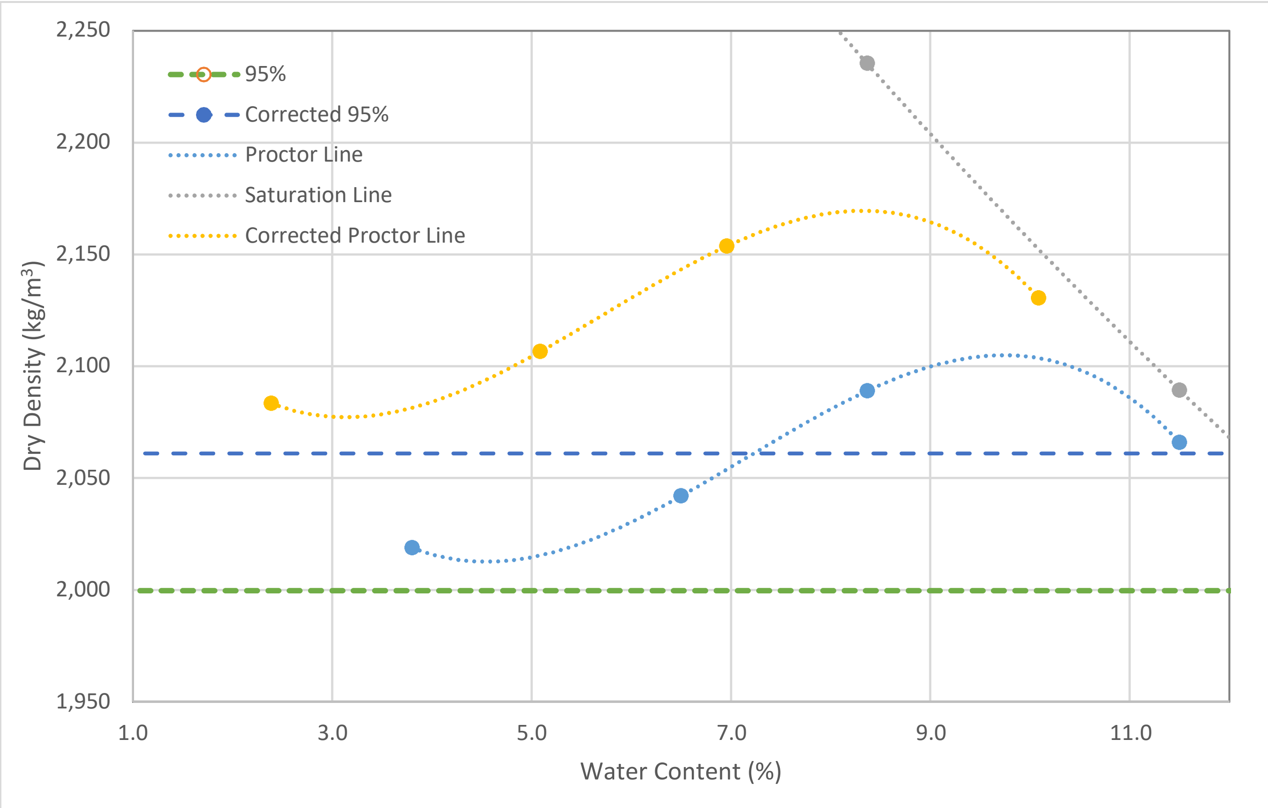
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**100.6-2 18A**
Depth:	**25.0'**
Natural MC (%):	**0.0**

Optimum MC (%):	**9.7**
Max. Dry Density (kg/m^3):	**2105**
95% of MDD (kg/m^3)	**2000**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**14.5**
Corrected Optimum MC (%):	**8.3**	
Corrected Dry Density (kg/m^3):	**2169**	
Corrected 95% of MDD (kg/m^3)	**2061**	

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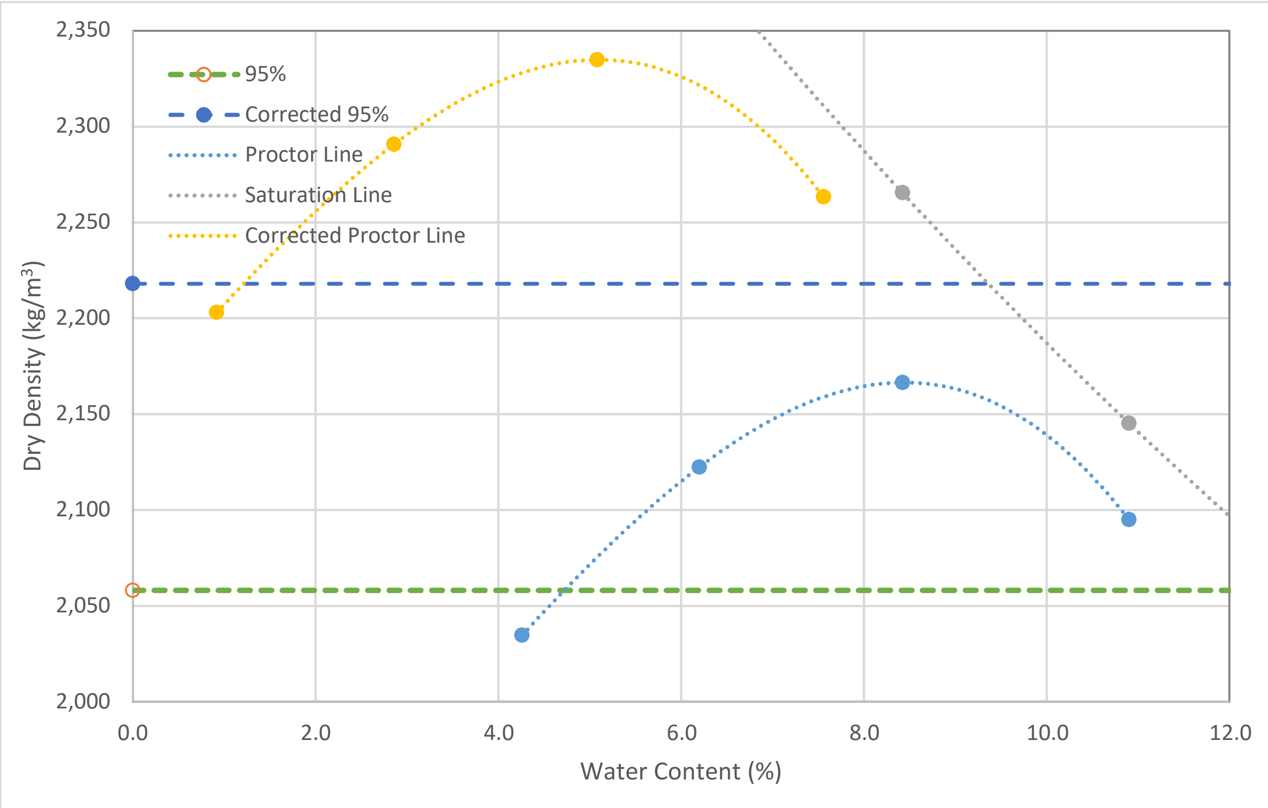
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**95.6-1 28A**
Depth:	**2.5'**
Natural MC (%):	**3.7**

Optimum MC (%):	**8.4**
Max. Dry Density (kg/m^3):	**2166**
95% of MDD (kg/m^3)	**2058**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**39.6**
Corrected Optimum MC (%):	**5.1**	
Corrected Dry Density (kg/m^3):	**2335**	
Corrected 95% of MDD (kg/m^3)	**2218**	

Use ASTM D4718 for oversize correction with deviation of particle remain on 3/4">30%.

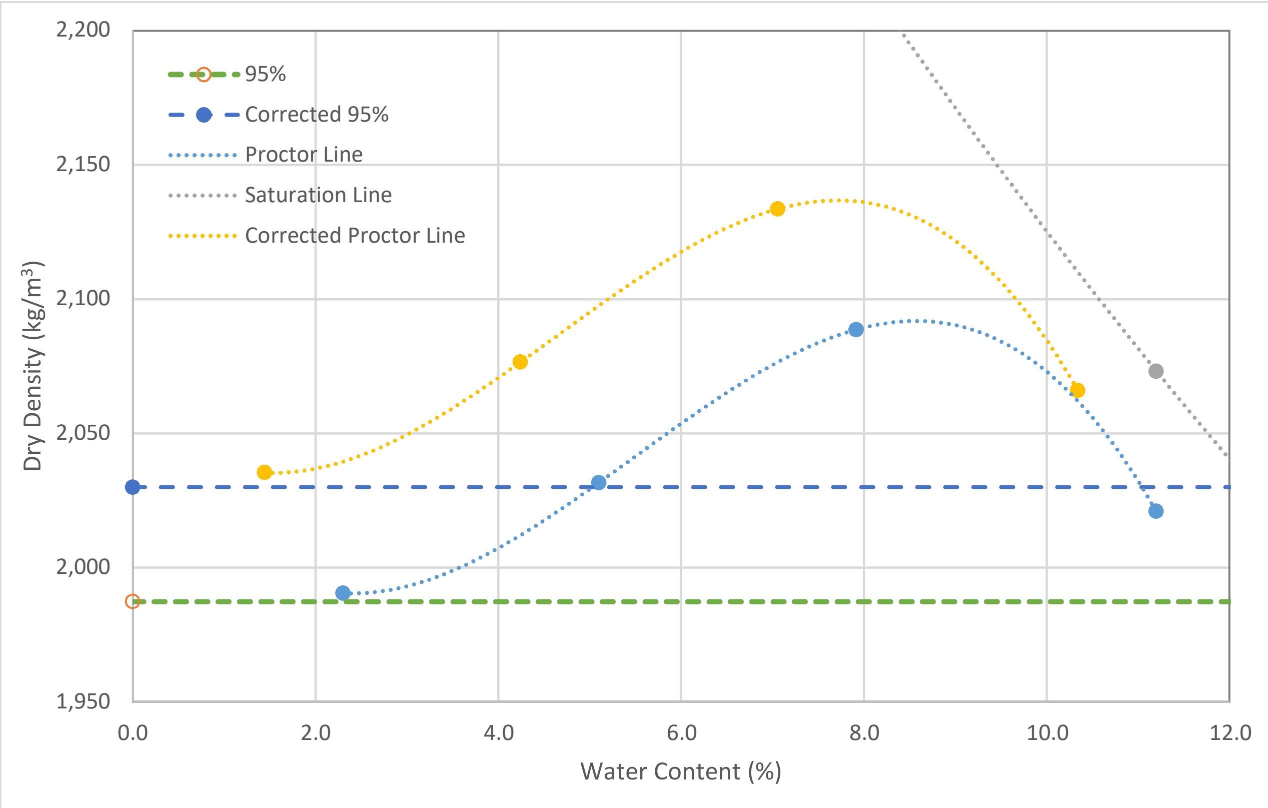
SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**95.6-2 35A**
Depth:	**2.5'**
Natural MC (%):	**0.0**

Optimum MC (%):	**8.6**
Max. Dry Density (kg/m^3):	**2092**
95% of MDD (kg/m^3)	**1987**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**10.0**
Corrected Optimum MC (%):	**7.7**	
Corrected Dry Density (kg/m^3):	**2137**	
Corrected 95% of MDD (kg/m^3)	**2030**	

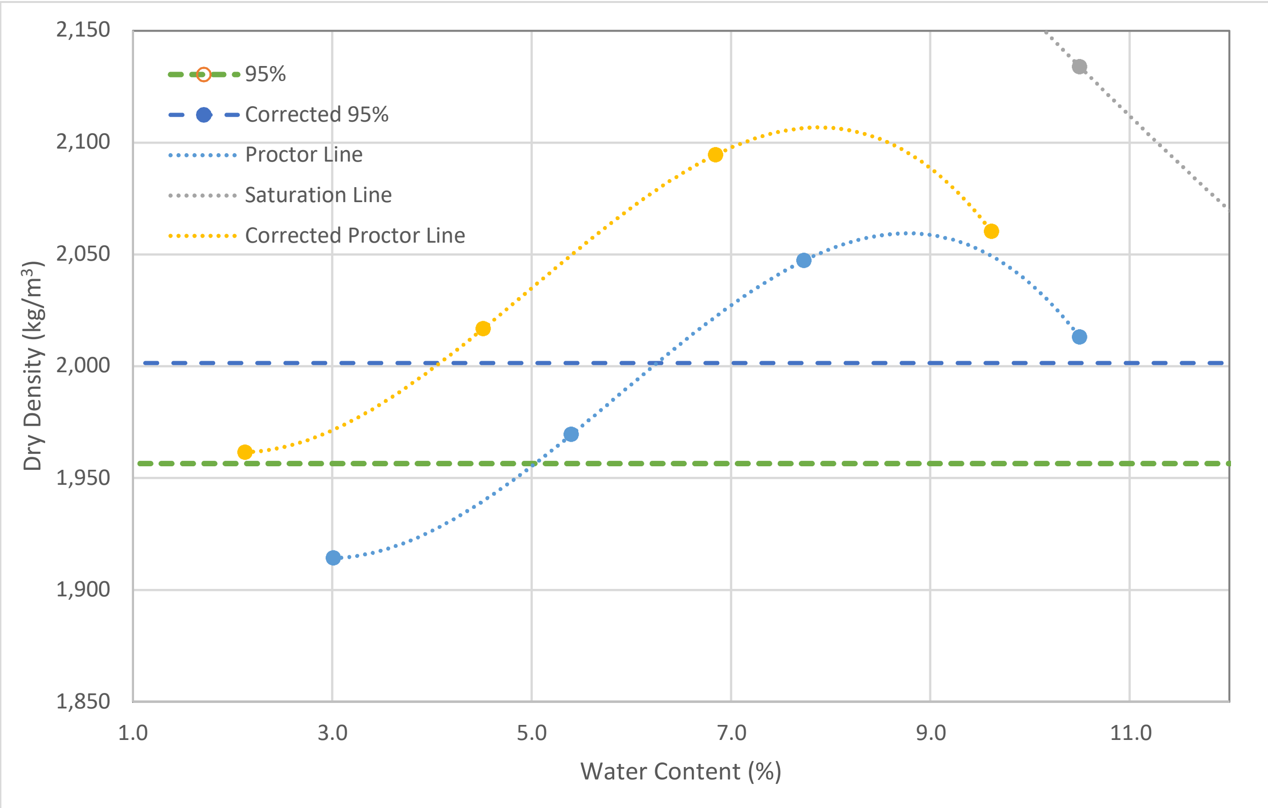
SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Geo. Inv. For Culvert Sites

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Standard Proctor Test Report (ASTM D698)



Test Method:	**C**
Sample ID.:	**95.6-2 39A**
Depth:	**15.0'**
Natural MC (%):	**6.5**

Optimum MC (%):	**8.8**
Max. Dry Density (kg/m^3):	**2059**
95% of MDD (kg/m^3)	**1956**

OverSize Correction	**ASTM D4718**	
% Particles Ret. on Sieve	**¾"**	**10.1**
Corrected Optimum MC (%):	**7.9**	
Corrected Dry Density (kg/m^3):	**2107**	
Corrected 95% of MDD (kg/m^3)	**2001**	

Geo. Inv. For Culvert Sites

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

Project No.: **61021019.00**

Solum Job No.: **08201171201(196)**

Boring No.	100.6-1	Project No.:	61021019.00
Sample No.	1B	Job Name	Geo. Inv. For Culvert Sites
Depth (ft)	2.5'	Tested By	SF & KC
Date	2017-12-20	Calculated By	SF
Solum No.:	08201171201(196)	Checked By	SF

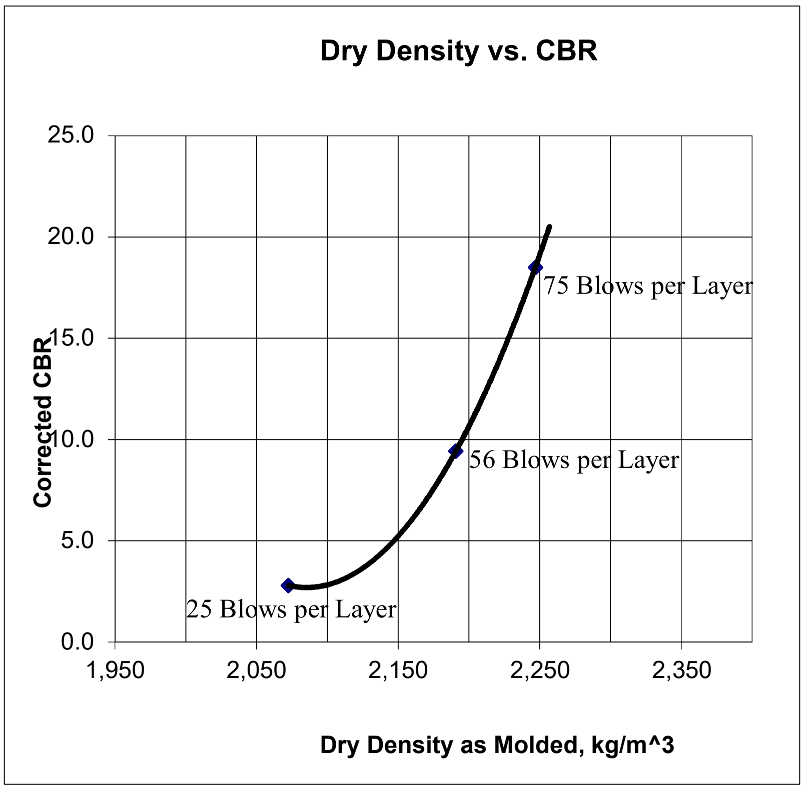
Solum Consultants Ltd.

California Bearing Ratio - ASTM D1883 (One Water Content Only)

(Optimum Moisture Content / Soaked)

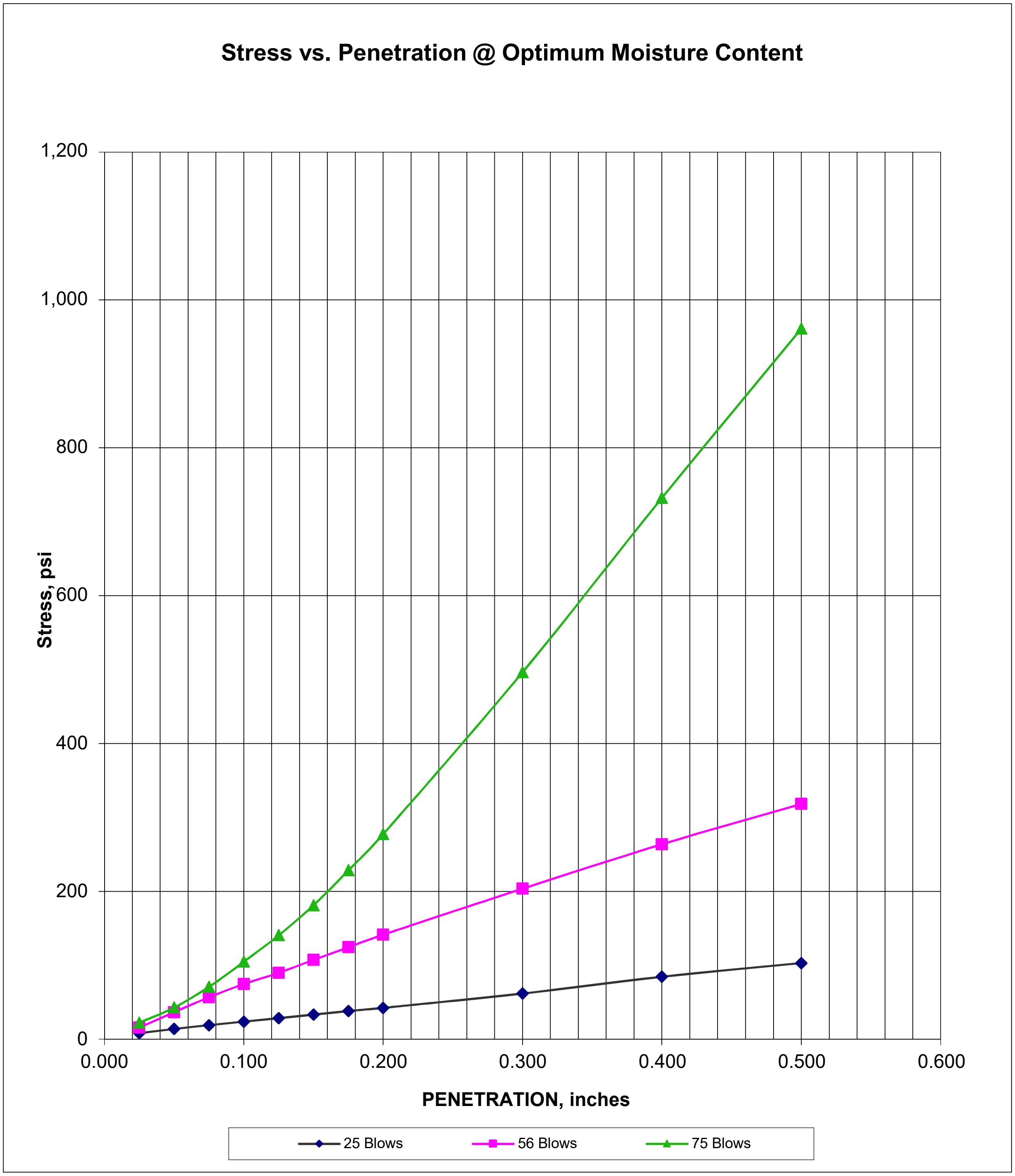
Surcharge Amount: 4.54 kG

	25 Blows	56 Blows	75 Blows
Dry density before soak, kg/m^3	2,072	2,191	2,247
Dry density after soak, kg/m^3	2,074	2,192	2,247
Moisture Content before soak, %	9.0	9.0	9.0
Moisture Content after soak, avg., %	15.4	13.5	10.8
Moisture Content after soak, top 1", %	16.2	15.3	12.8
% Swell(+)/Consolidation(-) after 96 hour soak	-0.1	-0.1	0.0
Bearing Ratio, 0.200" penetration	2.8	9.4	18.5



%MDD	Density (kg/m^3)	Corrected CBR
95	2096	2.9
100	2206	10.5
102	2250	18.5

Boring No.	2	**Solum Consultants Ltd.**	Project No.:	61021019
Sample No.	59		Job Name	Geo. Inv. For Marble Canyon
Depth (ft)	5'		Tested By	SF & KC
Date	2017-12-20	**STANDARD TEST METHOD**	Calculated By	SF
Solum No.:	08201170719(91)	**for CBR ASTM D1883-05**	Checked By	SF



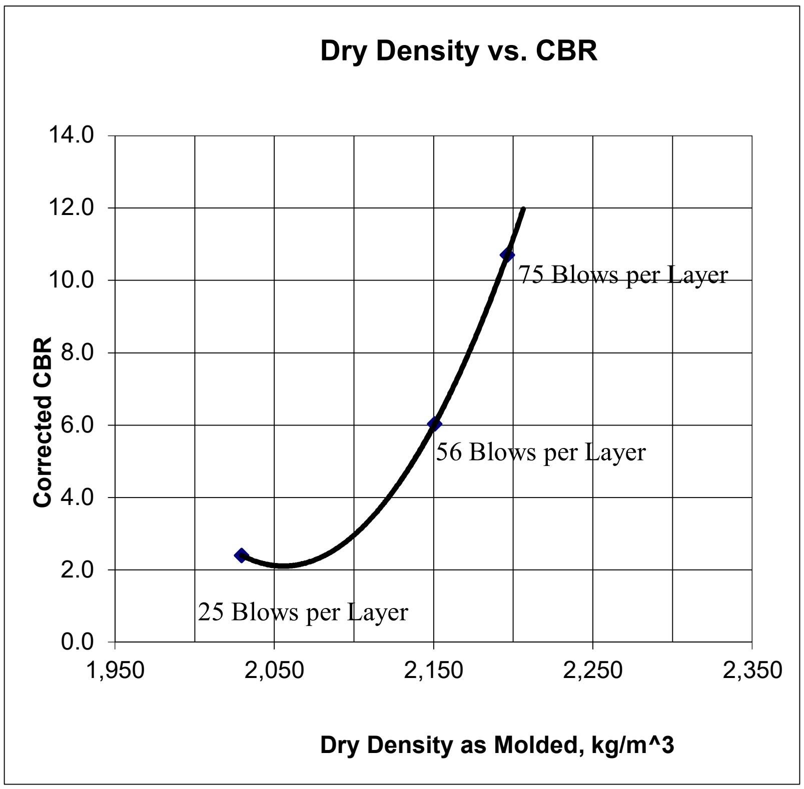
Boring No.	95.6-1		Project No.:	61021019.00
Sample No.	28A		Job Name	Geo. Inv. For Culvert Sites
Depth (ft)	2.5'	**Solum Consultants Ltd.**	Tested By	SF & KC
Date	2017-12-20		Calculated By	SF
Solum No.:	08201171201(196)		Checked By	SF

California Bearing Ratio - ASTM D1883 (One Water Content Only)

(Optimum Moisture Content / Soaked)

Surcharge Amount: 4.54 kG

	25 Blows	56 Blows	75 Blows
Dry density before soak, kg/m^3	2,030	2,151	2,196
Dry density after soak, kg/m^3	2,033	2,154	2,195
Moisture Content before soak, %	8.4	8.4	8.4
Moisture Content after soak, avg., %	16.1	14.3	12.7
Moisture Content after soak, top 1", %	18.5	15.6	14.4
% Swell(+)/Consolidation(-) after 96 hour soak	-0.2	-0.1	0.1
Bearing Ratio, 0.200" penetration	2.4	6.0	10.7

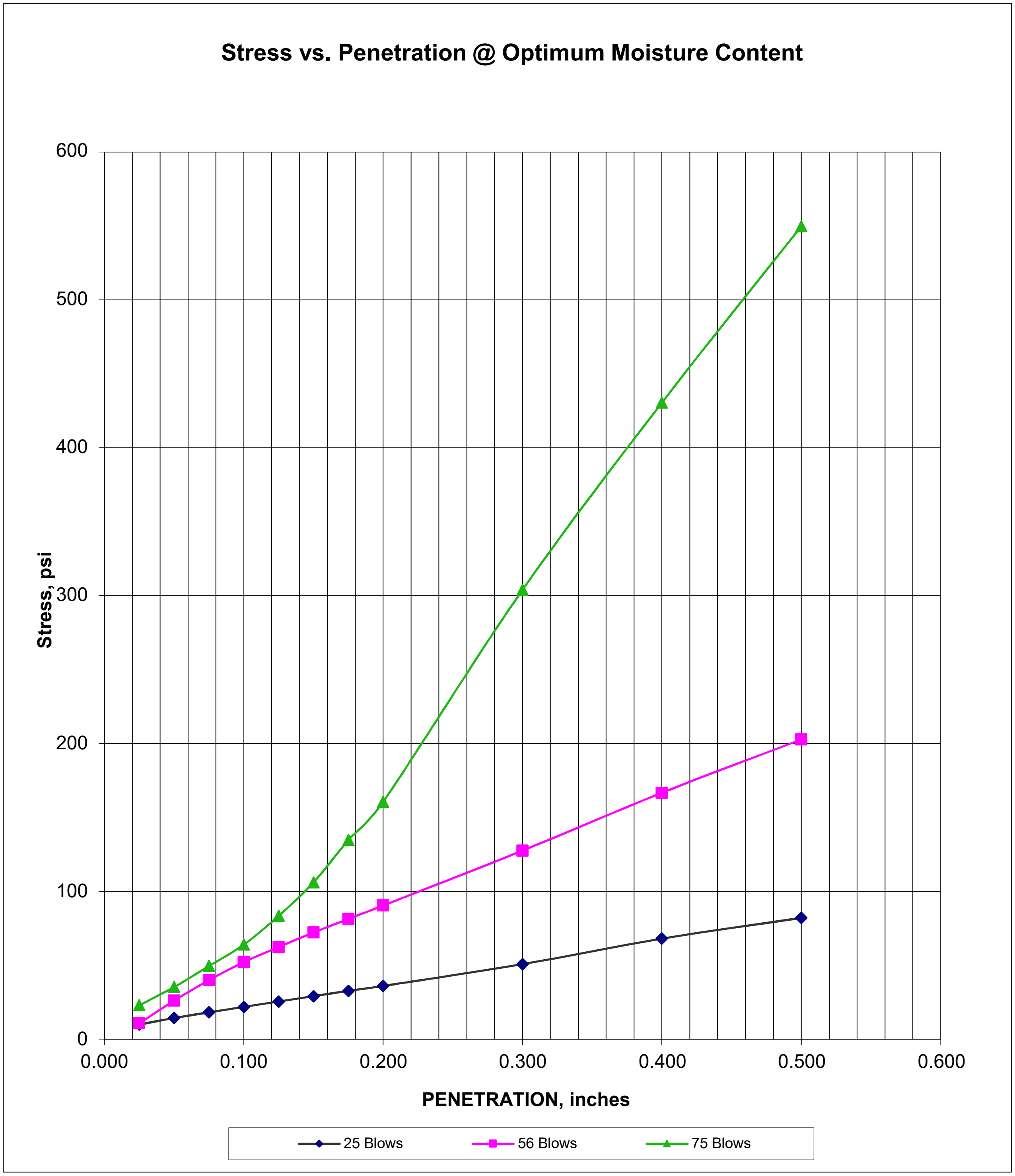


%MDD	Density (kg/m^3)	Corrected CBR
95	2058	2.0
100	2166	6.2
102	2209	12.0

Boring No.	2	Project No.:	61021019
Sample No.	59	Job Name	Geo. Inv. For Marble Canyon
Depth (ft)	5'	Tested By	SF & KC
Date	2017-12-20	Calculated By	SF
Solum No.:	08201170719(91)	Checked By	SF

Solum Consultants Ltd.

STANDARD TEST METHOD for CBR ASTM D1883-05



Boring No.	95.6-2	Project No.:	61021019.00
Sample No.	35A	Job Name	Geo. Inv. For Culvert Sites
Depth (ft)	2.5'	Tested By	SF & KC
Date	2017-12-20	Calculated By	SF
Solum No.:	08201171201(196)	Checked By	SF

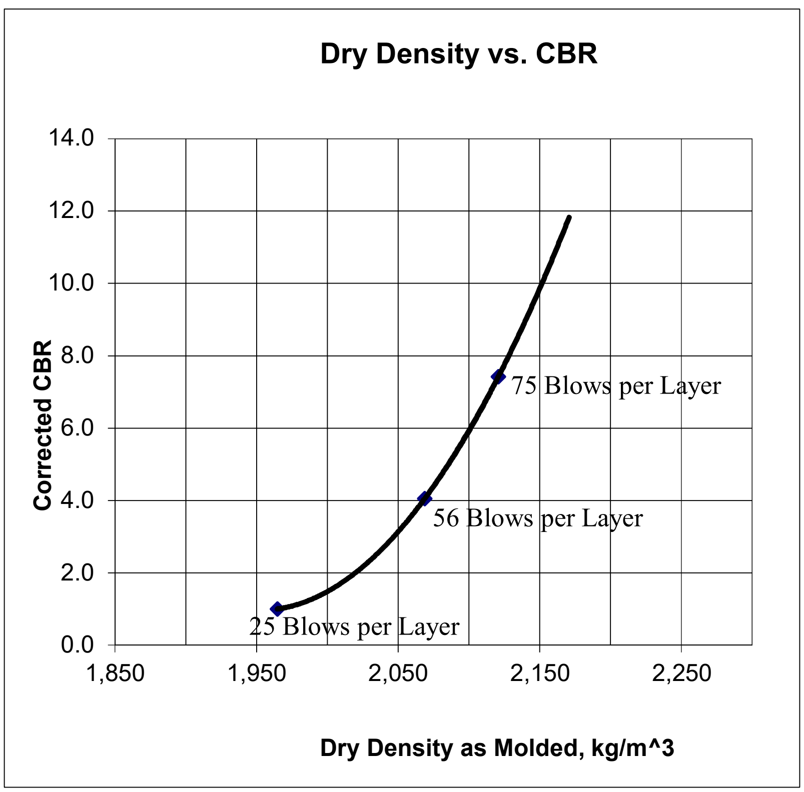
Solum Consultants Ltd.

California Bearing Ratio - ASTM D1883 (One Water Content Only)

(Optimum Moisture Content / Soaked)

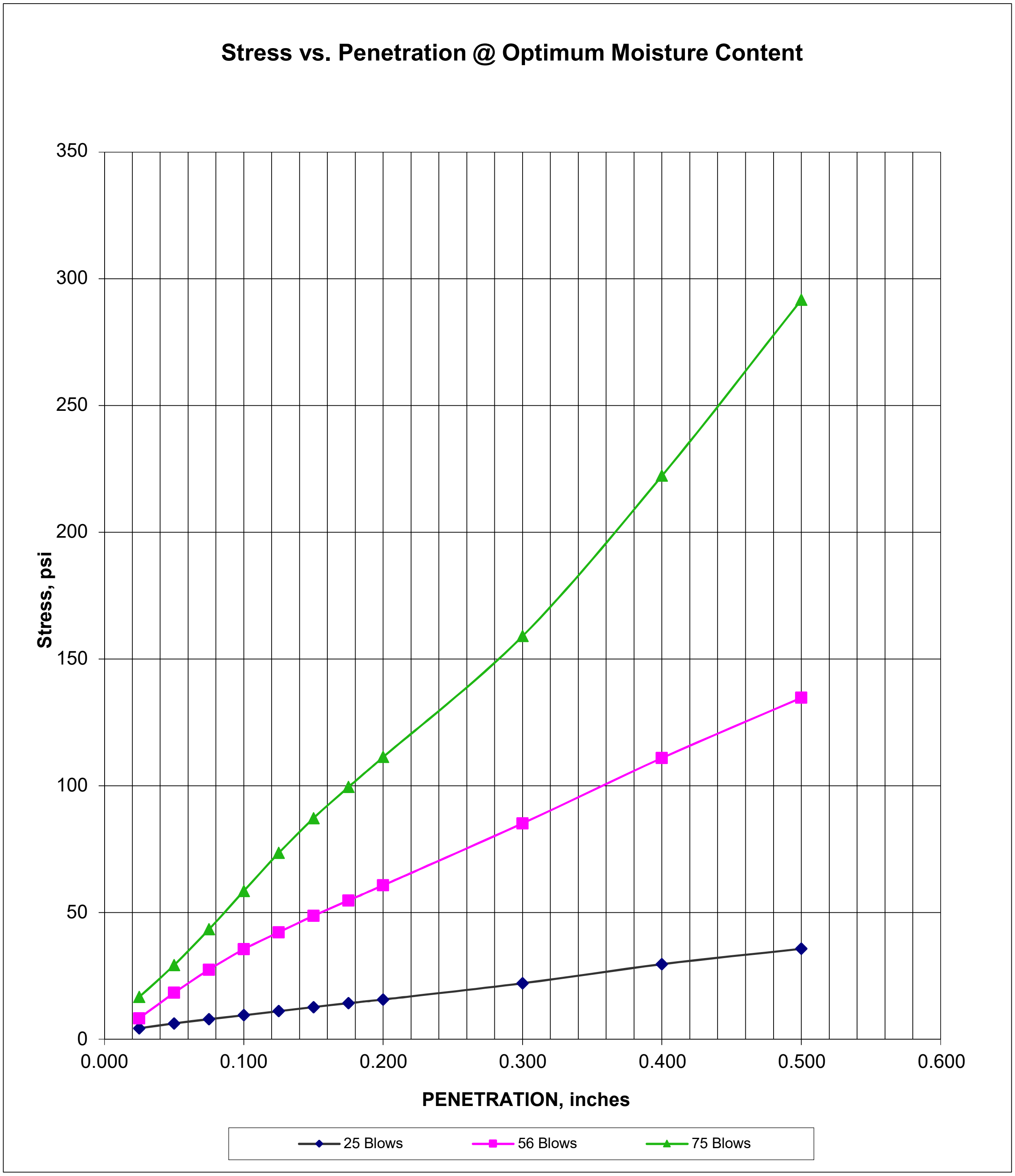
Surcharge Amount: 4.54 kG

	25 Blows	56 Blows	75 Blows
Dry density before soak, kg/m^3	1,965	2,069	2,121
Dry density after soak, kg/m^3	1,969	2,072	2,123
Moisture Content before soak, %	8.6	8.6	8.6
Moisture Content after soak, avg., %	18.9	15.2	12.5
Moisture Content after soak, top 1", %	20.1	18.6	16.9
% Swell(+)/Consolidation(-) after 96 hour soak	-0.2	-0.2	-0.1
Bearing Ratio, 0.200" penetration	1.0	4.0	7.4



%MDD	Density (kg/m^3)	Corrected CBR
95	1987	1.6
100	2092	5.8
102	2134	9.1

Boring No.	2	**Solum Consultants Ltd.**	Project No.:	61021019
Sample No.	59		Job Name	Geo. Inv. For Marble Canyon
Depth (ft)	5'		Tested By	SF & KC
Date	2017-12-20	**STANDARD TEST METHOD**	Calculated By	SF
Solum No.:	08201170719(91)	**for CBR ASTM D1883-05**	Checked By	SF



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GEOTECHNICAL & MATERIAL
TESTING LABORATORY

Client:	**Barr Eng.**
Project Number:	**61021019.00**
Project Name:	**Geo. Inv. For Culvert Sites**
Sample ID:	**100.6-1 #3A**
Depth:	**7.5'**
Reporting Date:	**20-Dec-17**

Test Requested:

- [ ] DSH 3 pts w/ Cycling Plot
- [X] DSH 3 pts

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.

GEOTECHNICAL & MATERIAL TESTING LABORATORY

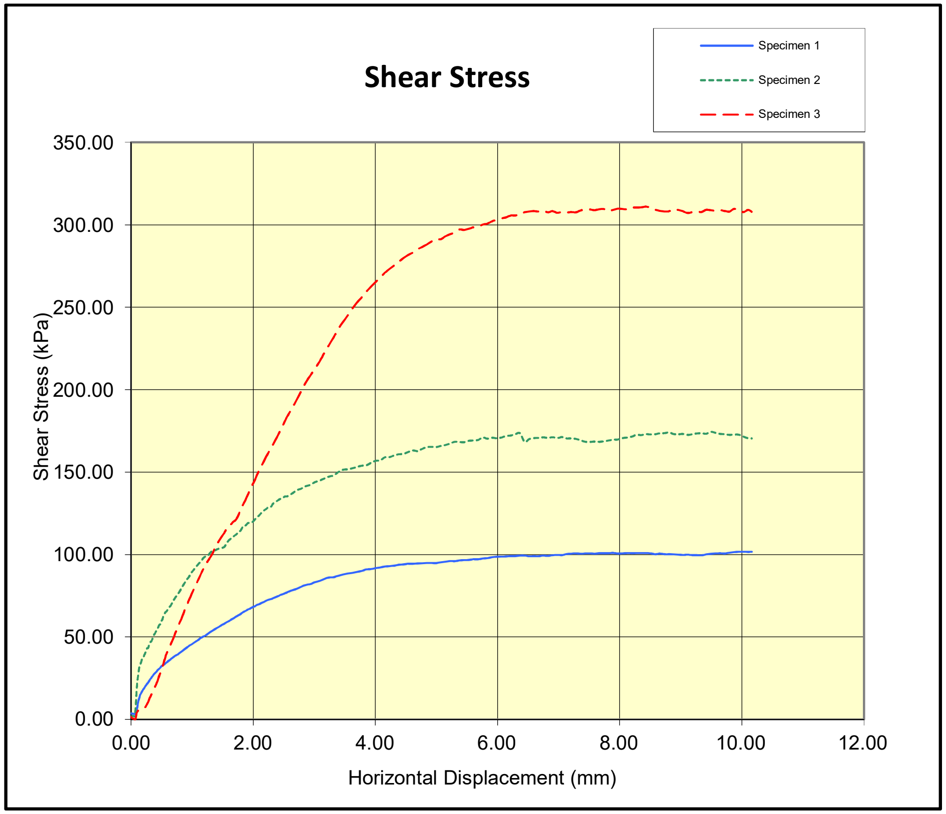
Project Number:	61021019.00
Client:	Barr Eng.
Project Name:	Geo. Inv. For Culvert Sites
Location:	Kootenay National Park

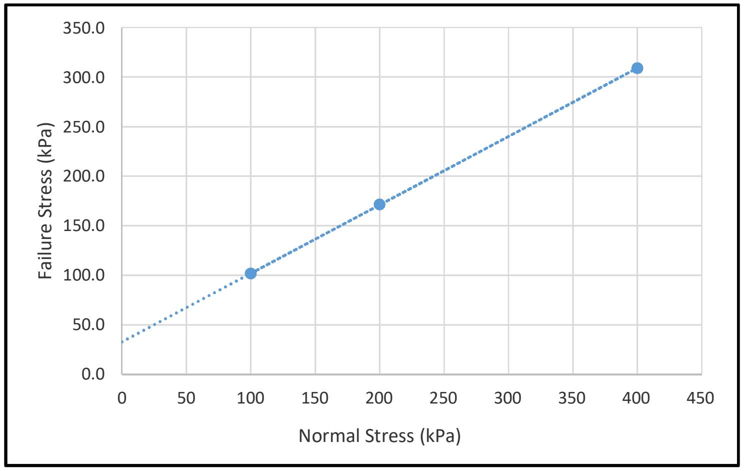
Sample ID:	100.6-1 #3A	Depth:	7.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Test Results

Tested Sample Info: ☐ Undisturbed ☒ Remoulded $\gamma_{wet, initial}$ 2002 (kg/m^3) Initial Mc 1.6 (%)

Specimen No.	Normal Stress (kPa)	Peak Stress(kPa)	Residual Stress(kPa)	Shear Disp.@ Failure (mm)	Shearing Rate (mm/min)	MC After Shearing	Add Water
1	100	101.6	N/A	10.2	0.025	---	yes
2	200	171.3	N/A	10.2	0.025	---	yes
3	400	308.9	N/A	10.2	0.025	---	yes





C, kPa	**32.8**
Ø, deg	**34.6**
Tan (Ø)	**0.69**

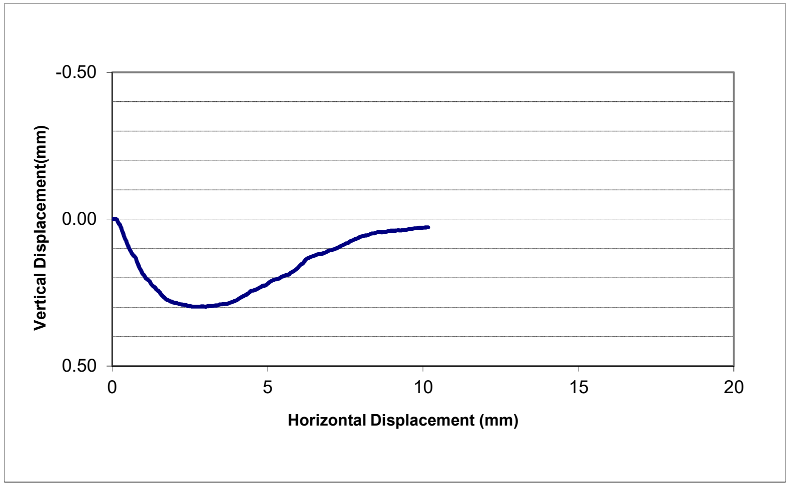
Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

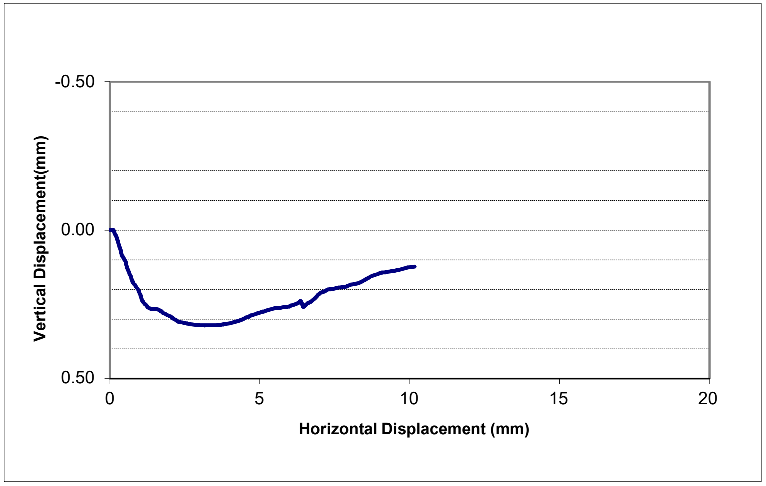
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-1 #3A	Depth:	7.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Height Change

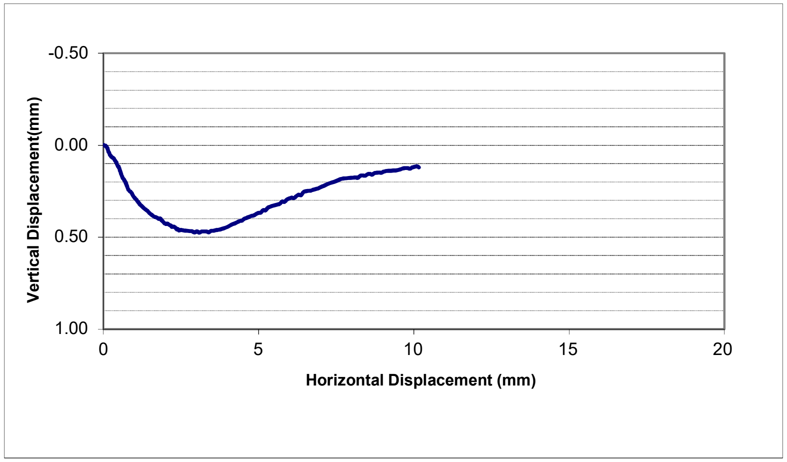
100 kPa



200 kPa



400 kPa



SOLUM™
CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL
TESTING LABORATORY

Client:	**Barr Eng.**
Project Number:	**61021019.00**
Project Name:	**Geo. Inv. For Culvert Sites**
Sample ID:	**100.6-1 #6A**
Depth:	**15.0'**
Reporting Date:	**20-Dec-17**

Test Requested:

- [ ] DSH 3 pts w/ Cycling Plot
- [X] DSH 3 pts

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.

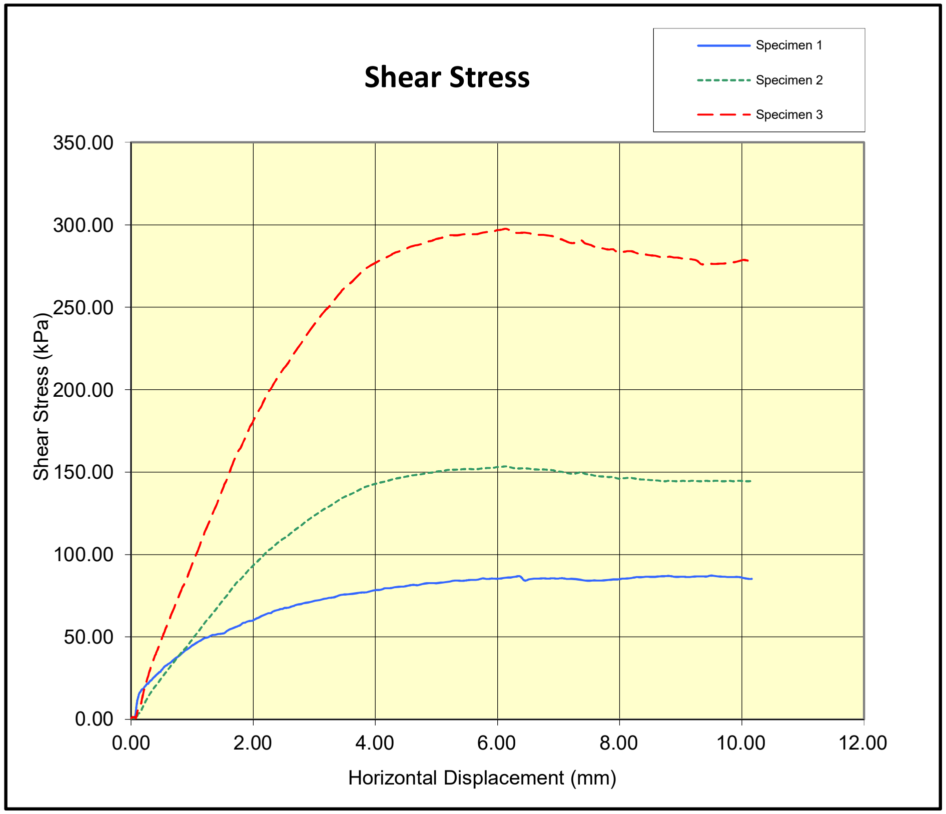
GEOTECHNICAL & MATERIAL TESTING LABORATORY

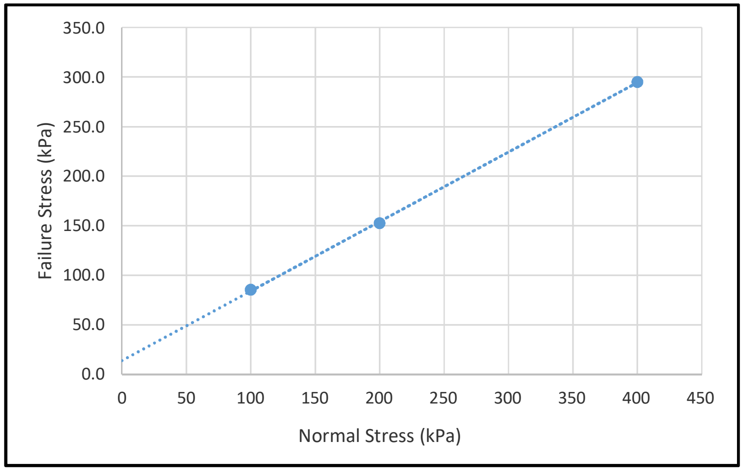
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-1 #6A	Depth:	15.0'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Test Results

Tested Sample Info: ☐ Undisturbed ☒ Remoulded $\gamma_{wet,\ initial}$ 2047 (kg/m^3) Initial Mc 2.6 (%)

Specimen No.	Normal Stress (kPa)	Peak Stress(kPa)	Residual Stress(kPa)	Shear Disp.@ Failure (mm)	Shearing Rate (mm/min)	MC After Shearing	Add Water
1	100	85.2	N/A	10.2	0.025	---	yes
2	200	152.4	N/A	6.2	0.025	---	yes
3	400	295.0	N/A	6.4	0.025	---	yes





C, kPa	13.9
Ø, deg	35.0
Tan (Ø)	0.70

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™
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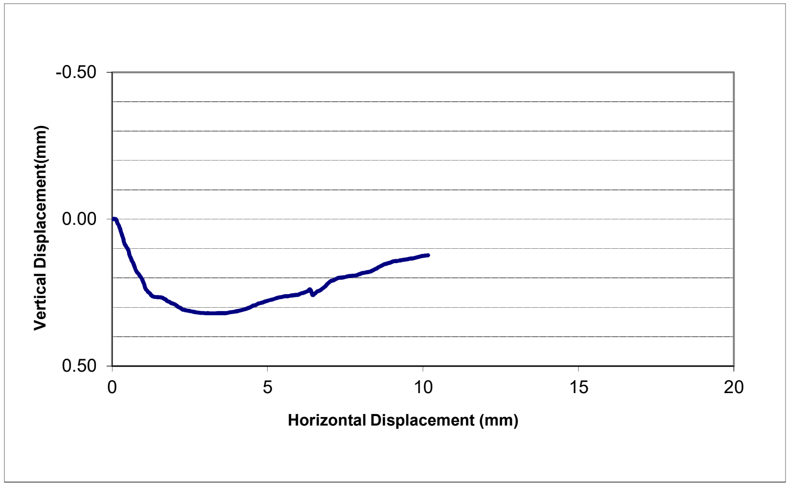
GEOTECHNICAL & MATERIAL TESTING LABORATORY

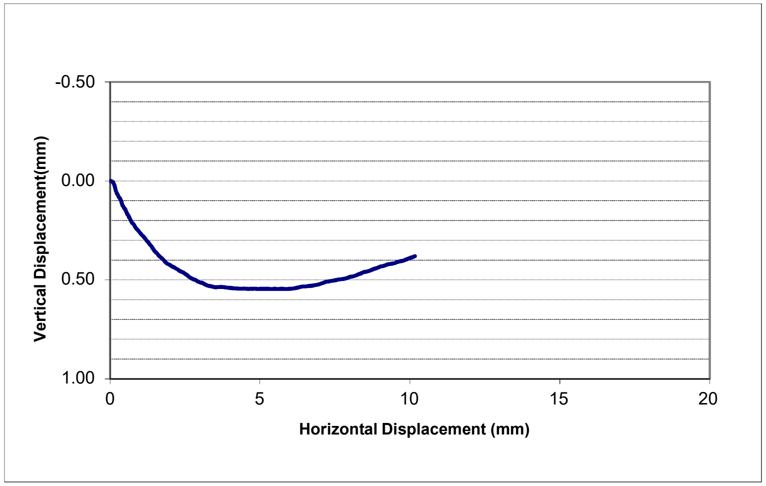
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-1 #6A	Depth:	15.0'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Height Change

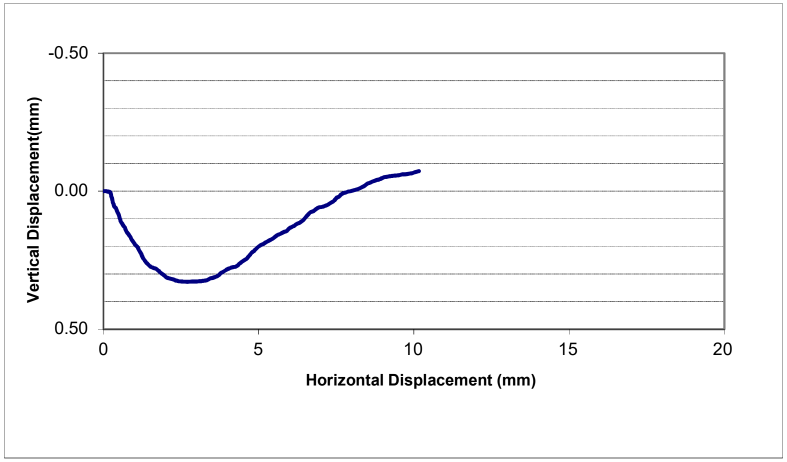
100 kPa



200 kPa



400 kPa



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GEOTECHNICAL & MATERIAL
TESTING LABORATORY

Client:	**Barr Eng.**
Project Number:	**61021019.00**
Project Name:	**Geo. Inv. For Culvert Sites**
Sample ID:	**100.6-1 #9A**
Depth:	**15.0'**
Reporting Date:	**20-Dec-17**

Test Requested:

- [ ] DSH 3 pts w/ Cycling Plot
- [X] DSH 3 pts

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.

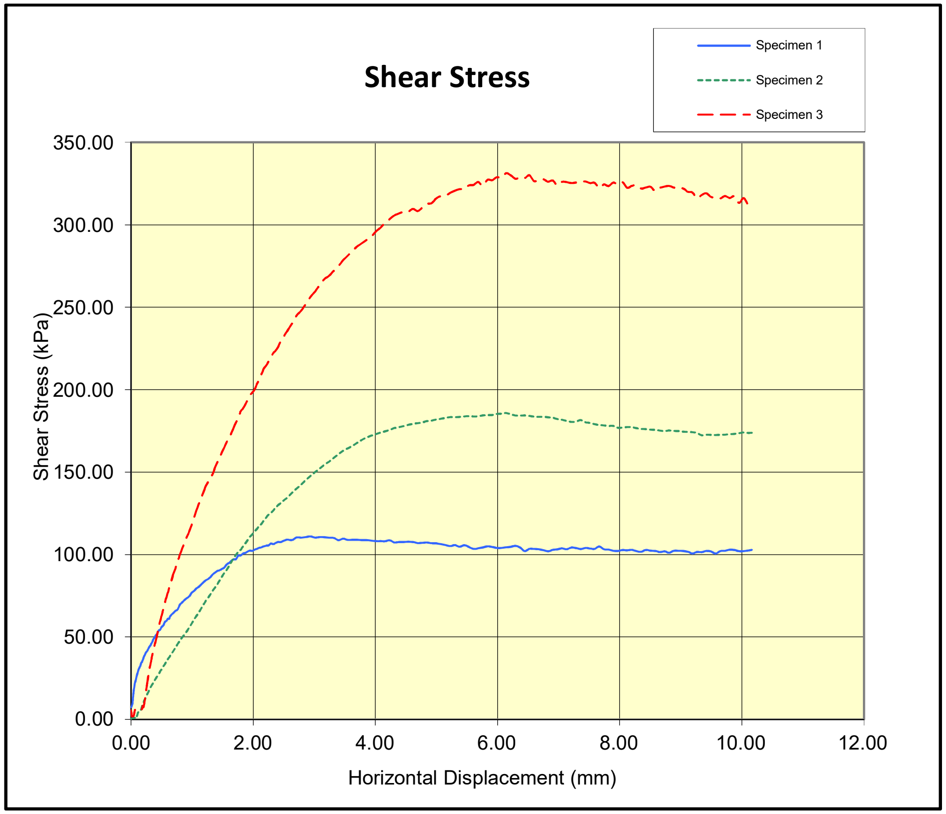
GEOTECHNICAL & MATERIAL TESTING LABORATORY

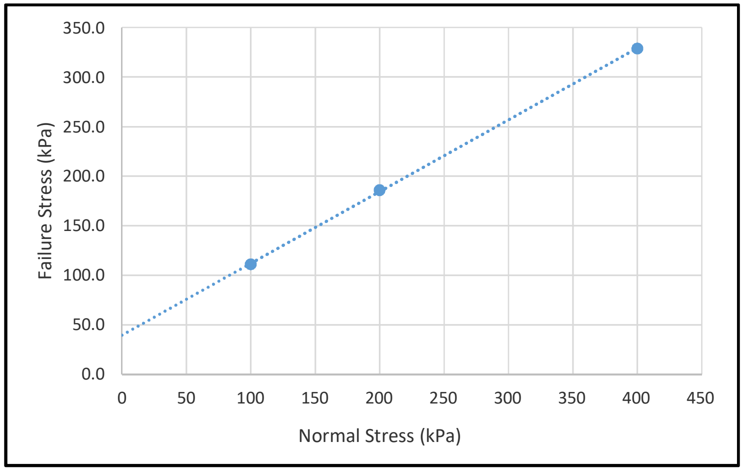
Project Number:	61021019.00
Client:	Barr Eng.
Project Name:	Geo. Inv. For Culvert Sites
Location:	Kootenay National Park
Sample ID:	100.6-1 #9A
Depth:	15.0'
Tested By:	SF/KC
Reviewed By:	SF
Date of Testing:	20-Dec-17 (dd-mmm-yy)

Test Results

Tested Sample Info: ☐ Undisturbed ☒ Remoulded $\gamma_{wet,\ initial}$ 2130 (kg/m^3) Initial Mc 9.2 (%)

Specimen No.	Normal Stress (kPa)	Peak Stress(kPa)	Residual Stress(kPa)	Shear Disp.@ Failure (mm)	Shearing Rate (mm/min)	MC After Shearing	Add Water
1	100	111.0	N/A	3.1	0.025	---	yes
2	200	185.8	N/A	6.1	0.025	---	yes
3	400	328.7	N/A	6.0	0.025	---	yes





C, kPa	39.5
Ø, deg	35.9
Tan (Ø)	0.72

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

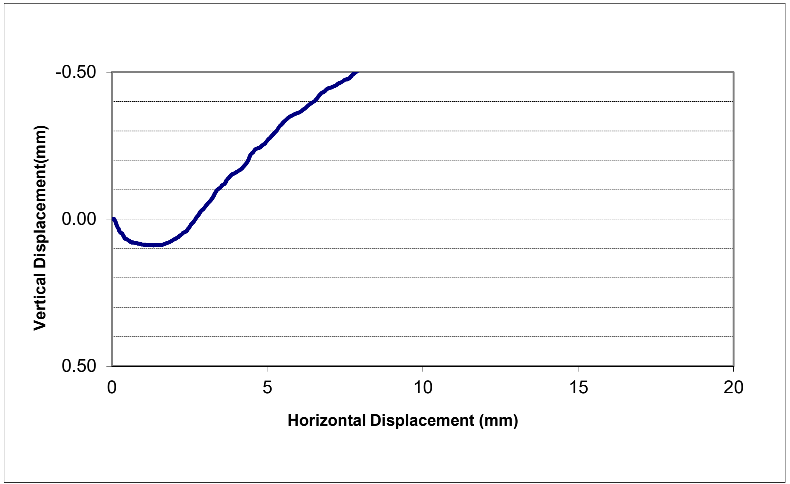
SOLUM™ CONSULTANTS LTD.

GEOTECHNICAL & MATERIAL TESTING LABORATORY

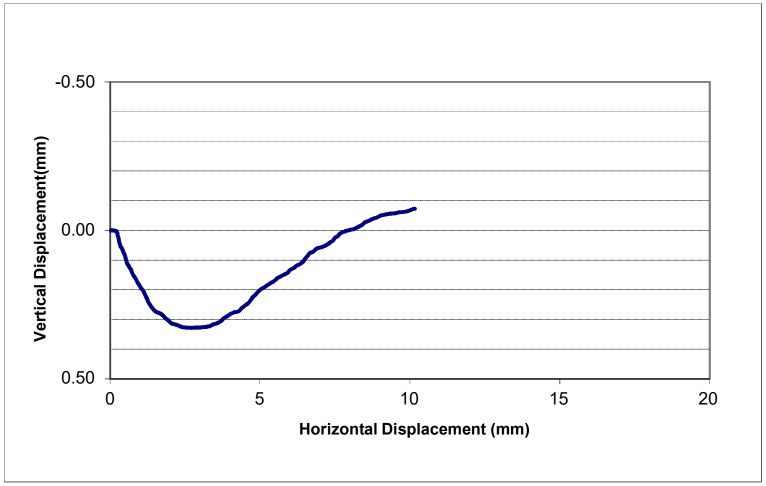
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-1 #9A	Depth:	15.0'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Height Change

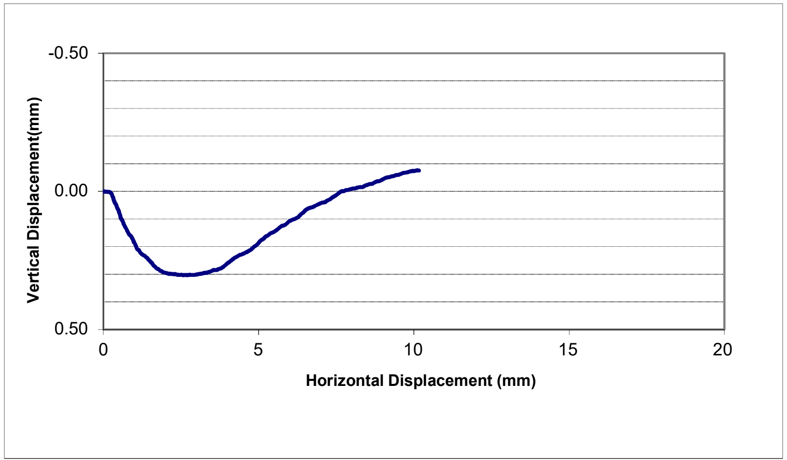
100 kPa



200 kPa



400 kPa



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GEOTECHNICAL & MATERIAL
TESTING LABORATORY

Client:	**Barr Eng.**
Project Number:	**61021019.00**
Project Name:	**Geo. Inv. For Culvert Sites**
Sample ID:	**100.6-2 #15A**
Depth:	**7.5'**
Reporting Date:	**20-Dec-17**

Test Requested:

- [ ] DSH 3 pts w/ Cycling Plot
- [X] DSH 3 pts

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.

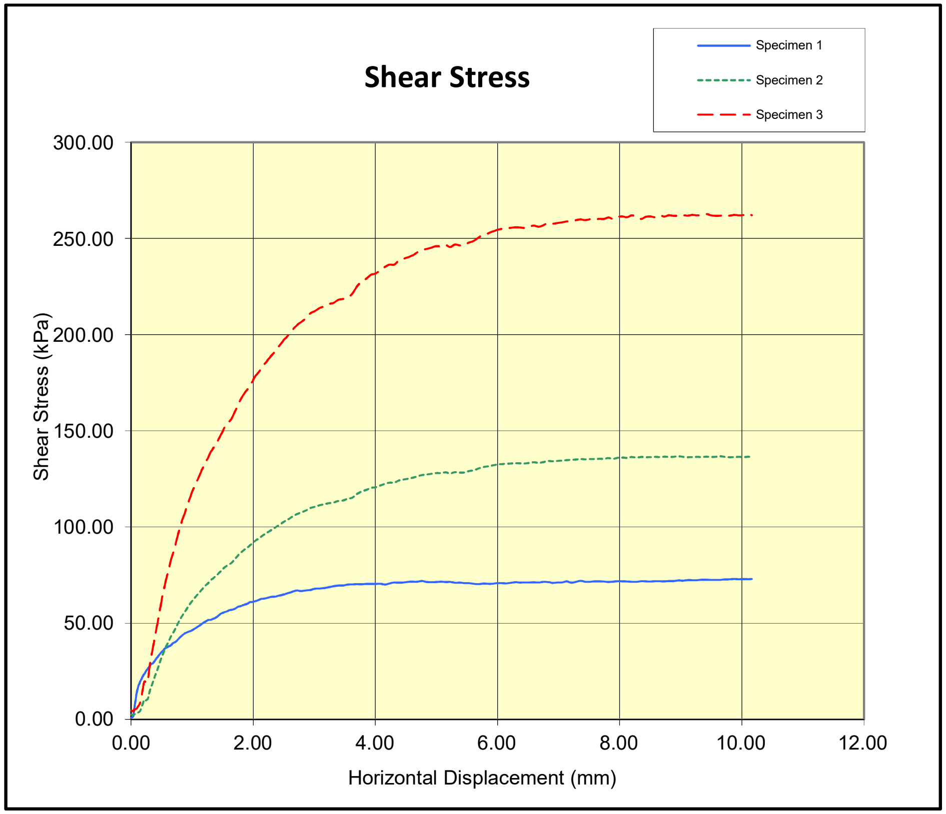
GEOTECHNICAL & MATERIAL TESTING LABORATORY

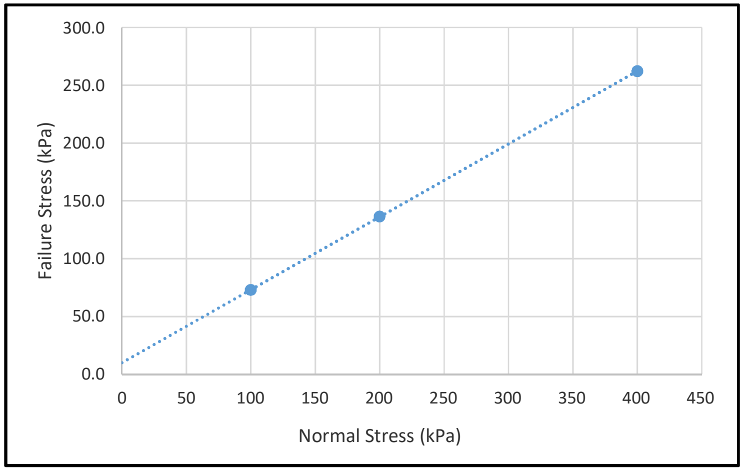
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-2 #15A	Depth:	7.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Test Results

Tested Sample Info: ☐ Undisturbed ☒ Remoulded $\gamma_{wet,\ initial}$ 2114 (kg/m^3) Initial Mc 16.9 (%)

Specimen No.	Normal Stress (kPa)	Peak Stress(kPa)	Residual Stress(kPa)	Shear Disp.@ Failure (mm)	Shearing Rate (mm/min)	MC After Shearing	Add Water
1	100	72.9	N/A	10.2	0.025	---	yes
2	200	136.5	N/A	10.2	0.025	---	yes
3	400	262.2	N/A	10.2	0.025	---	yes





C, kPa	10.1
Ø, deg	32.3
Tan (Ø)	0.63

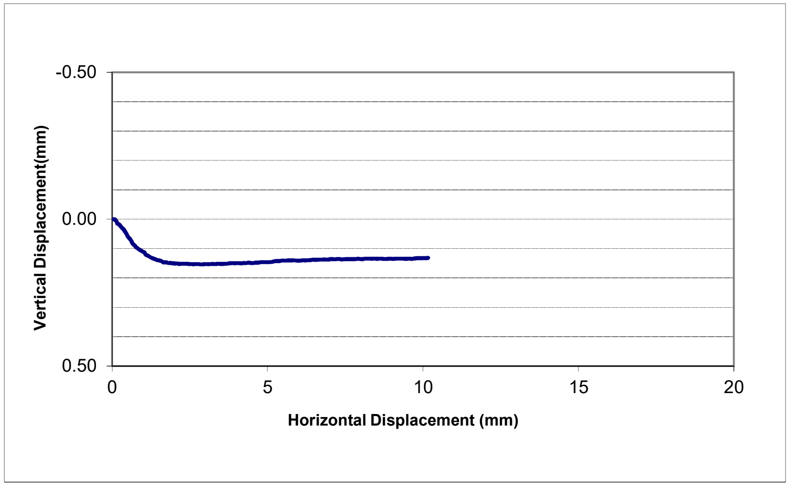
Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

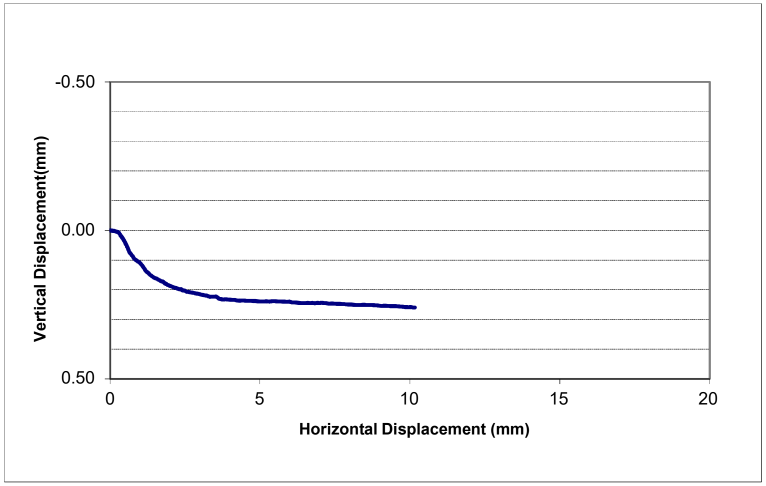
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	100.6-2 #15A	Depth:	7.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Height Change

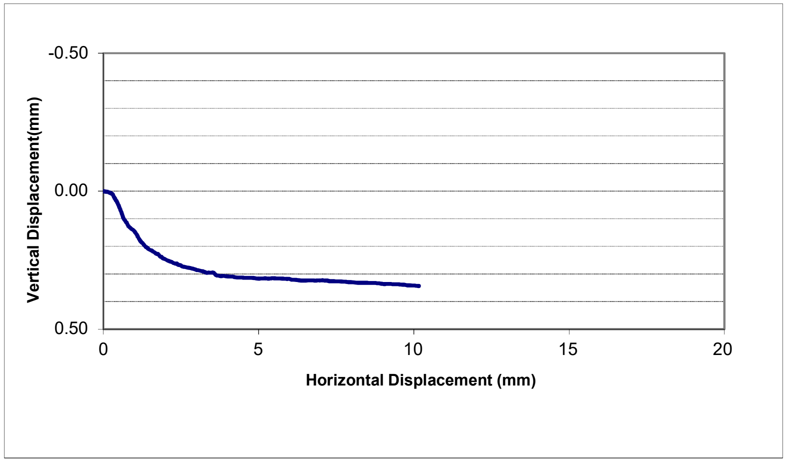
100 kPa



200 kPa



400 kPa



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GEOTECHNICAL & MATERIAL
TESTING LABORATORY

Client:	**Barr Eng.**
Project Number:	**61021019.00**
Project Name:	**Geo. Inv. For Culvert Sites**
Sample ID:	**95.6-1 28A**
Depth:	**2.5'**
Reporting Date:	**20-Dec-17**

Test Requested:

- [ ] DSH 3 pts w/ Cycling Plot
- [X] DSH 3 pts

Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.

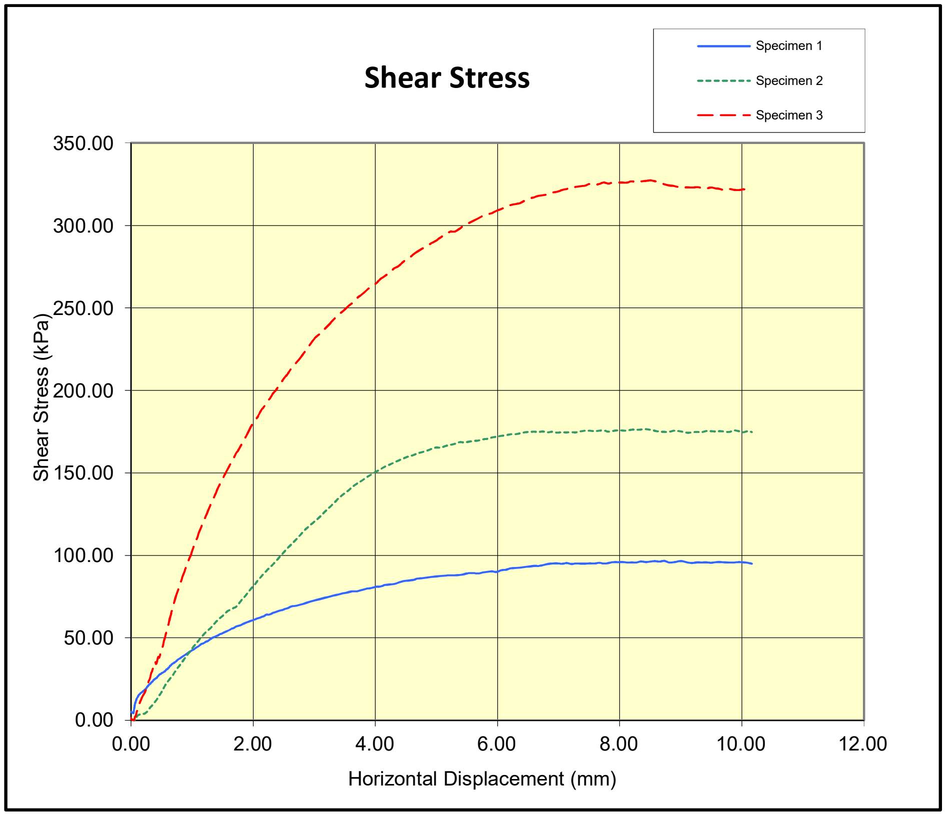
GEOTECHNICAL & MATERIAL TESTING LABORATORY

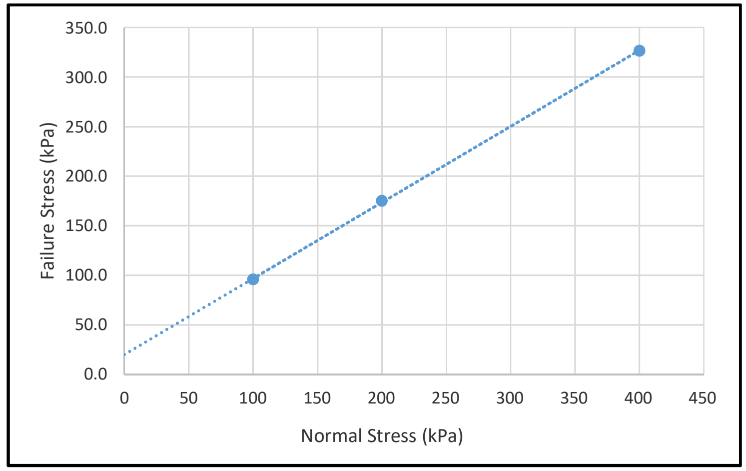
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	95.6-1 28A	Depth:	2.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Test Results

Tested Sample Info: ☐ Undisturbed ☒ Remoulded $\gamma_{wet, initial}$ 2012 (kg/m^3) Initial Mc 8.4 (%)

Specimen No.	Normal Stress (kPa)	Peak Stress(kPa)	Residual Stress(kPa)	Shear Disp.@ Failure (mm)	Shearing Rate (mm/min)	MC After Shearing	Add Water
1	100	95.7	N/A	10.2	0.025	---	yes
2	200	175.0	N/A	10.2	0.025	---	yes
3	400	326.4	N/A	10.2	0.025	---	yes





C, kPa	**20.0**
Ø, deg	**37.5**
Tan (Ø)	**0.77**

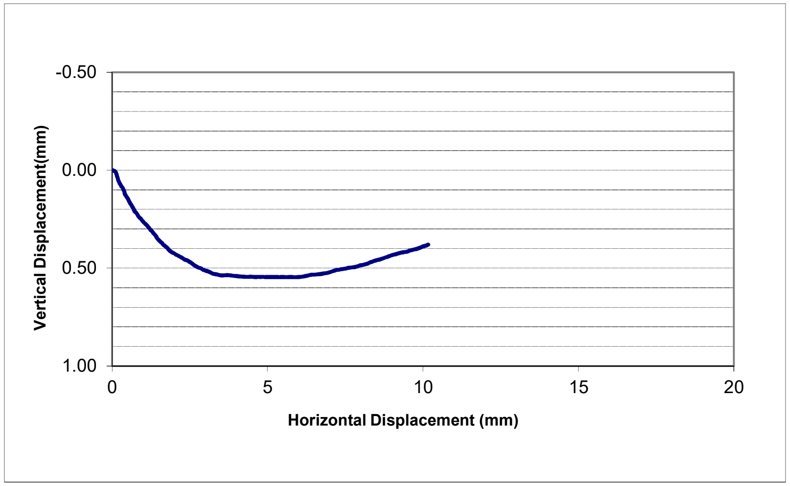
Direct Shear Test of Soils Under Consolidated Drained Conditions - ASTM D3080

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

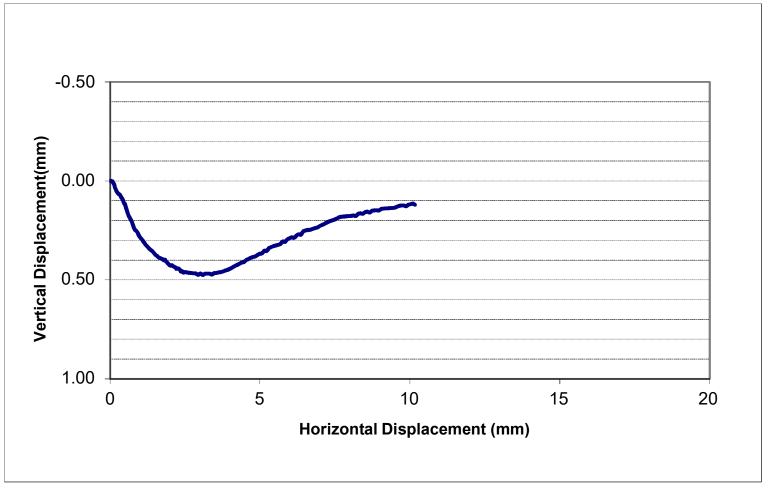
Project Number:	61021019.00		
Client:	Barr Eng.		
Project Name:	Geo. Inv. For Culvert Sites		
Location:	Kootenay National Park		
Sample ID:	95.6-1 28A	Depth:	2.5'
Tested By:	SF/KC	Reviewed By:	SF
Date of Testing:	20-Dec-17	(dd-mmm-yy)	

Height Change

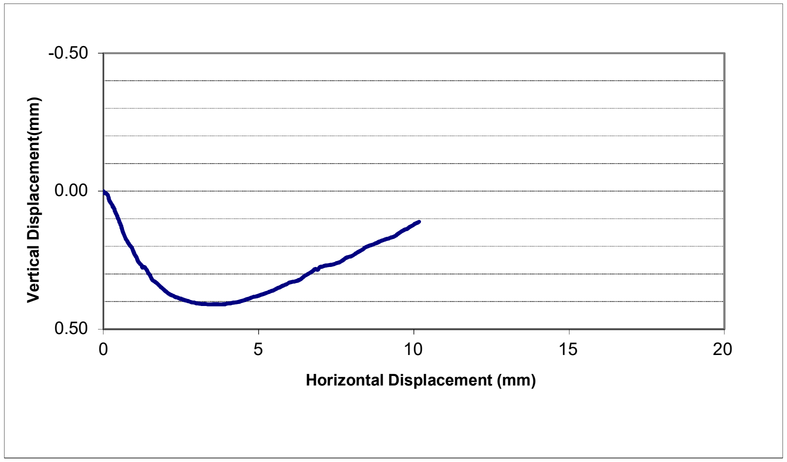
100 kPa



200 kPa



400 kPa



CONSOLIDATION TEST DATA

2017-12-20

Client: Barr Eng.
Project: Geo. Inv. for Culvert Sites
Project Number: 61021019.00
Depth: 25.0' **Sample Number:** 100.6-1 #9A

Test Specimen Data

NATURAL MOISTURE		VOID RATIO		AFTER TEST	
Wet w+t =	92.81 g.	**Spec. Gr.**	= 2.7	**Wet w+t =**	172.10 g.
Dry w+t =	85.07 g.	**Est. Ht. Solids**	= 1.429 cm.	**Dry w+t =**	160.17 g.
Tare Wt. =	12.56 g.	**Init. V.R.**	= 0.399	**Tare Wt. =**	43.00 g.
Moisture =	10.7 %	**Init. Sat.**	= 72.3 %	**Moisture =**	10.2 %

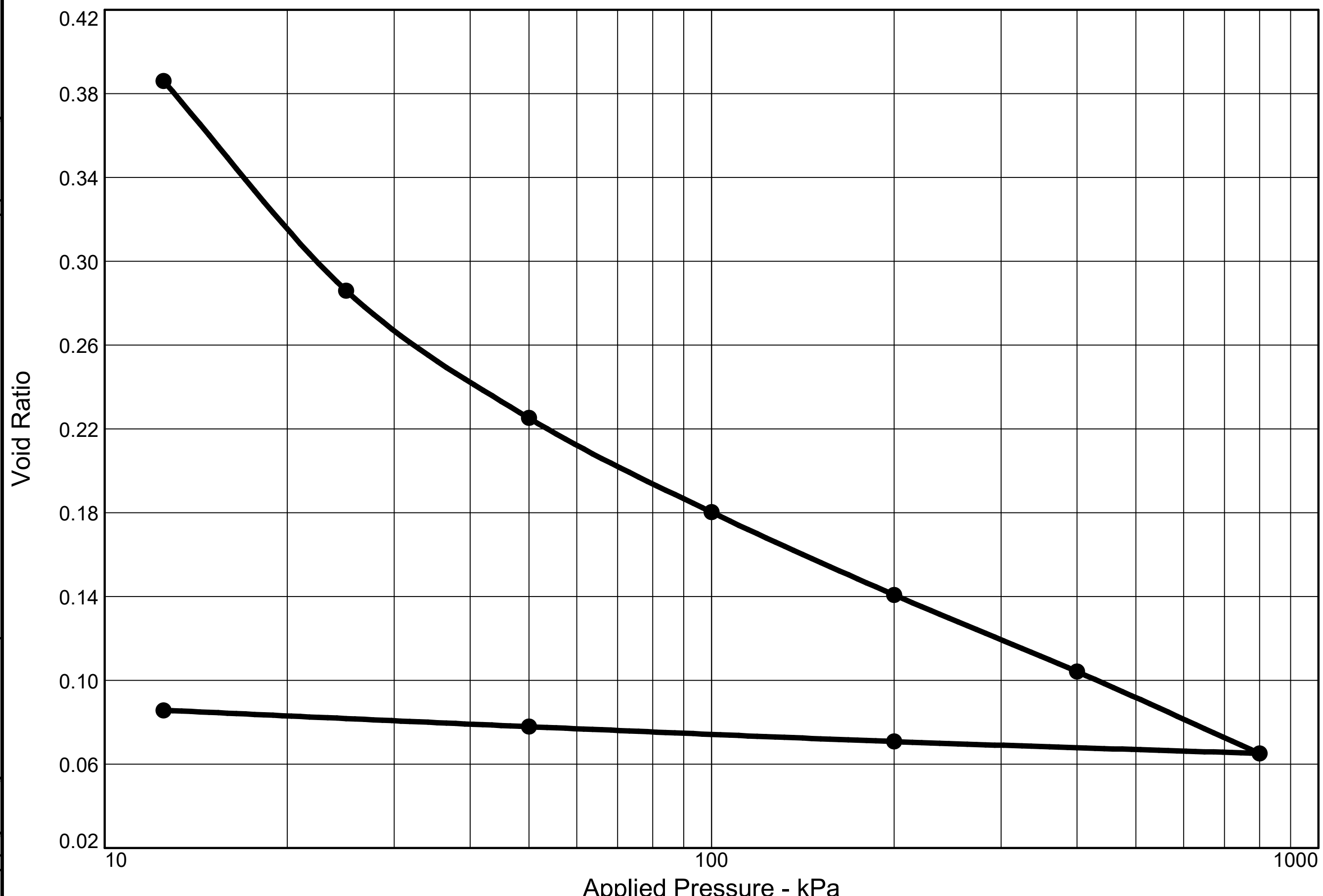
UNIT WEIGHT		TEST START			
				Dry Wt. =	117.17 g.
Height =	0.787 in.	**Height**	= 0.787 in.		
Diameter =	2.433 in.	**Diameter**	= 2.433 in.		
Weight =	128.10 g.				
Dry Dens. =	1930 kg/m^3				

End-Of-Load Summary

Pressure (kPa)	Final Dial (in.)	Deformation (in.)	C_v (cm.^{2}/min.)	C_α	Void Ratio	% Strain
start	0.00000	0.00000			0.399	
12.5	-0.00710	0.00710	0.151		0.386	0.9 Comprs.
25.0	-0.06340	0.06340	1.241		0.286	8.1 Comprs.
50.0	-0.09760	0.09760	0.515		0.225	12.4 Comprs.
100.0	-0.12290	0.12290	0.490		0.180	15.6 Comprs.
200.0	-0.14510	0.14510	0.346		0.141	18.4 Comprs.
400.0	-0.16570	0.16570	0.196		0.104	21.1 Comprs.
800.0	-0.18770	0.18770	0.159		0.065	23.9 Comprs.
200.0	-0.18450	0.18450	2.070		0.071	23.4 Comprs.
50.0	-0.18050	0.18050	0.440		0.078	22.9 Comprs.
12.5	-0.17610	0.17610	0.085		0.086	22.4 Comprs.

Compression index (C_c), kPa = 0.12 **Preconsolidation pressure (P_p), kPa =** 0

CONSOLIDATION TEST REPORT



Coefficients of Consolidation and Secondary Consolidation											
No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α
1	12.5	0.151		9	50.0	0.440					
2	25.0	1.241		10	12.5	0.085					
3	50.0	0.515									
4	100.0	0.490									
5	200.0	0.346									
6	400.0	0.196									
7	800.0	0.159									
8	200.0	2.070									

Natural		Dry Dens. (kg/m^3)	LL	PI	Sp. Gr.	P_c (kPa)	C_c	Initial Void Ratio
Saturation	Moisture							
72.3 %	10.7 %	1930			2.7	0	0.12	0.399

MATERIAL DESCRIPTION	USCS	AASHTO

Project No. 61021019.00 **Client:** Barr Eng.

Project: Geo. Inv. for Culvert Sites

Depth: 25.0' **Sample Number:** 100.6-1 #9A

SOLUM CONSULTANTS LTD
GEOTECHNICAL & MATERIAL TESTING LABORATORY

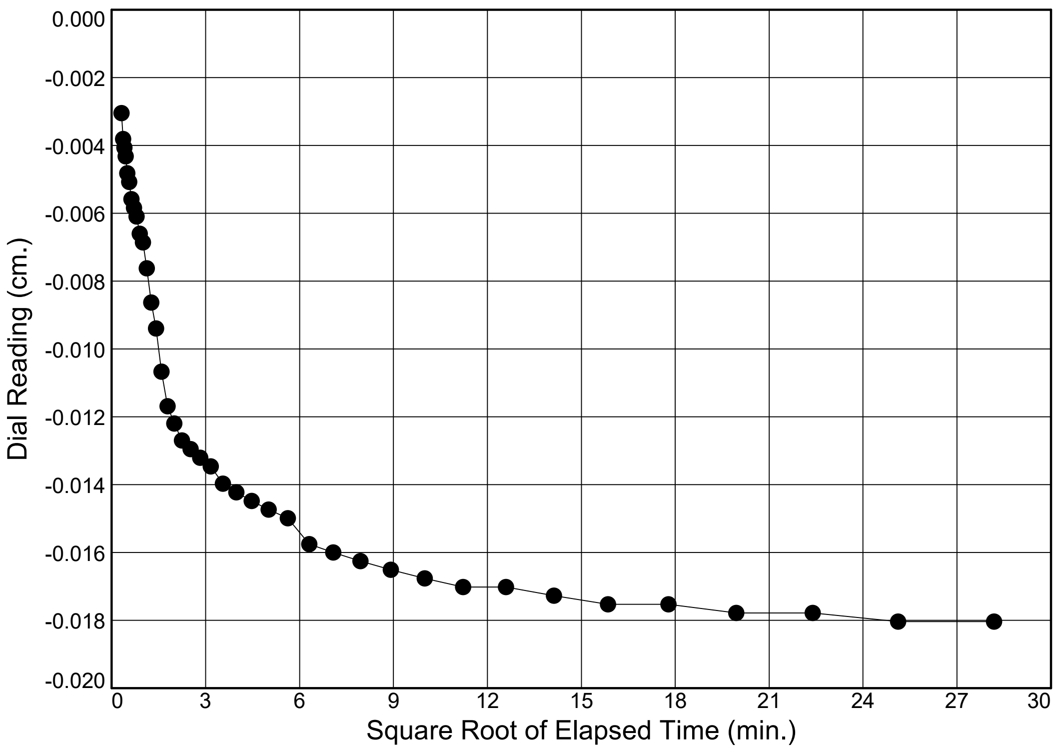
Remarks:

Figure

Dial Reading vs. Time

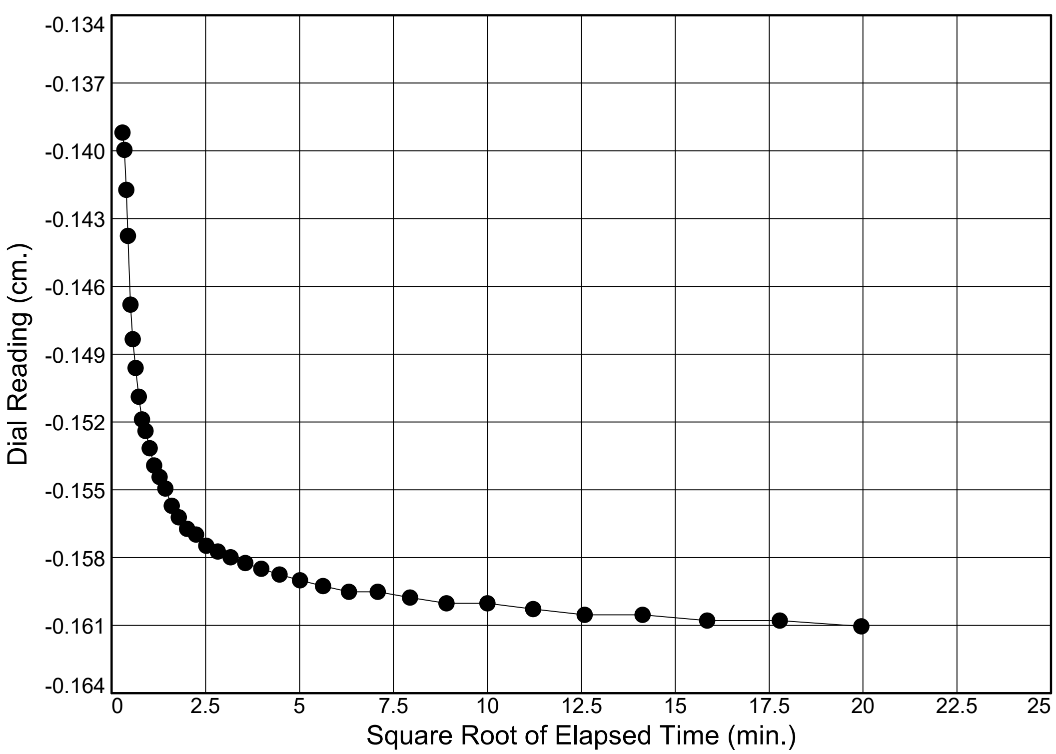
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0'   Sample Number: 100.6-1 #9A



Load No.= 1
Load= 12.5 kPa
D_0 = -0.0048
D_{90} = -0.0325
D_{100} = -0.0356
T_{90} = 5.57 min.

C_v @ T_{90}
0.151 cm.^{2}/min.



Load No.= 2
Load= 25.0 kPa
D_0 = -0.3284
D_{90} = -0.3846
D_{100} = -0.3909
T_{90} = 0.59 min.

C_v @ T_{90}
1.241 cm.^{2}/min.

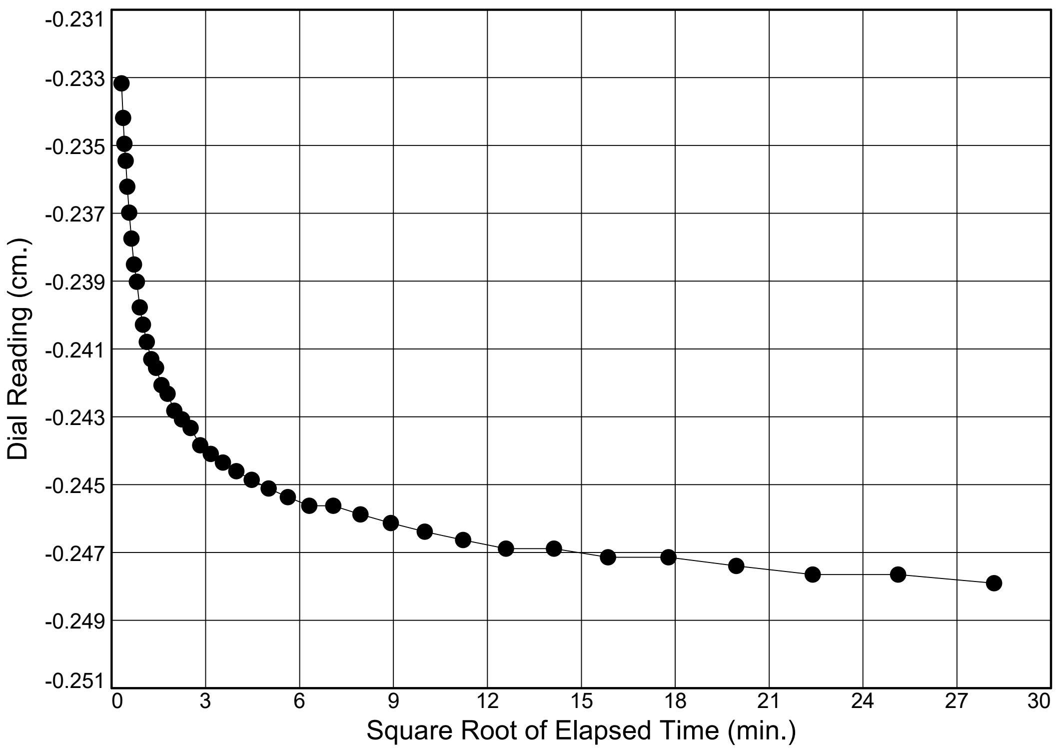
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

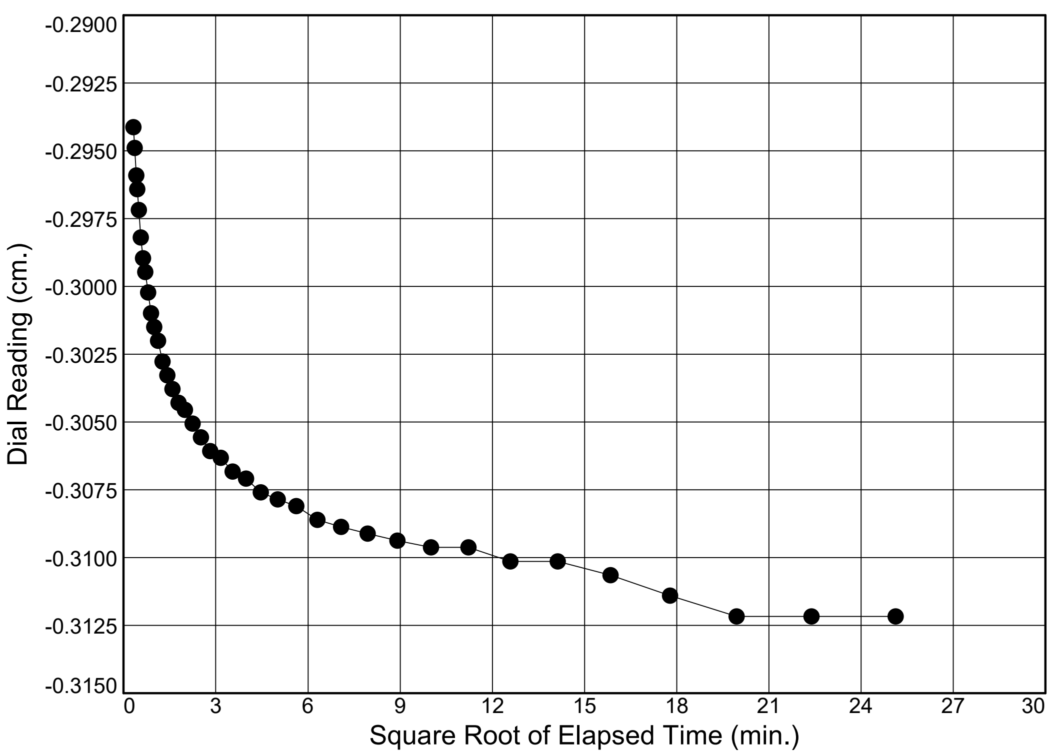
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-1 #9A



Load No.= 3
Load= 50.0 kPa
D_0 = -0.5862
D_{90} = -0.6117
D_{100} = -0.6145
T_{90} = 1.28 min.

C_v @ T_{90}
0.515 cm.^{2}/min.



Load No.= 4
Load= 100.0 kPa
D_0 = -0.7404
D_{90} = -0.7670
D_{100} = -0.7700
T_{90} = 1.25 min.

C_v @ T_{90}
0.490 cm.^{2}/min.

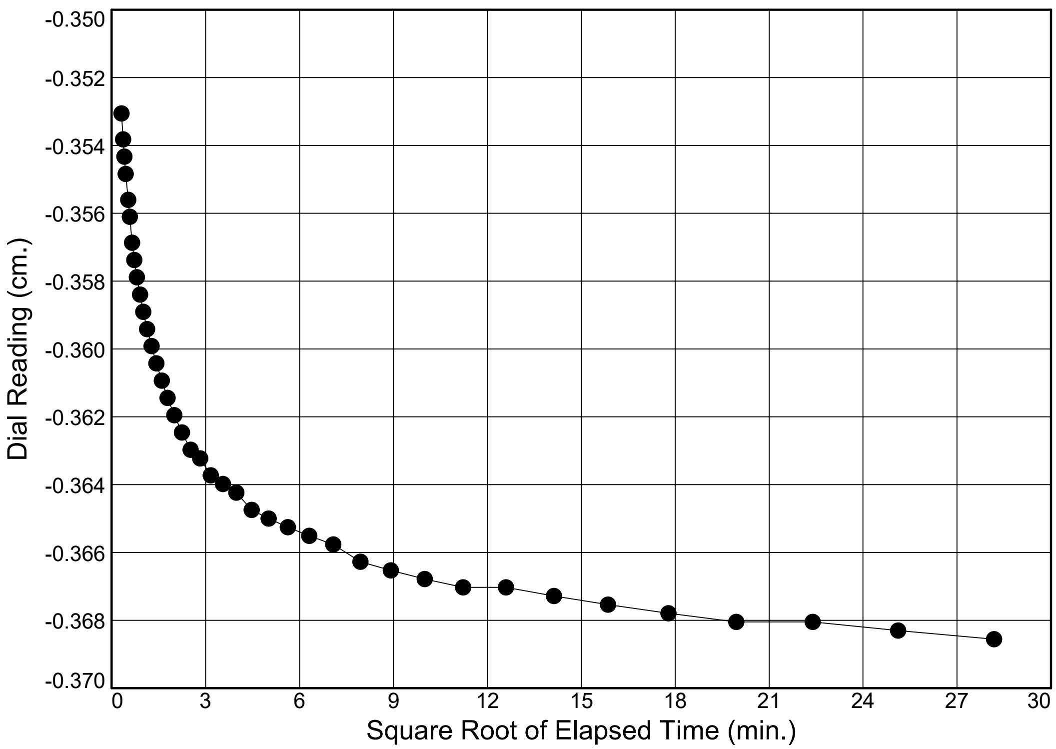
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

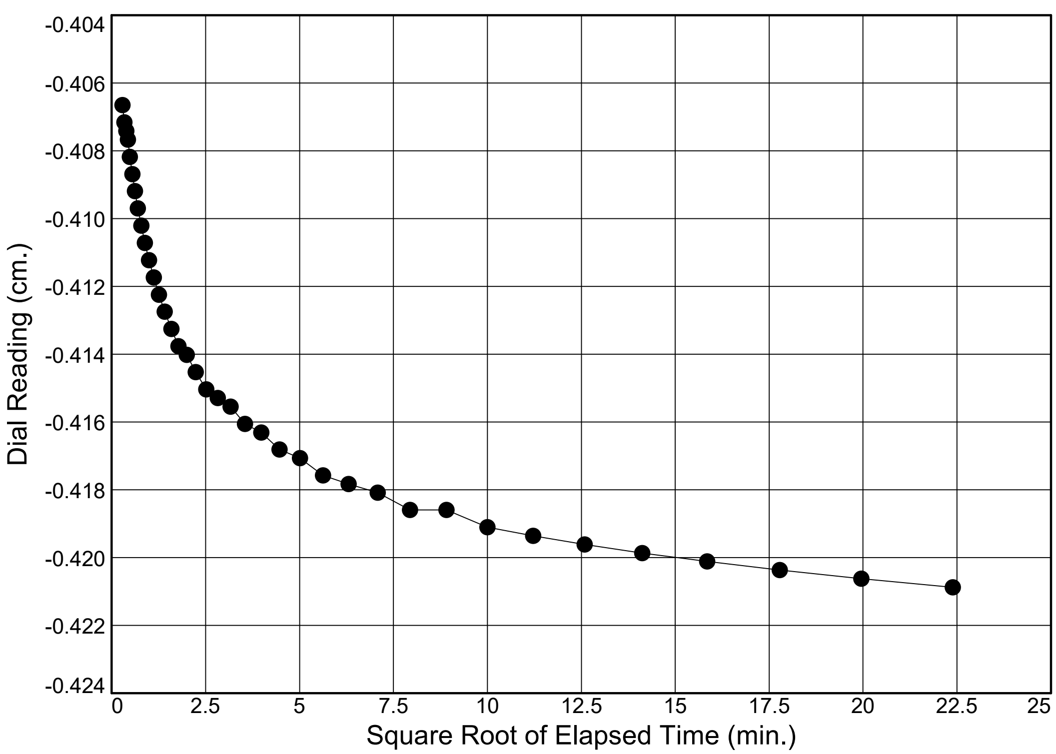
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-1 #9A



Load No.= 5
Load= 200.0 kPa
D_0 = -0.8923
D_{90} = -0.9143
D_{100} = -0.9167
T_{90} = 1.65 min.

C_v @ T_{90}
0.346 cm.^{2}/min.



Load No.= 6
Load= 400.0 kPa
D_0 = -1.0300
D_{90} = -1.0501
D_{100} = -1.0523
T_{90} = 2.72 min.

C_v @ T_{90}
0.196 cm.^{2}/min.

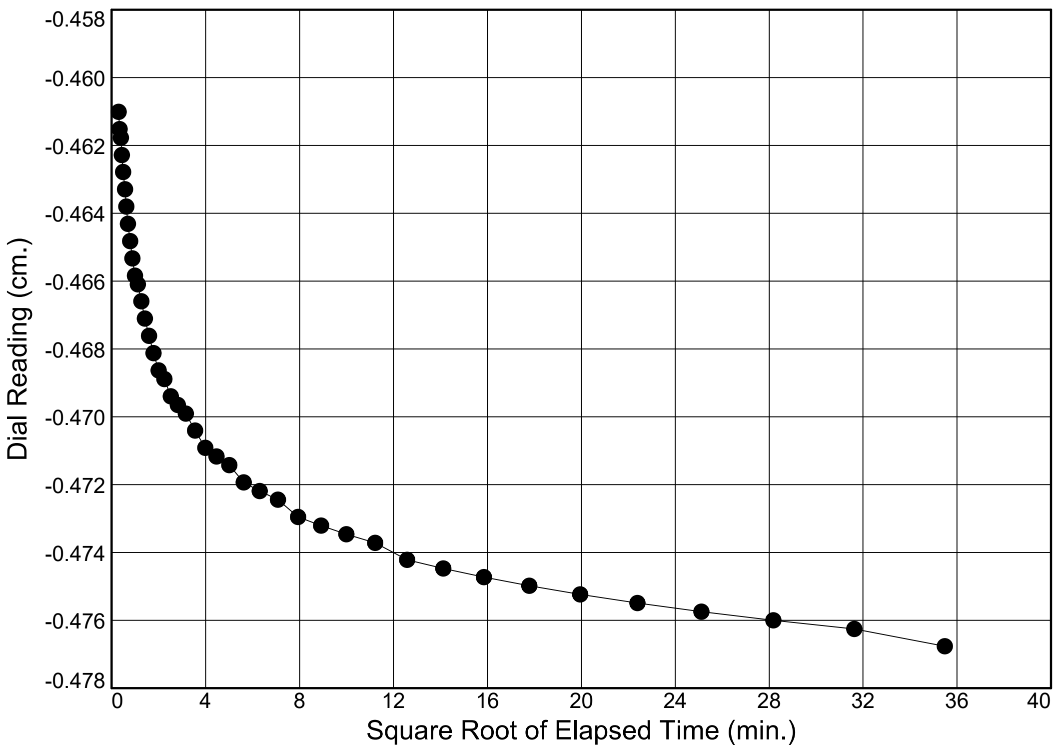
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

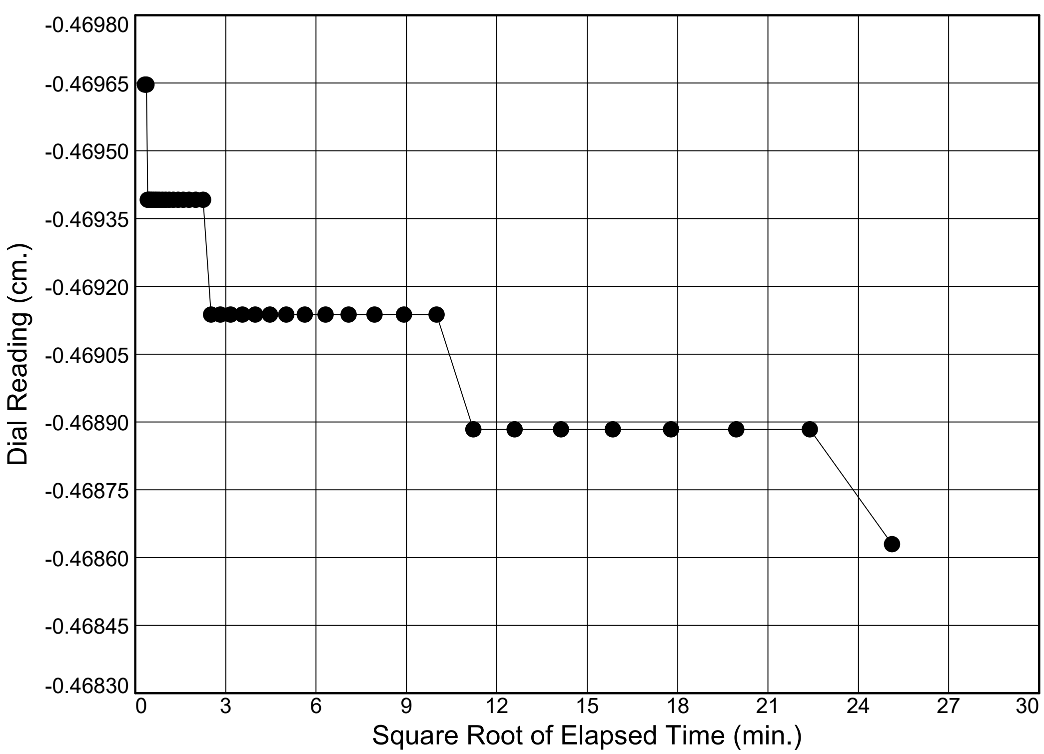
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-1 #9A



Load No.= 7
Load= 800.0 kPa
D_0 = -1.1690
D_{90} = -1.1890
D_{100} = -1.1912
T_{90} = 3.13 min.

C_v @ T_{90}
0.159 cm.^{2}/min.



Load No.= 8
Load= 200.0 kPa
D_0 = -1.1952
D_{90} = -1.1923
D_{100} = -1.1919
T_{90} = 0.24 min.

C_v @ T_{90}
2.070 cm.^{2}/min.

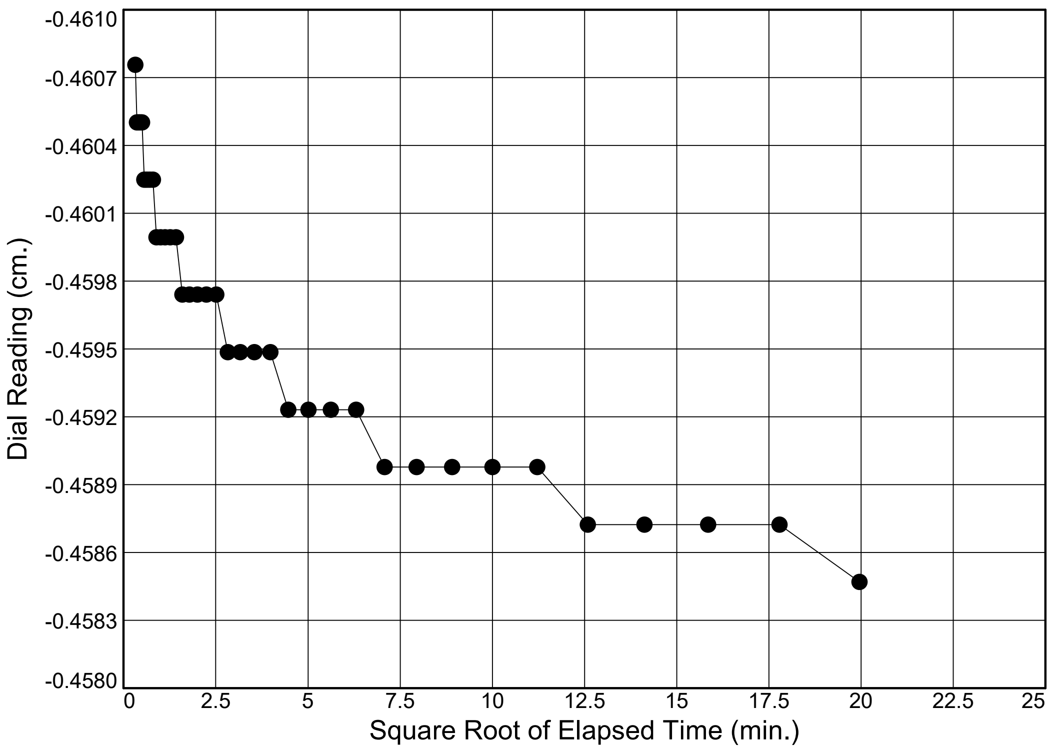
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

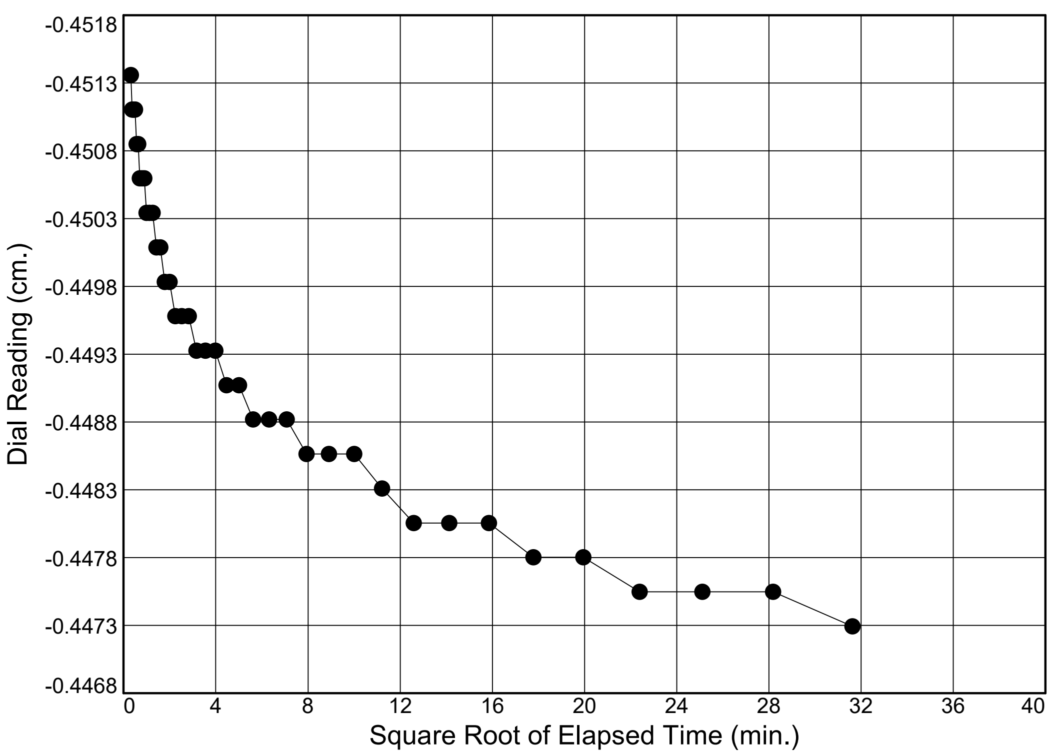
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-1 #9A



Load No.= 9
Load= 50.0 kPa
D_0 = -1.1708
D_{90} = -1.1684
D_{100} = -1.1681
T_{90} = 1.14 min.

C_v @ T_{90}
0.440 cm.^{2}/min.



Load No.= 10
Load= 12.5 kPa
D_0 = -1.1465
D_{90} = -1.1419
D_{100} = -1.1414
T_{90} = 6.01 min.

C_v @ T_{90}
0.085 cm.^{2}/min.

Figure

Solum Consultants Ltd.

CONSOLIDATION TEST DATA

2017-12-20

Client: Barr Eng.
Project: Geo. Inv. for Culvert Sites
Project Number: 61021019.00
Depth: 15'
Sample Number: 100.6-2 #17

Test Specimen Data

NATURAL MOISTURE		VOID RATIO		AFTER TEST	
Wet w+t =	249.65 g.	**Spec. Gr.**	= 2.75	**Wet w+t** =	170.15 g.
Dry w+t =	213.53 g.	**Est. Ht. Solids**	= 1.272 cm.	**Dry w+t** =	147.95 g.
Tare Wt. =	54.44 g.	**Init. V.R.**	= 0.571	**Tare Wt.** =	43.00 g.
Moisture =	22.7 %	**Init. Sat.**	= 109.3 %	**Moisture** =	21.2 %

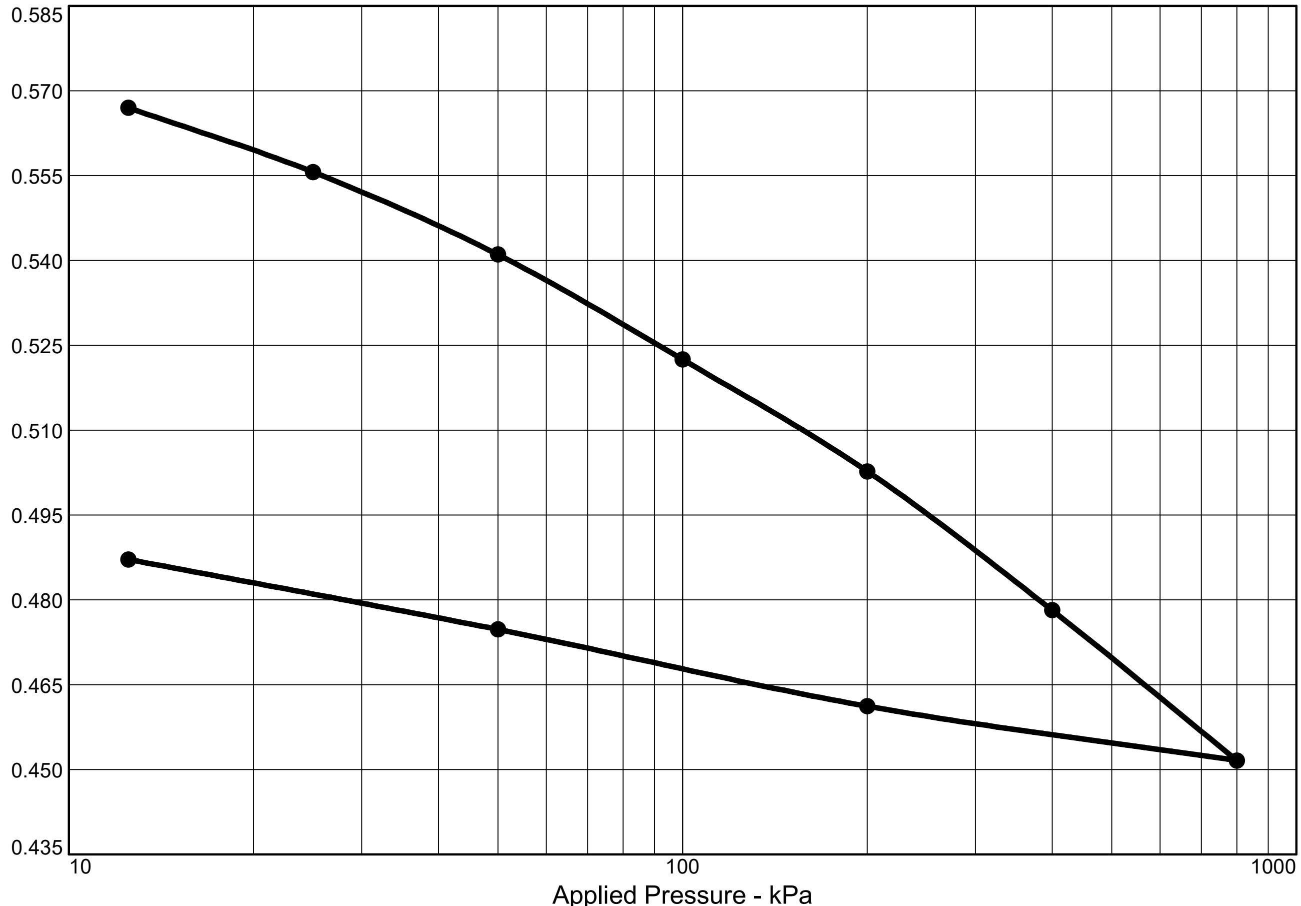
UNIT WEIGHT		TEST START			
				Dry Wt. =	104.95 g.
Height =	0.787 in.	**Height**	= 0.787 in.		
Diameter =	2.433 in.	**Diameter**	= 2.433 in.		
Weight =	128.77 g.				
Dry Dens. =	1750 kg/m^3				

End-Of-Load Summary

Pressure (kPa)	Final Dial (in.)	Deformation (in.)	C_v ($cm.^2/min.$)	C_α	Void Ratio	% Strain
start	0.00000	0.00000			0.571	
12.5	-0.00210	0.00210	0.119		0.567	0.3 Comprs.
25.0	-0.00780	0.00780	0.187		0.556	1.0 Comprs.
50.0	-0.01510	0.01510	0.244		0.541	1.9 Comprs.
100.0	-0.02440	0.02440	0.278		0.522	3.1 Comprs.
200.0	-0.03430	0.03430	0.298		0.503	4.4 Comprs.
400.0	-0.04660	0.04660	0.534		0.478	5.9 Comprs.
800.0	-0.05990	0.05990	0.474		0.452	7.6 Comprs.
200.0	-0.05510	0.05510	0.707		0.461	7.0 Comprs.
50.0	-0.04830	0.04830	0.353		0.475	6.1 Comprs.
12.5	-0.04210	0.04210	0.125		0.487	5.3 Comprs.

Compression index (C_c), kPa = 0.06 **Preconsolidation pressure (P_p), kPa =** 48 **Void ratio at P_p (e_m) =** 0.542

CONSOLIDATION TEST REPORT



Coefficients of Consolidation and Secondary Consolidation											
No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α
1	12.5	0.119		9	50.0	0.353					
2	25.0	0.187		10	12.5	0.125					
3	50.0	0.244									
4	100.0	0.278									
5	200.0	0.298									
6	400.0	0.534									
7	800.0	0.474									
8	200.0	0.707									

Natural		Dry Dens. (kg/m^3)	LL	PI	Sp. Gr.	P_c (kPa)	C_c	Initial Void Ratio
Saturation	Moisture							
109.3 %	22.7 %	1750			2.75	48	0.06	0.571

MATERIAL DESCRIPTION	USCS	AASHTO

Project No. 61021019.00 **Client:** Barr Eng.

Project: Geo. Inv. for Culvert Sites

Depth: 15' **Sample Number:** 100.6-2 #17

SOLUM CONSULTANTS LTD. GEOTECHNICAL & MATERIAL TESTING LABORATORY

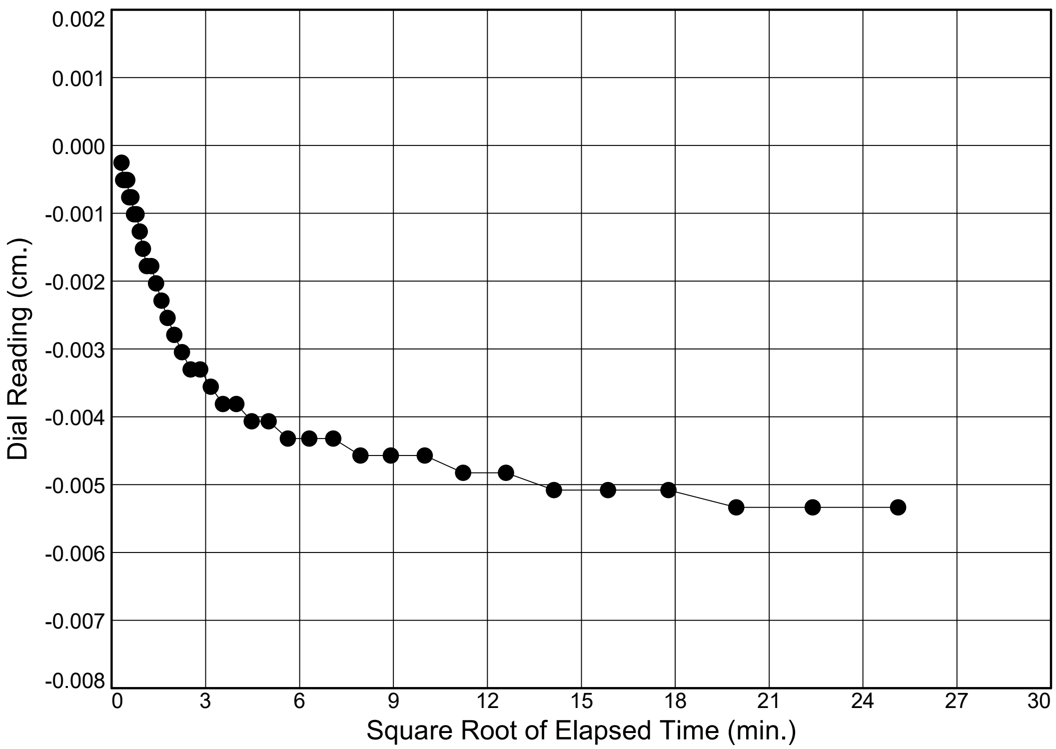
Remarks:

Figure

Dial Reading vs. Time

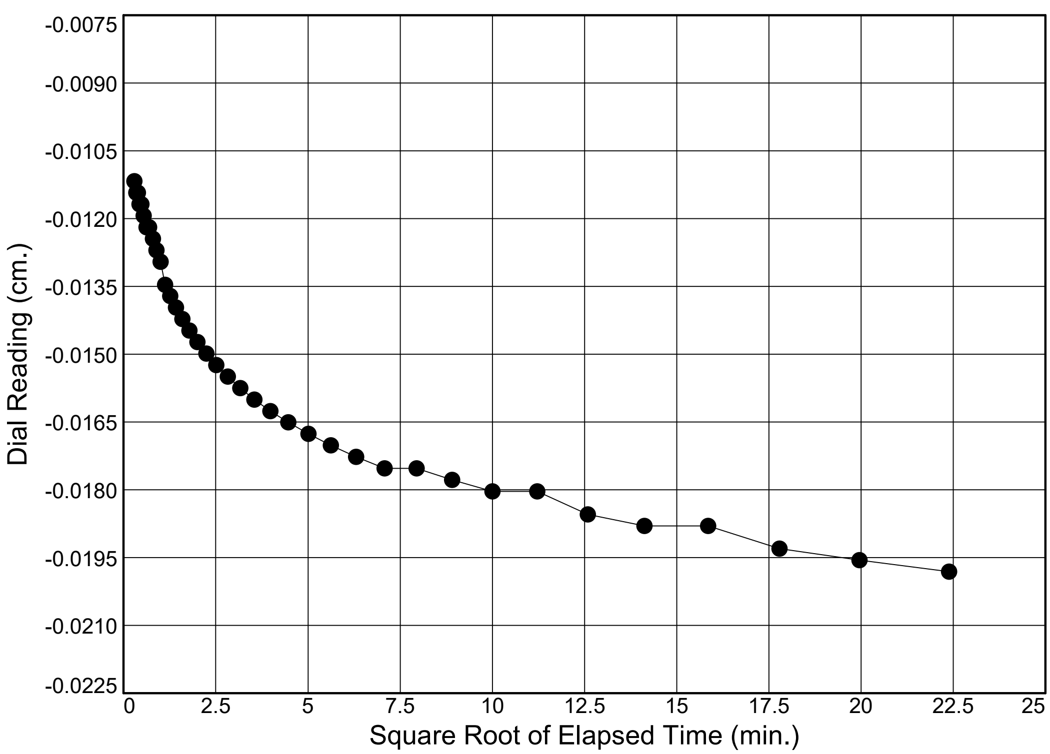
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15'   Sample Number: 100.6-2 #17



Load No.= 1
Load= 12.5 kPa
D_0 = 0.0002
D_{90} = -0.0084
D_{100} = -0.0093
T_{90} = 7.08 min.

C_v @ T_{90}
0.119 cm.^{2}/min.



Load No.= 2
Load= 25.0 kPa
D_0 = -0.0271
D_{90} = -0.0377
D_{100} = -0.0389
T_{90} = 4.46 min.

C_v @ T_{90}
0.187 cm.^{2}/min.

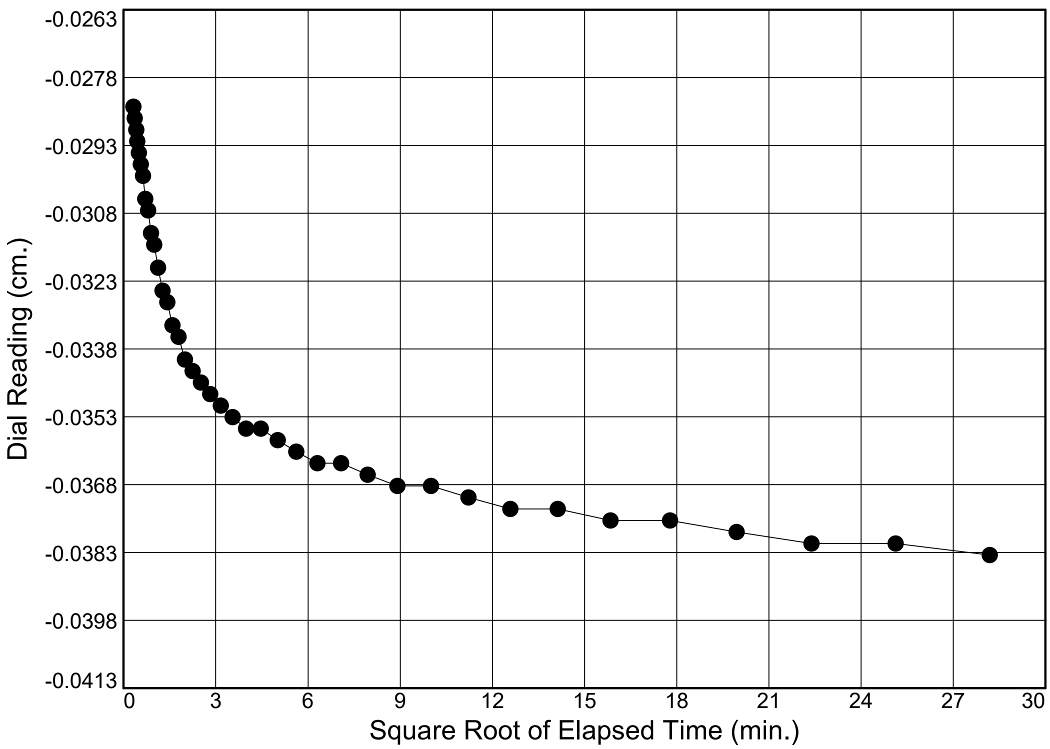
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

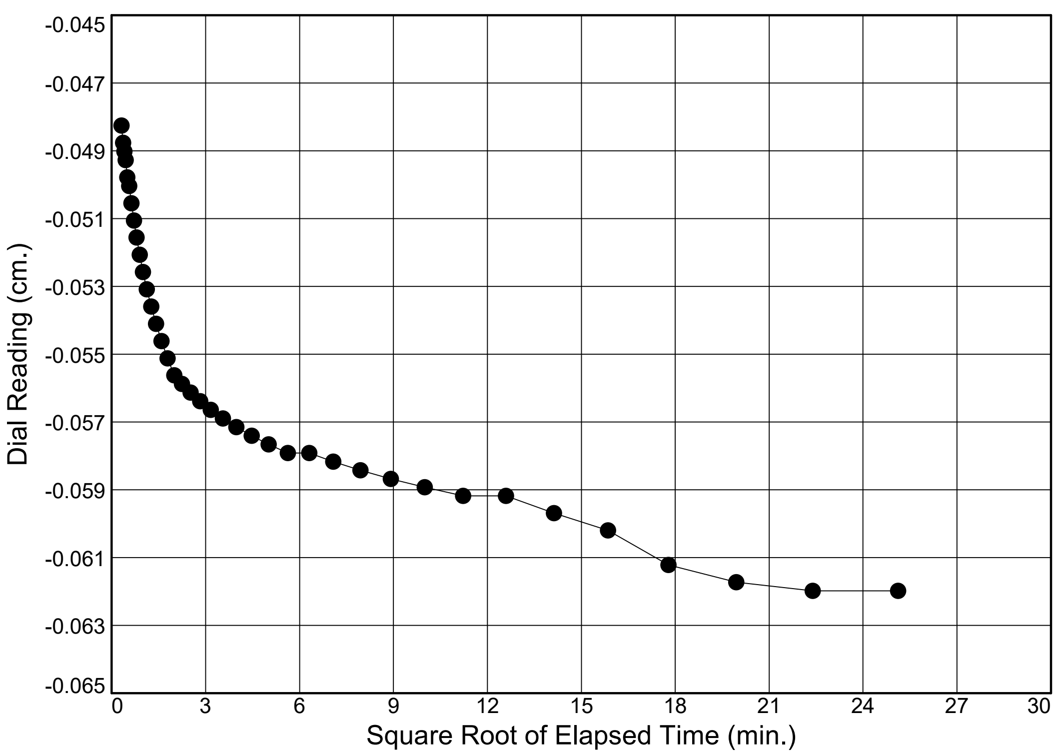
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15'   Sample Number: 100.6-2 #17



Load No.= 3
Load= 50.0 kPa
D_0 = -0.0699
D_{90} = -0.0854
D_{100} = -0.0872
T_{90} = 3.36 min.

C_v @ T_{90}
0.244 cm.^{2}/min.



Load No.= 4
Load= 100.0 kPa
D_0 = -0.1194
D_{90} = -0.1394
D_{100} = -0.1416
T_{90} = 2.88 min.

C_v @ T_{90}
0.278 cm.^{2}/min.

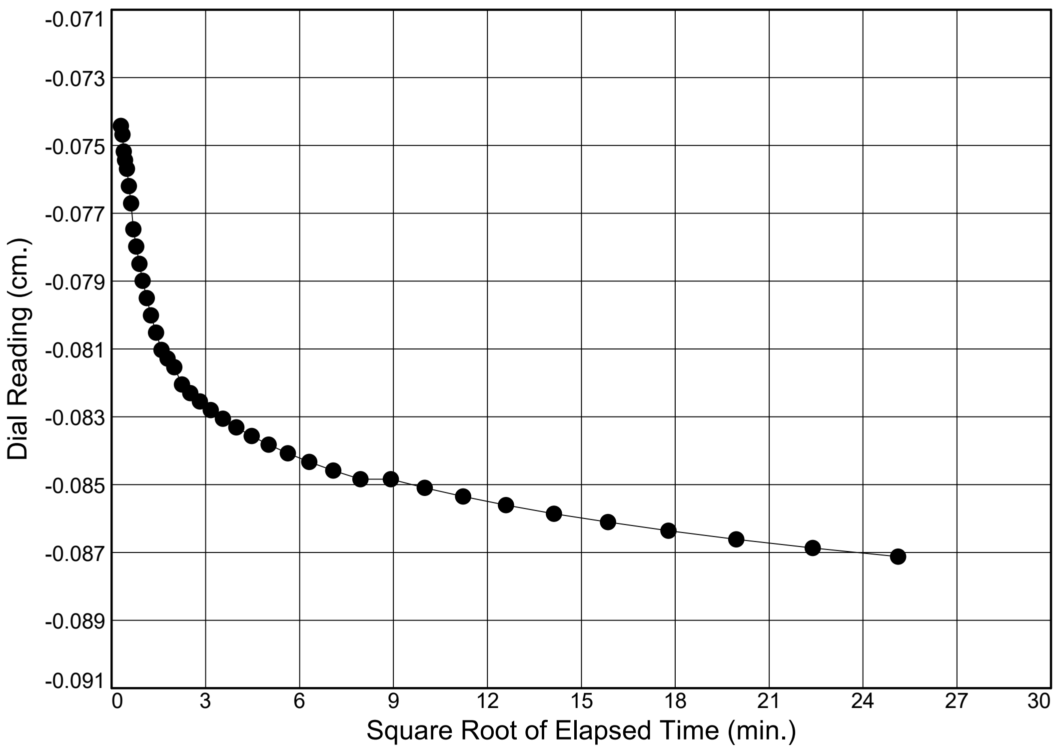
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

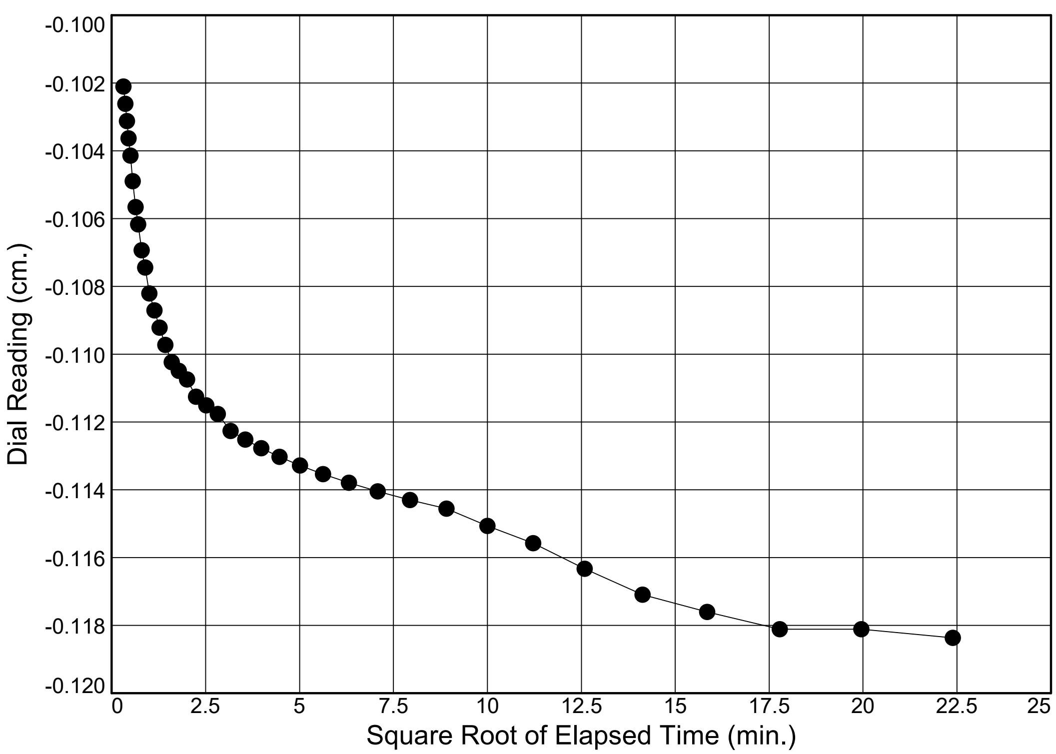
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15'   Sample Number: 100.6-2 #17



Load No.= 5
Load= 200.0 kPa
D_0 = -0.1856
D_{90} = -0.2059
D_{100} = -0.2082
T_{90} = 2.62 min.

C_v @ T_{90}
0.298 cm.^{2}/min.



Load No.= 6
Load= 400.0 kPa
D_0 = -0.2528
D_{90} = -0.2766
D_{100} = -0.2793
T_{90} = 1.42 min.

C_v @ T_{90}
0.534 cm.^{2}/min.

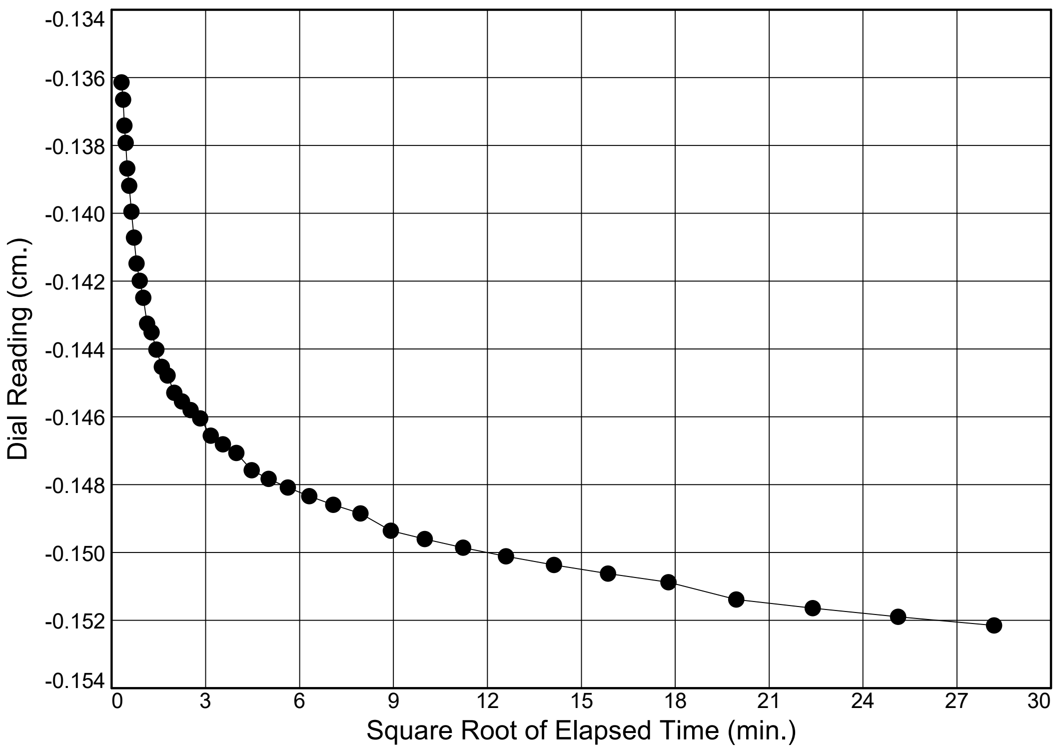
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

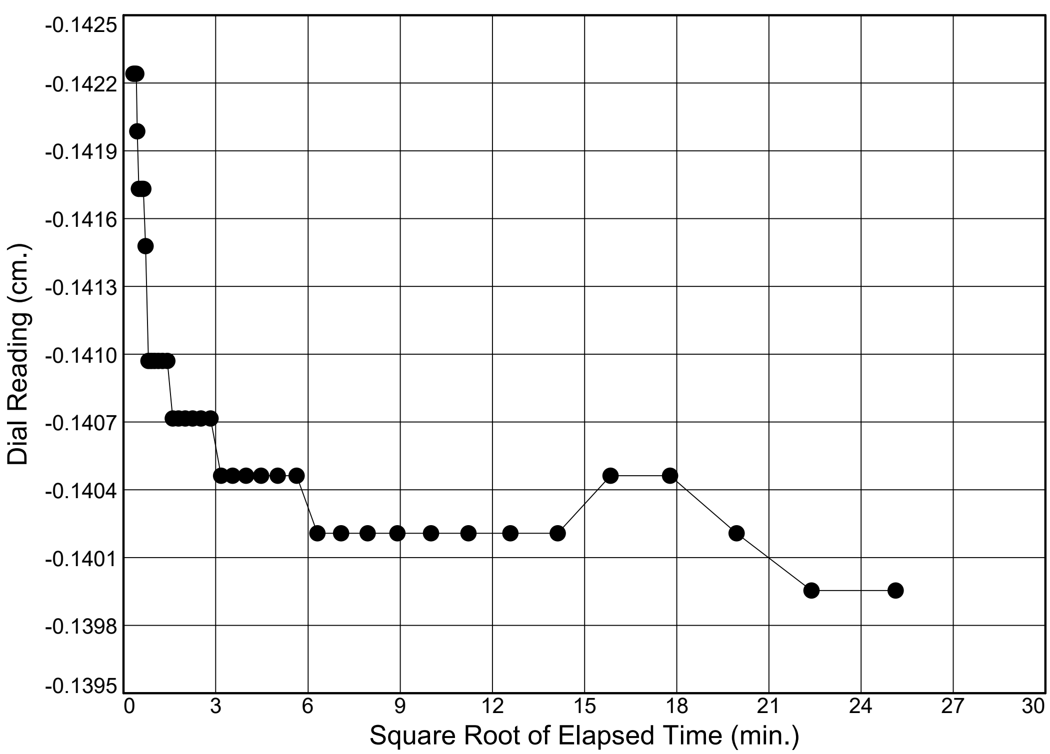
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15' Sample Number: 100.6-2 #17



Load No.= 7
Load= 800.0 kPa
D_0 = -0.3403
D_{90} = -0.3644
D_{100} = -0.3671
T_{90} = 1.54 min.

C_v @ T_{90}
0.474 cm.^{2}/min.



Load No.= 8
Load= 200.0 kPa
D_0 = -0.3635
D_{90} = -0.3581
D_{100} = -0.3575
T_{90} = 1.03 min.

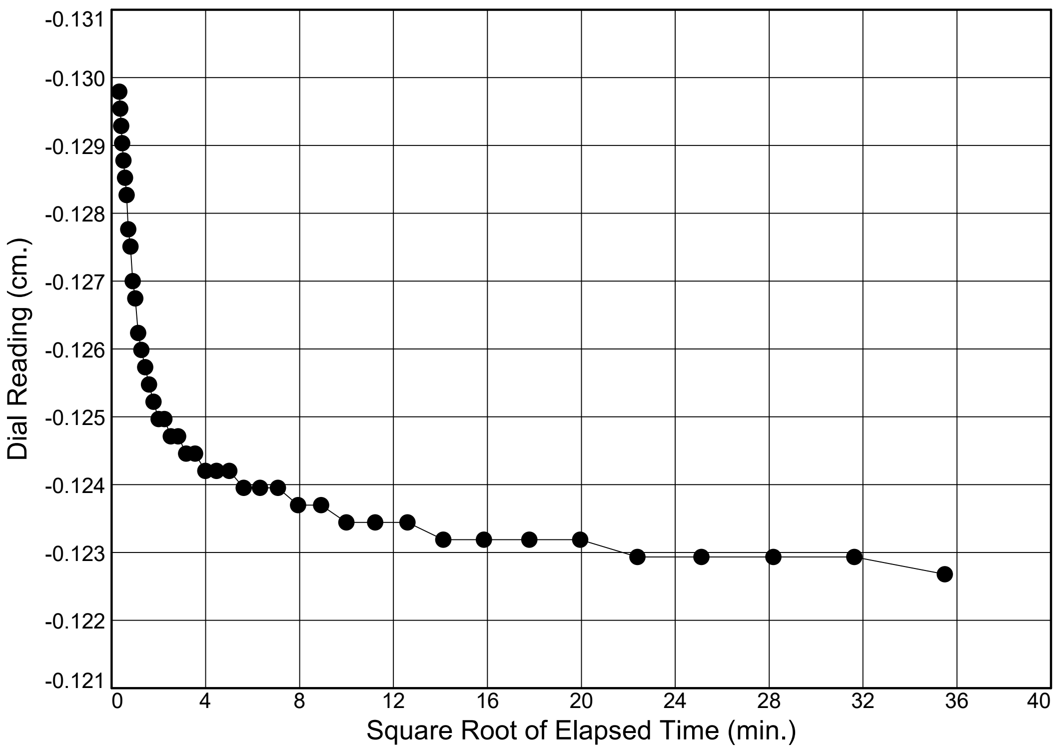
C_v @ T_{90}
0.707 cm.^{2}/min.

Figure

Dial Reading vs. Time

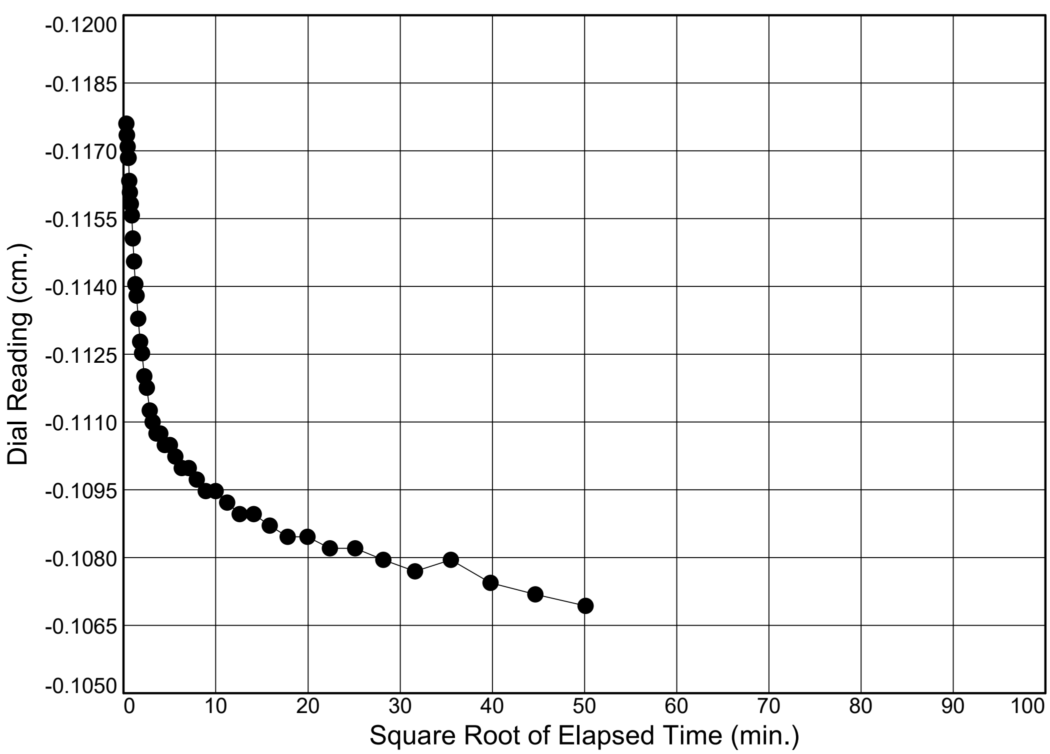
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15'   Sample Number: 100.6-2 #17



Load No.= 9
Load= 50.0 kPa
D_0 = -0.3325
D_{90} = -0.3192
D_{100} = -0.3178
T_{90} = 2.10 min.

C_v @ T_{90}
0.353 cm.^{2}/min.



Load No.= 10
Load= 12.5 kPa
D_0 = -0.3004
D_{90} = -0.2840
D_{100} = -0.2822
T_{90} = 6.04 min.

C_v @ T_{90}
0.125 cm.^{2}/min.

Figure

Solum Consultants Ltd.

CONSOLIDATION TEST DATA

2017-12-20

Client: Barr Eng.
Project: Geo. Inv. for Culvert Sites
Project Number: 61021019.00
Depth: 25.0' **Sample Number:** 100.6-2 #18A

Test Specimen Data

NATURAL MOISTURE		VOID RATIO		AFTER TEST	
Wet w+t =	99.60 g.	**Spec. Gr.**	= 2.7	**Wet w+t** =	174.10 g.
Dry w+t =	89.70 g.	**Est. Ht. Solids**	= 1.441 cm.	**Dry w+t** =	161.30 g.
Tare Wt. =	12.10 g.	**Init. V.R.**	= 0.387	**Tare Wt.** =	43.00 g.
Moisture =	12.8 %	**Init. Sat.**	= 88.9 %	**Moisture** =	10.8 %

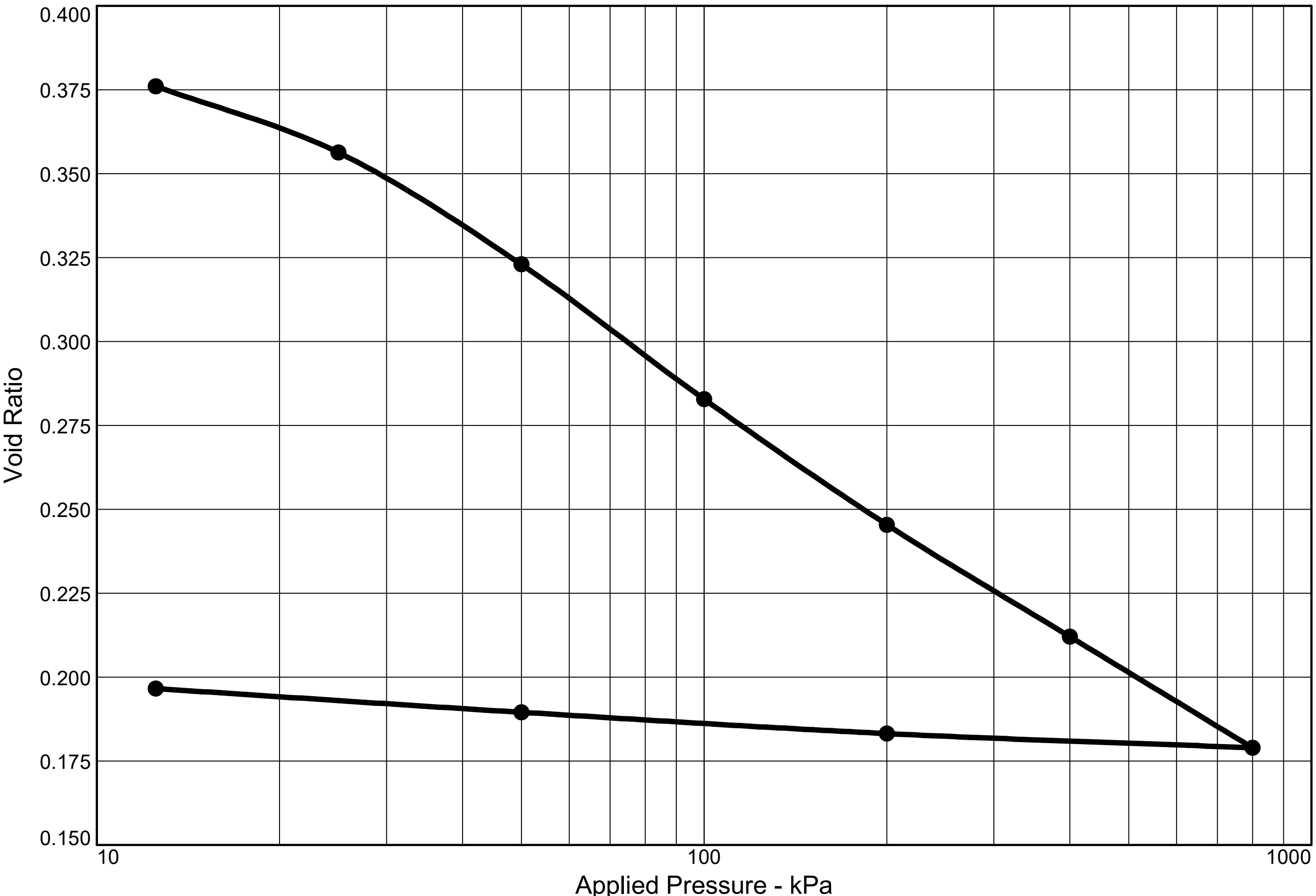
UNIT WEIGHT		TEST START			
				Dry Wt. =	118.30 g.
Height =	0.787 in.	**Height**	= 0.787 in.		
Diameter =	2.433 in.	**Diameter**	= 2.433 in.		
Weight =	131.58 g.				
Dry Dens. =	1946 kg/m^3				

End-Of-Load Summary

Pressure (kPa)	Final Dial (in.)	Deformation (in.)	C_v ($cm.^2/min.$)	C_α	Void Ratio	% Strain
start	0.00000	0.00000			0.387	
12.5	-0.00640	0.00640	0.060		0.376	0.8 Comprs.
25.0	-0.01760	0.01760	0.109		0.356	2.2 Comprs.
50.0	-0.03650	0.03650	0.137		0.323	4.6 Comprs.
100.0	-0.05930	0.05930	0.219		0.283	7.5 Comprs.
200.0	-0.08050	0.08050	0.201		0.245	10.2 Comprs.
400.0	-0.09940	0.09940	0.266		0.212	12.6 Comprs.
800.0	-0.11820	0.11820	0.253		0.179	15.0 Comprs.
200.0	-0.11580	0.11580	1.370		0.183	14.7 Comprs.
50.0	-0.11220	0.11220	0.254		0.190	14.3 Comprs.
12.5	-0.10820	0.10820	0.161		0.197	13.7 Comprs.

Compression index (C_c), kPa = 0.11 **Preconsolidation pressure (P_p), kPa =** 16 **Void ratio at P_p (e_m) =** 0.371

CONSOLIDATION TEST REPORT



Coefficients of Consolidation and Secondary Consolidation

No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α
1	12.5	0.060		9	50.0	0.254					
2	25.0	0.109		10	12.5	0.161					
3	50.0	0.137									
4	100.0	0.219									
5	200.0	0.201									
6	400.0	0.266									
7	800.0	0.253									
8	200.0	1.370									

Natural		Dry Dens. (kg/m^3)	LL	PI	Sp. Gr.	P_c (kPa)	C_c	Initial Void Ratio
Saturation	Moisture							
88.9 %	12.8 %	1946			2.7	16	0.11	0.387

MATERIAL DESCRIPTION	USCS	AASHTO

Project No. 61021019.00 **Client:** Barr Eng.

Project: Geo. Inv. for Culvert Sites

Depth: 25.0' **Sample Number:** 100.6-2 #18A

SOLUM™ CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

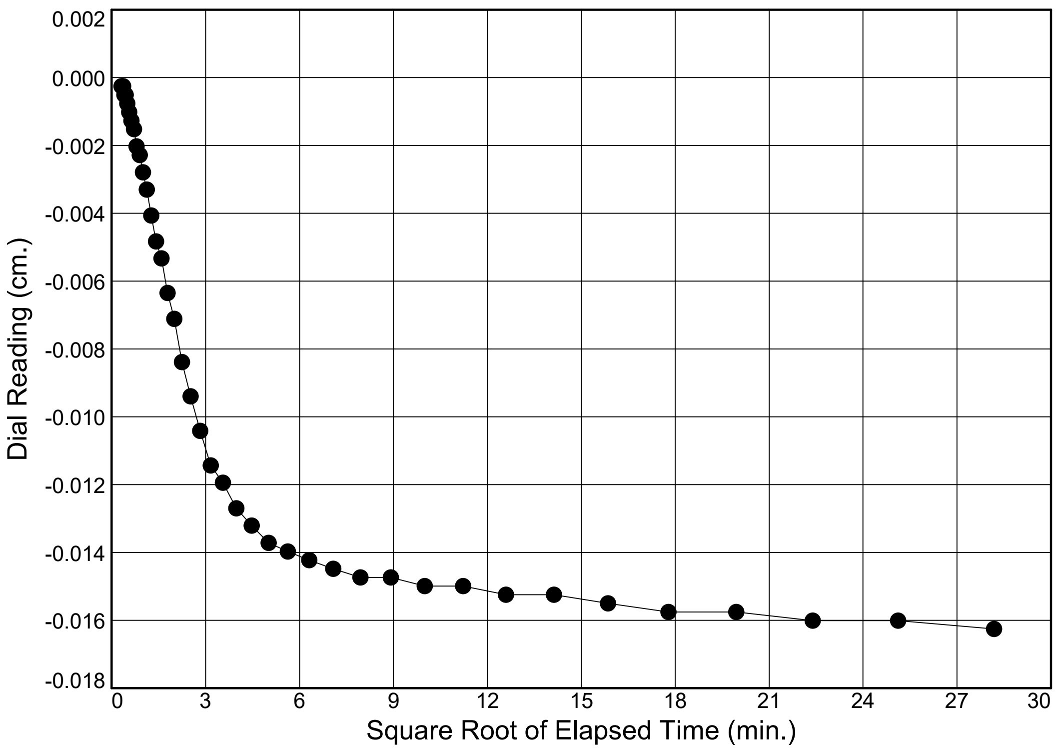
Remarks:

Figure

Dial Reading vs. Time

Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0'   Sample Number: 100.6-2 #18A



Load No.= 1

Load= 12.5 kPa

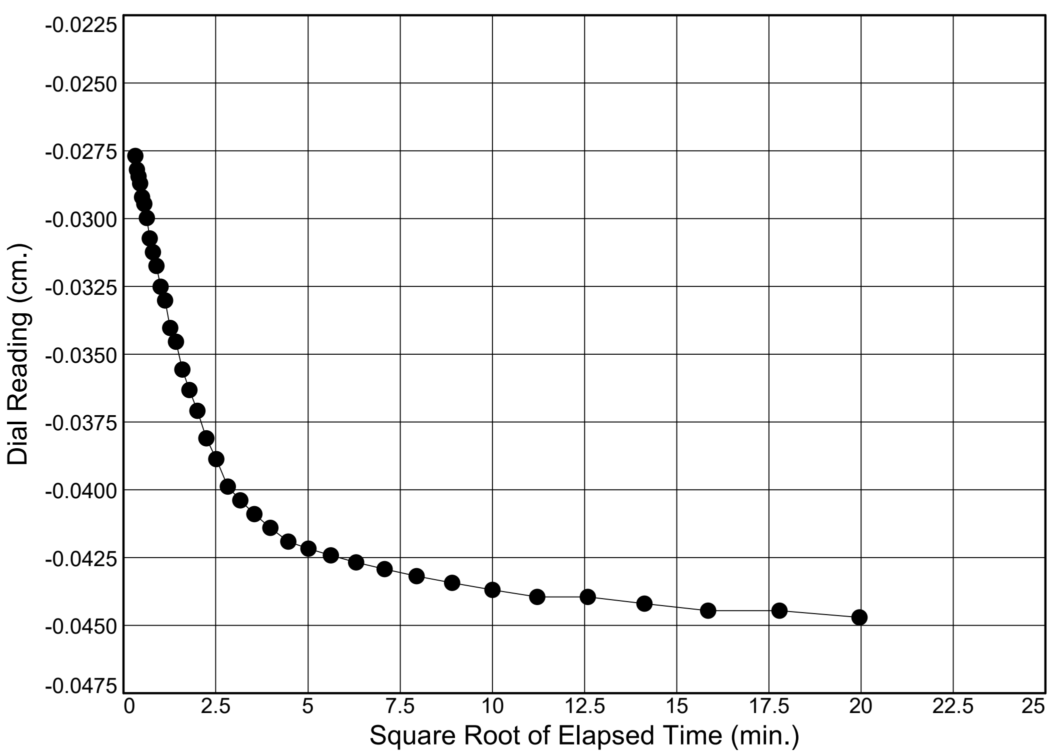
D_0 = 0.0032

D_{90} = -0.0312

D_{100} = -0.0351

T_{90} = 14.11 min.

C_v @ T_{90}
0.060 cm.^{2}/min.



Load No.= 2

Load= 25.0 kPa

D_0 = -0.0674

D_{90} = -0.1006

D_{100} = -0.1043

T_{90} = 7.53 min.

C_v @ T_{90}
0.109 cm.^{2}/min.

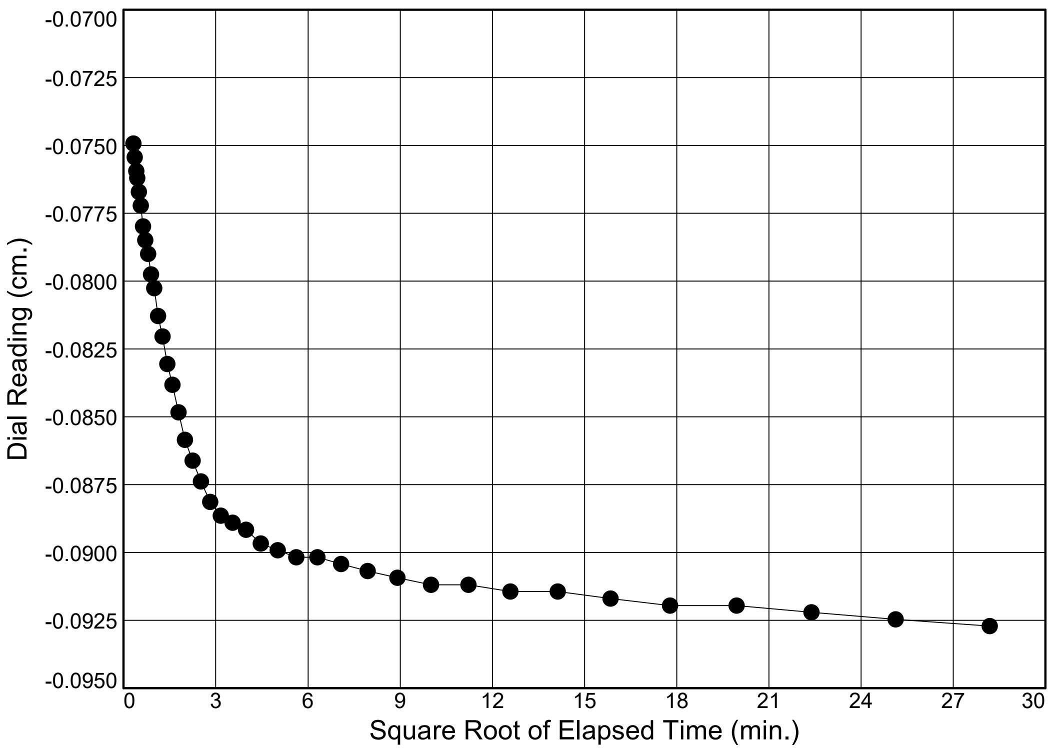
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

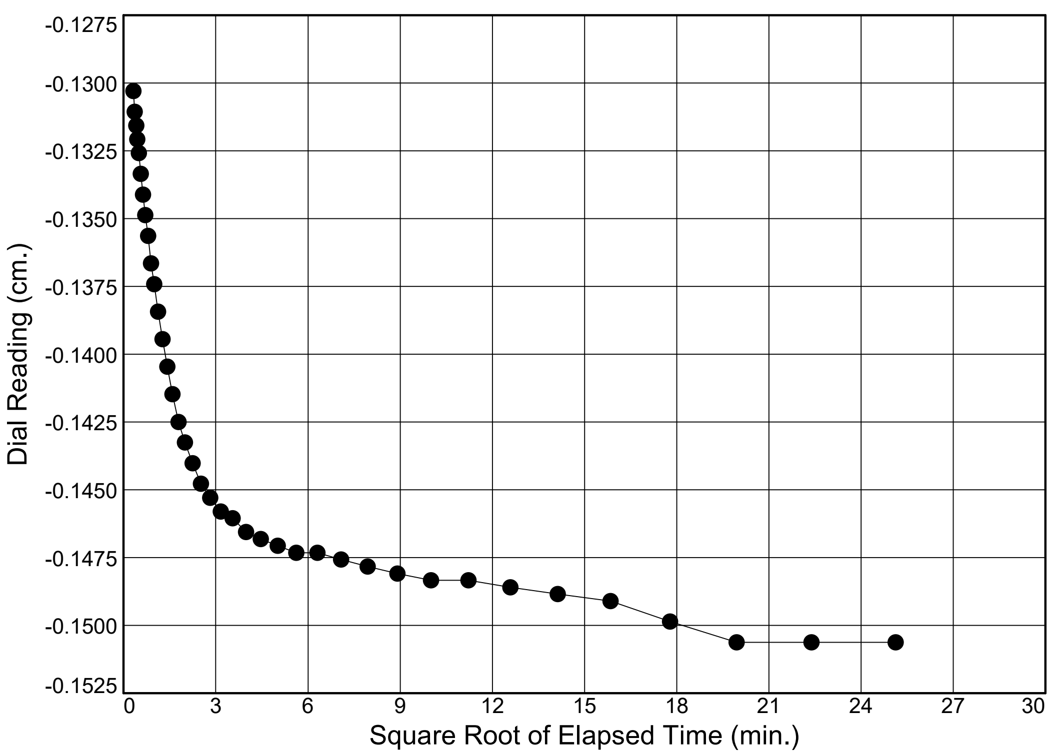
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-2 #18A



Load No.= 3
Load= 50.0 kPa
D_0 = -0.1868
D_{90} = -0.2210
D_{100} = -0.2248
T_{90} = 5.68 min.

C_v @ T_{90}
0.137 cm.^{2}/min.



Load No.= 4
Load= 100.0 kPa
D_0 = -0.3251
D_{90} = -0.3624
D_{100} = -0.3665
T_{90} = 3.35 min.

C_v @ T_{90}
0.219 cm.^{2}/min.

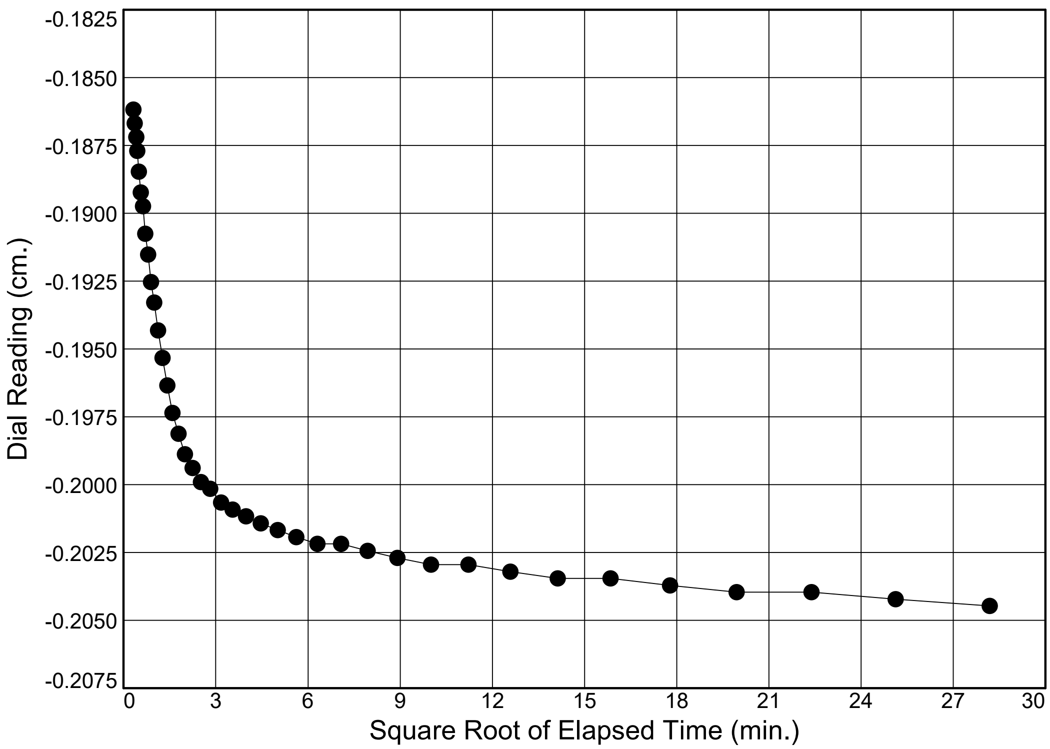
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

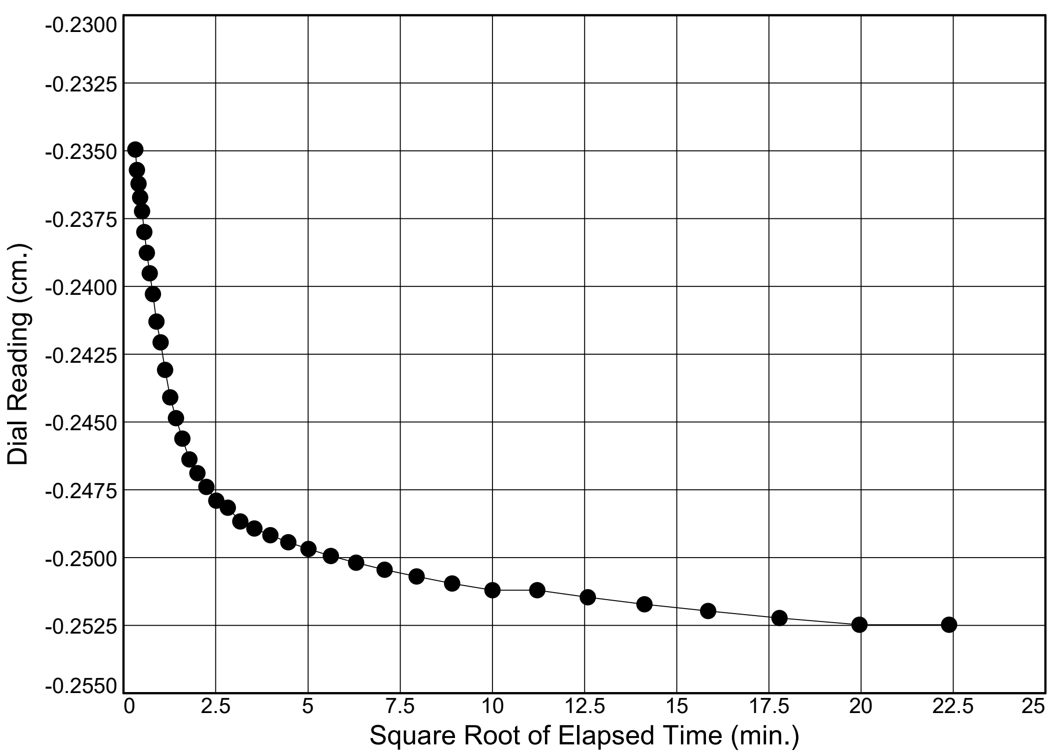
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-2 #18A



Load No.= 5
Load= 200.0 kPa
D_0 = -0.4672
D_{90} = -0.5039
D_{100} = -0.5079
T_{90} = 3.44 min.

C_v @ T_{90}
0.201 cm.^{2}/min.



Load No.= 6
Load= 400.0 kPa
D_0 = -0.5903
D_{90} = -0.6236
D_{100} = -0.6273
T_{90} = 2.46 min.

C_v @ T_{90}
0.266 cm.^{2}/min.

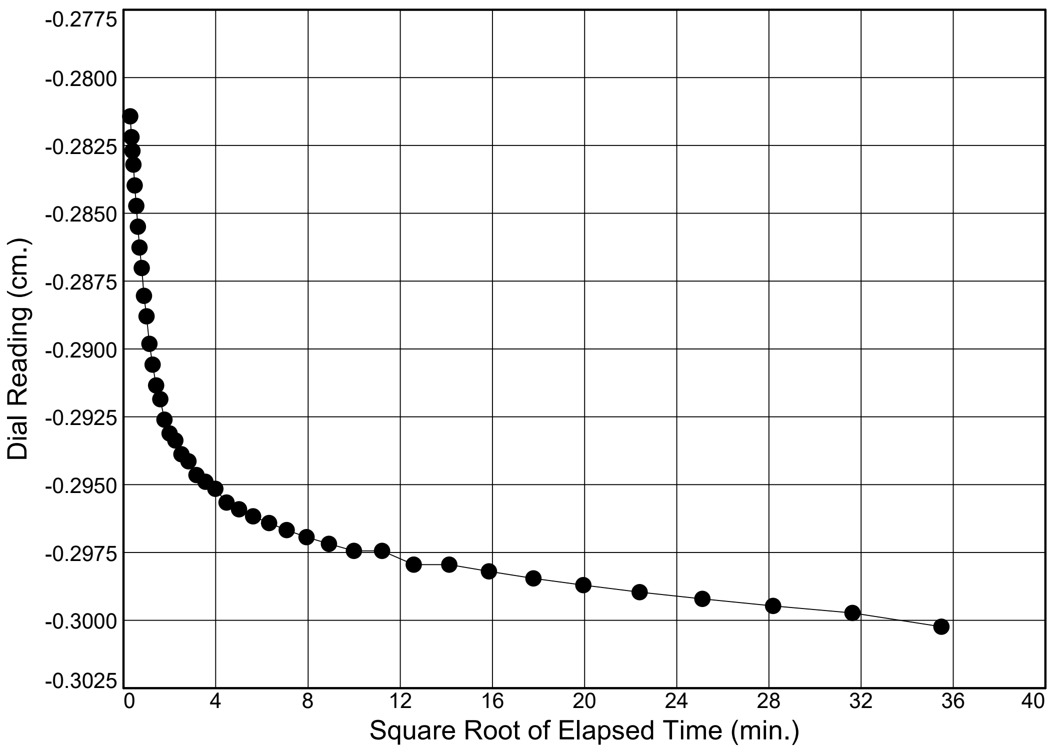
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

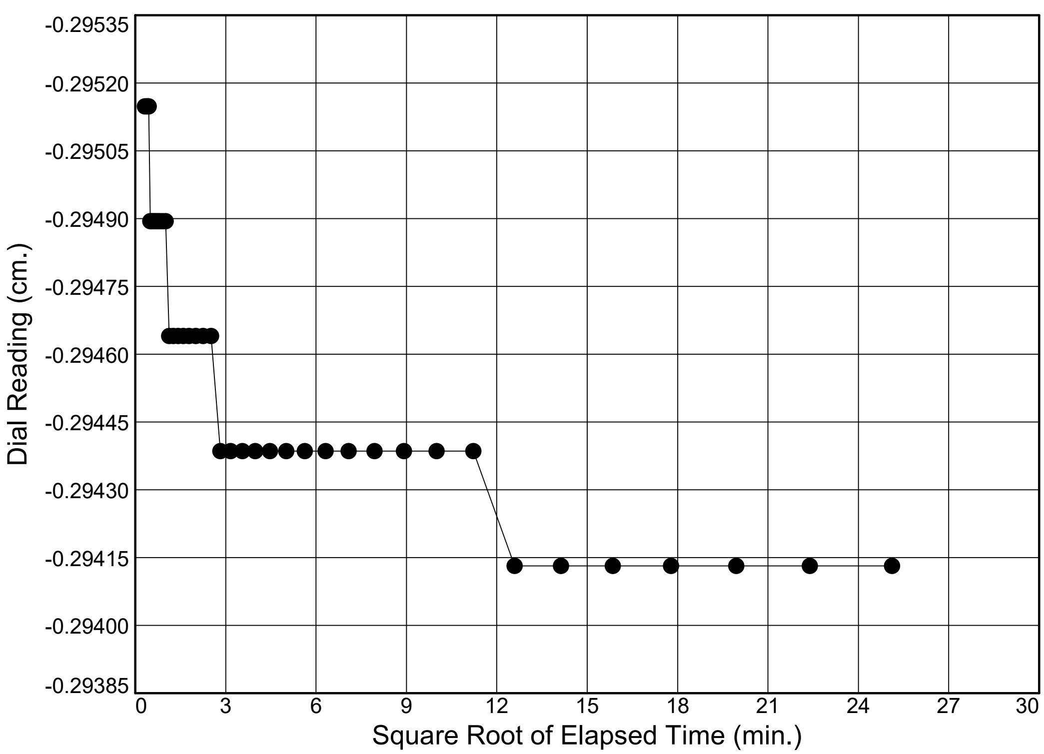
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-2 #18A



Load No.= 7
Load= 800.0 kPa
D_0 = -0.7100
D_{90} = -0.7411
D_{100} = -0.7446
T_{90} = 2.45 min.

C_v @ T_{90}
0.253 $cm.^2$/min.



Load No.= 8
Load= 200.0 kPa
D_0 = -0.7507
D_{90} = -0.7490
D_{100} = -0.7488
T_{90} = 0.45 min.

C_v @ T_{90}
1.370 $cm.^2$/min.

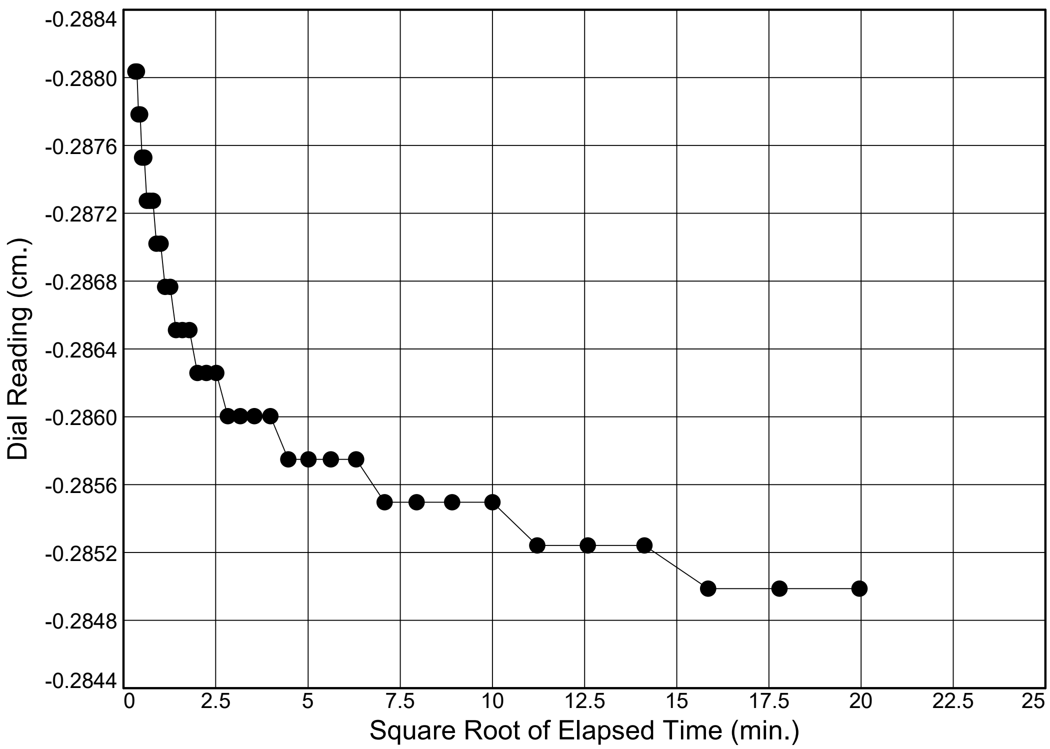
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

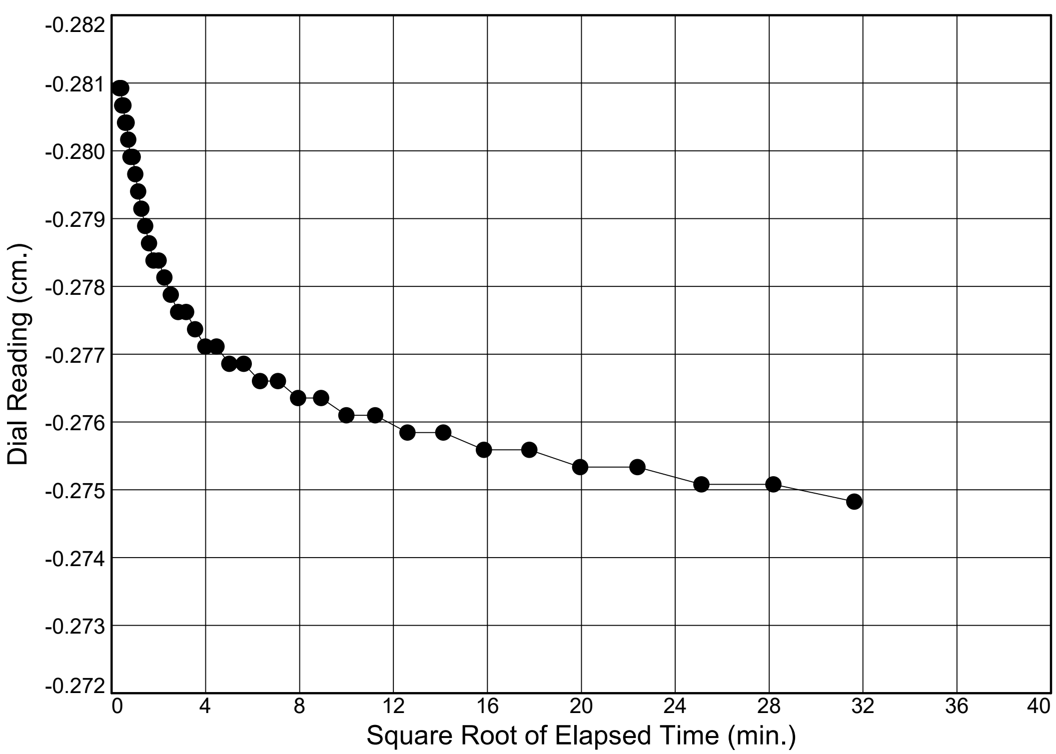
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 25.0' Sample Number: 100.6-2 #18A



Load No.= 9
Load= 50.0 kPa
D_0 = -0.7323
D_{90} = -0.7277
D_{100} = -0.7272
T_{90} = 2.45 min.

C_v @ T_{90}
0.254 cm.^{2}/min.



Load No.= 10
Load= 12.5 kPa
D_0 = -0.7151
D_{90} = -0.7071
D_{100} = -0.7062
T_{90} = 3.89 min.

C_v @ T_{90}
0.161 cm.^{2}/min.

Figure

Solum Consultants Ltd.

CONSOLIDATION TEST DATA

2017-12-20

Client: Barr Eng.
Project: Geo. Inv. for Culvert Sites
Project Number: 61021019.00
Depth: 15.0'   **Sample Number:** 95.6-2 #39A

Test Specimen Data

NATURAL MOISTURE		VOID RATIO		AFTER TEST	
Wet w+t =	91.53 g.	**Spec. Gr.**	= 2.7	**Wet w+t =**	170.57 g.
Dry w+t =	83.20 g.	**Est. Ht. Solids**	= 1.427 cm.	**Dry w+t =**	158.54 g.
Tare Wt. =	11.77 g.	**Init. V.R.**	= 0.401	**Tare Wt. =**	43.00 g.
Moisture =	11.7 %	**Init. Sat.**	= 78.6 %	**Moisture =**	10.4 %
UNIT WEIGHT		**TEST START**		**Dry Wt. =**	115.54 g.
Height =	0.787 in.	**Height**	= 0.787 in.		
Diameter =	2.433 in.	**Diameter**	= 2.433 in.		
Weight =	129.06 g.				
Dry Dens. =	1928 kg/m^3				

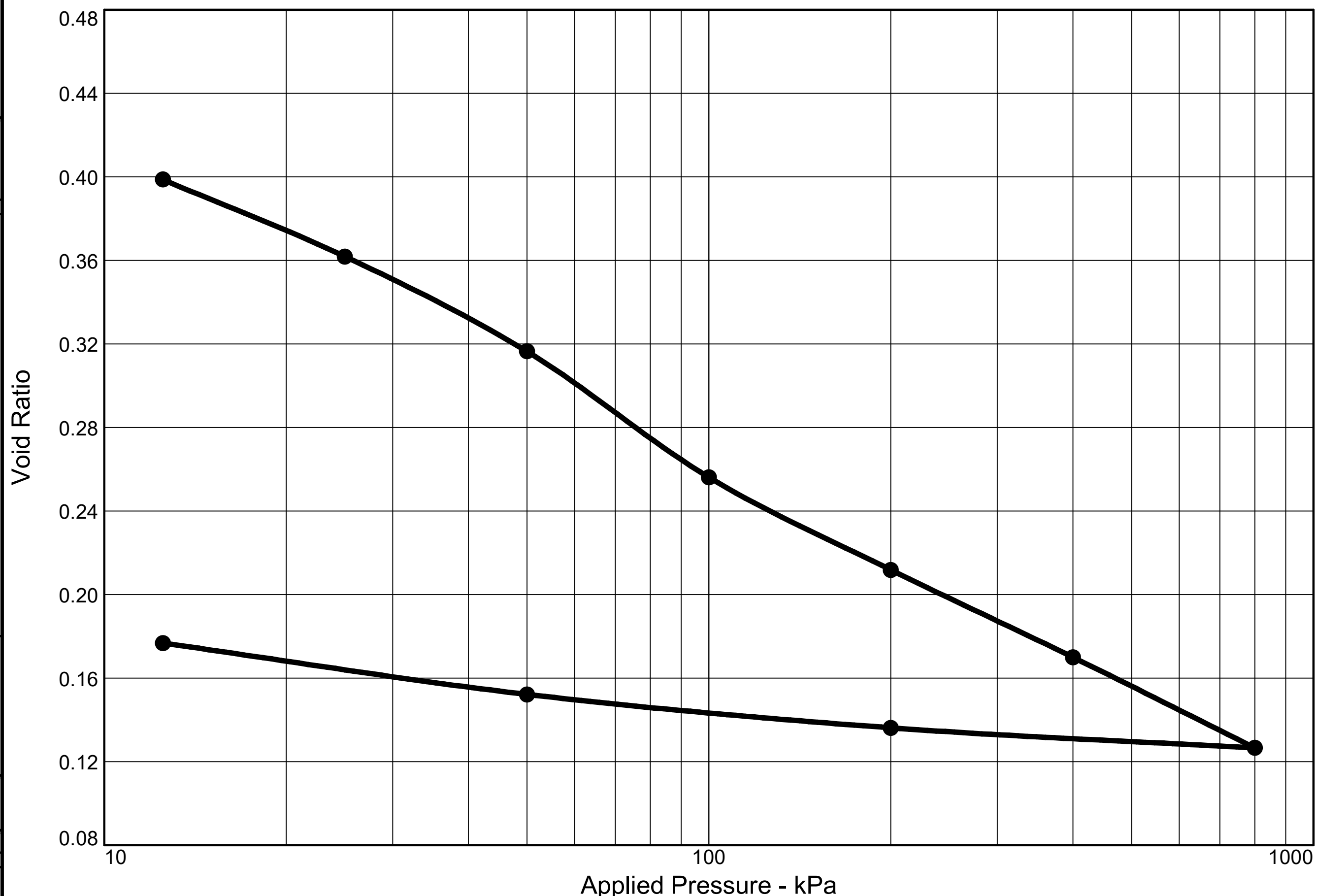
End-Of-Load Summary

Pressure (kPa)	Final Dial (in.)	Deformation (in.)	C_v (cm.^{2}/min.)	C_α	Void Ratio	% Strain
start	0.00000	0.00000			0.401	
12.5	-0.00110	0.00110	0.045		0.399	0.1 Comprs.
25.0	-0.02180	0.02180	0.007		0.362	2.8 Comprs.
50.0	-0.04730	0.04730	0.197		0.316	6.0 Comprs.
100.0	-0.08120	0.08120	0.160		0.256	10.3 Comprs.
200.0	-0.10610	0.10610	0.065		0.212	13.5 Comprs.
400.0	-0.12960	0.12960	0.078		0.170	16.5 Comprs.
800.0	-0.15400	0.15400	0.101		0.127	19.6 Comprs.
200.0	-0.14860	0.14860	0.287		0.136	18.9 Comprs.
50.0	-0.13960	0.13960	0.082		0.152	17.7 Comprs.
12.5	-0.12580	0.12580	0.009		0.177	16.0 Comprs.

Compression index (C_c), kPa = 0.13   **Preconsolidation pressure (P_p), kPa =** 81   **Void ratio at P_p (e_m) =** 0.274

These results are for the exclusive use of the client for whom they obtained. They apply only to the samples tested and are not indicitive of apparently identical samples.

CONSOLIDATION TEST REPORT



Coefficients of Consolidation and Secondary Consolidation

No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α	No.	Load (kPa)	C_v (cm.^{2}/min.)	C_α
1	12.5	0.045		9	50.0	0.082					
2	25.0	0.007		10	12.5	0.009					
3	50.0	0.197									
4	100.0	0.160									
5	200.0	0.065									
6	400.0	0.078									
7	800.0	0.101									
8	200.0	0.287									

Natural		Dry Dens. (kg/m^3)	LL	PI	Sp. Gr.	P_c (kPa)	C_c	Initial Void Ratio
Saturation	Moisture							
78.6 %	11.7 %	1928			2.7	81	0.13	0.401

MATERIAL DESCRIPTION	USCS	AASHTO

Project No. 61021019.00 **Client:** Barr Eng.

Project: Geo. Inv. for Culvert Sites

Depth: 15.0' **Sample Number:** 95.6-2 #39A

SOLUM CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL TESTING LABORATORY

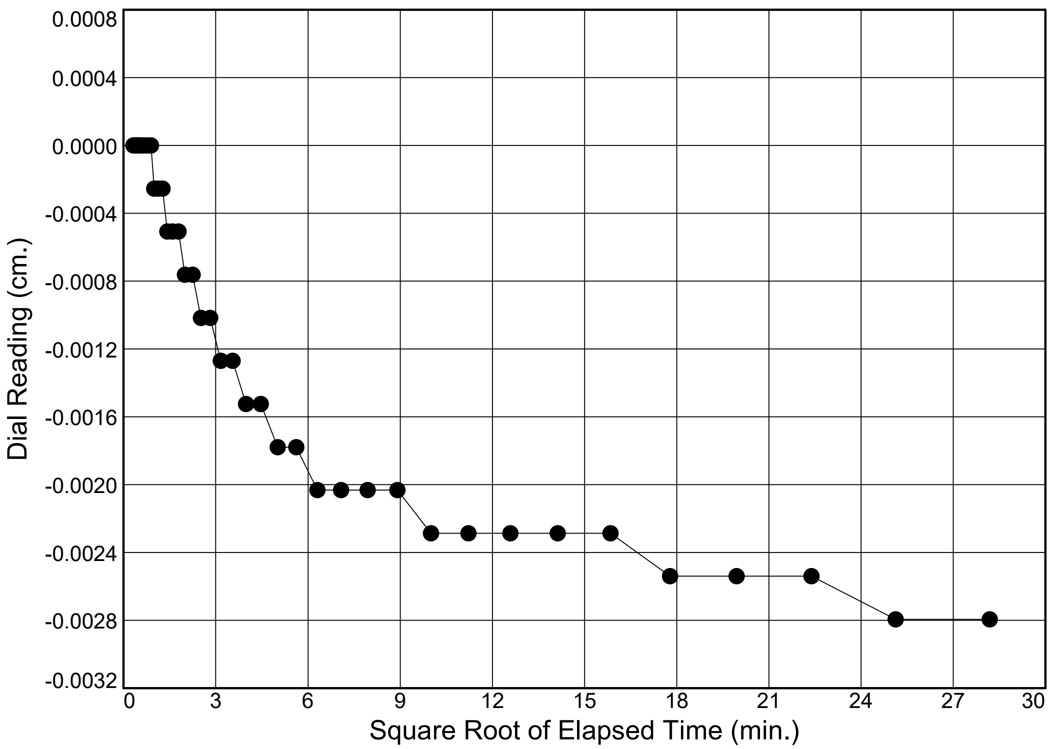
Remarks:

Figure

Dial Reading vs. Time

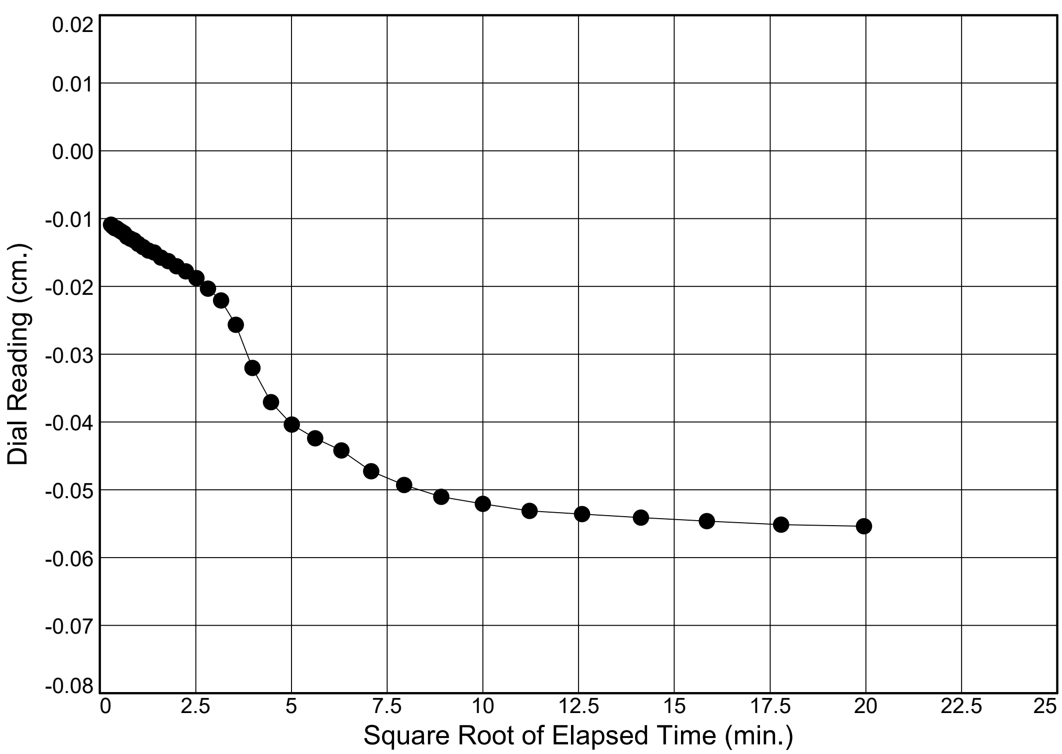
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15.0'   Sample Number: 95.6-2 #39A



Load No.= 1
Load= 12.5 kPa
D_0 = 0.0006
D_{90} = -0.0039
D_{100} = -0.0044
T_{90} = 18.96 min.

C_v @ T_{90}
0.045 cm.^{2}/min.



Load No.= 2
Load= 25.0 kPa
D_0 = -0.0229
D_{90} = -0.1344
D_{100} = -0.1468
T_{90} = 121.39 min.

C_v @ T_{90}
0.007 cm.^{2}/min.

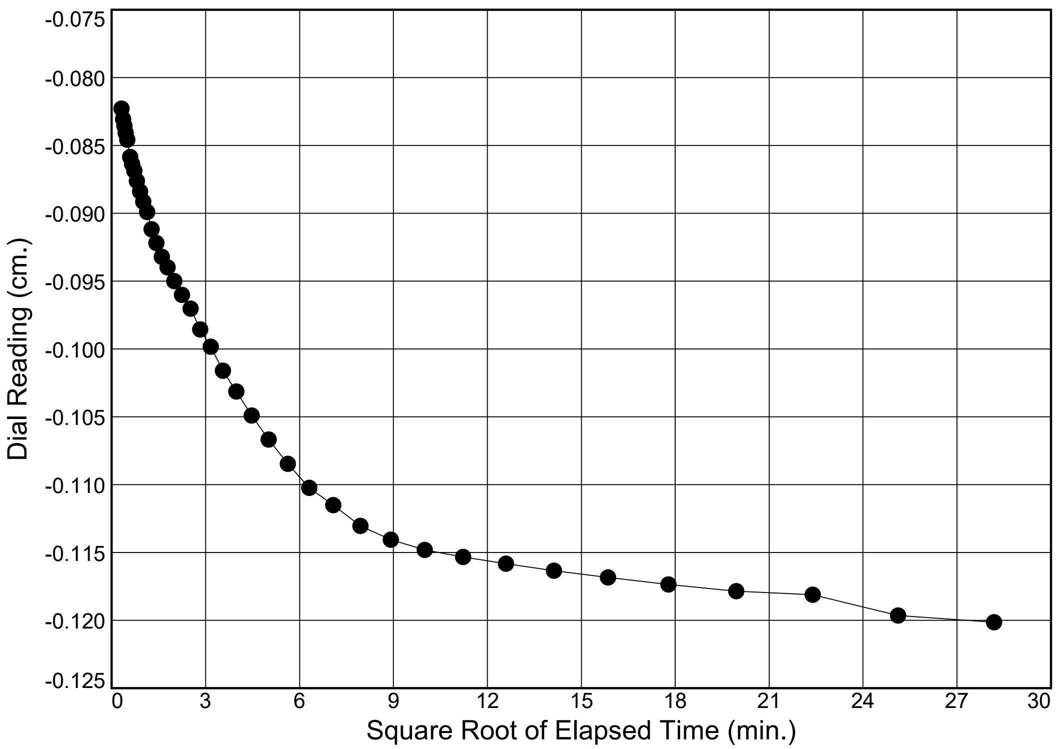
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

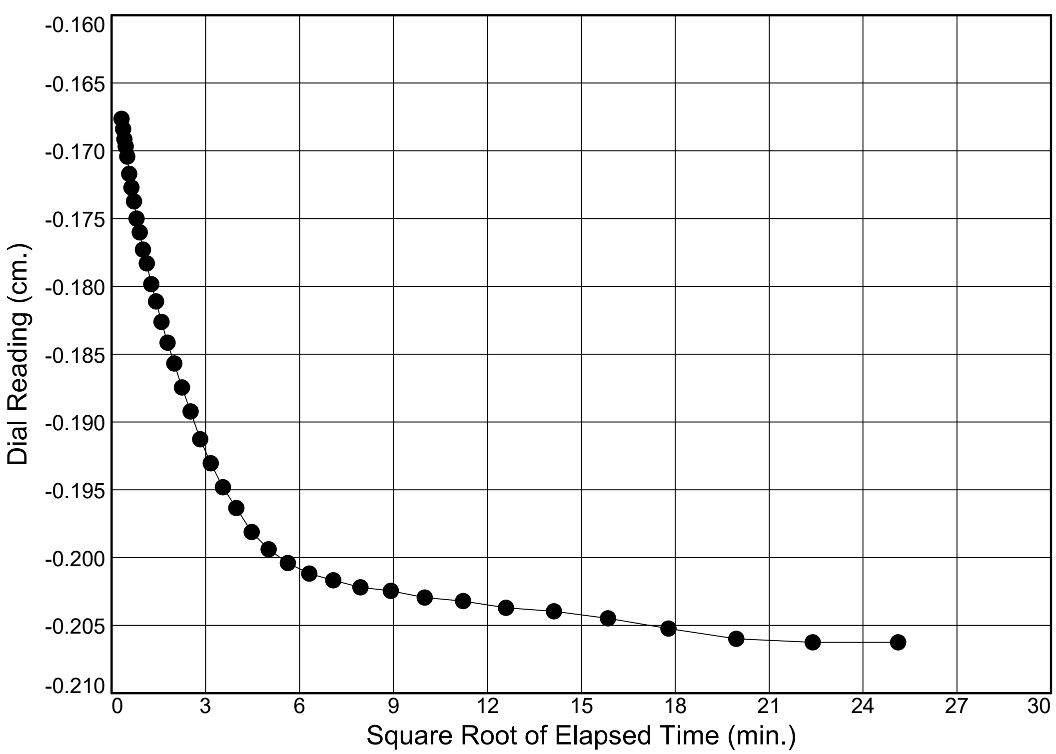
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15.0'   Sample Number: 95.6-2 #39A



Load No.= 3
Load= 50.0 kPa
D_0 = -0.2043
D_{90} = -0.2409
D_{100} = -0.2450
T_{90} = 3.89 min.

C_v @ T_{90}
0.197 cm.^{2}/min.



Load No.= 4
Load= 100.0 kPa
D_0 = -0.4183
D_{90} = -0.4733
D_{100} = -0.4794
T_{90} = 4.37 min.

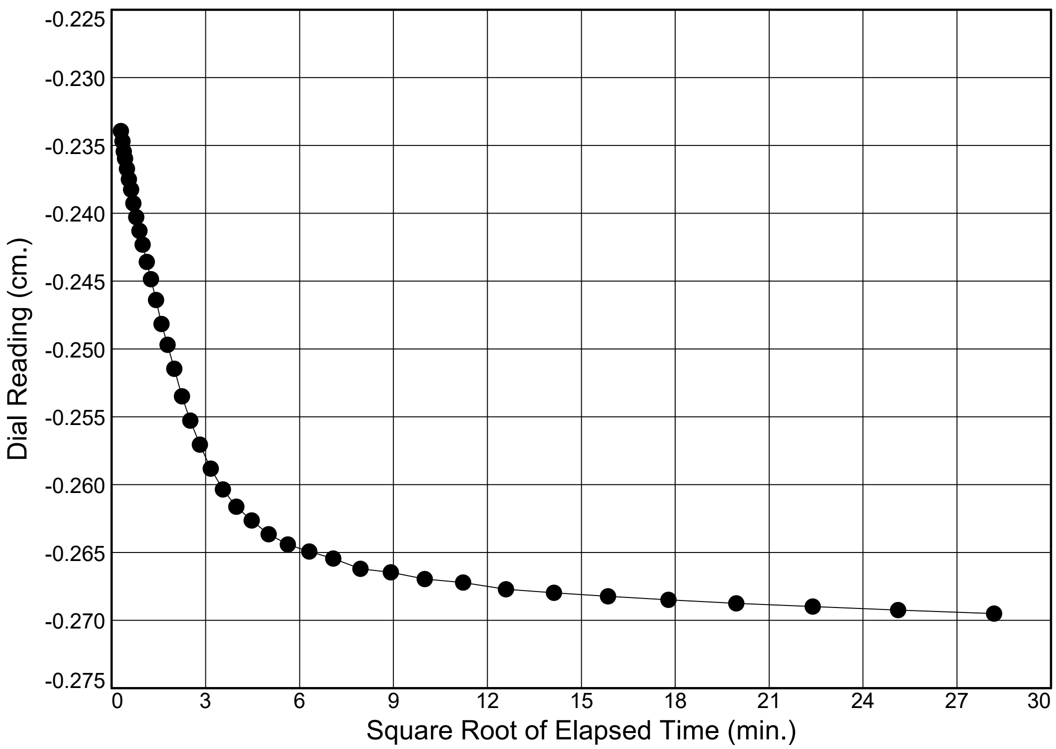
C_v @ T_{90}
0.160 cm.^{2}/min.

Figure

Dial Reading vs. Time

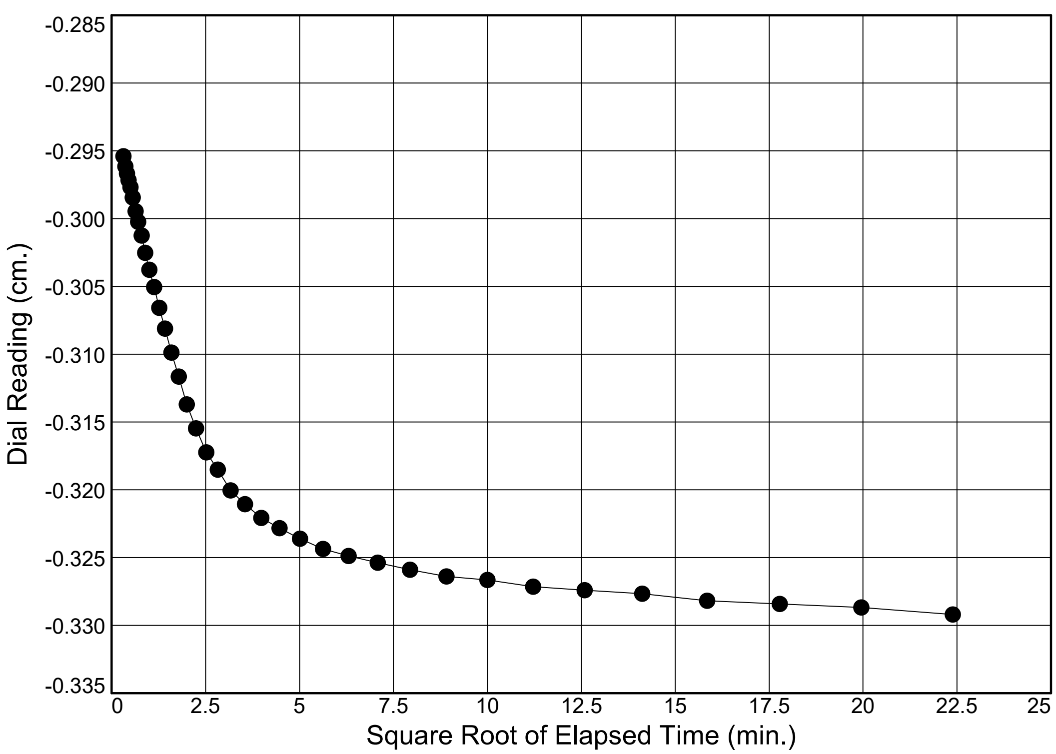
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15.0' Sample Number: 95.6-2 #39A



Load No.= 5
Load= 200.0 kPa
D_0 = -0.5897
D_{90} = -0.6574
D_{100} = -0.6649
T_{90} = 10.00 min.

C_v @ T_{90}
0.065 cm.^{2}/min.



Load No.= 6
Load= 400.0 kPa
D_0 = -0.7432
D_{90} = -0.8086
D_{100} = -0.8158
T_{90} = 7.72 min.

C_v @ T_{90}
0.078 cm.^{2}/min.

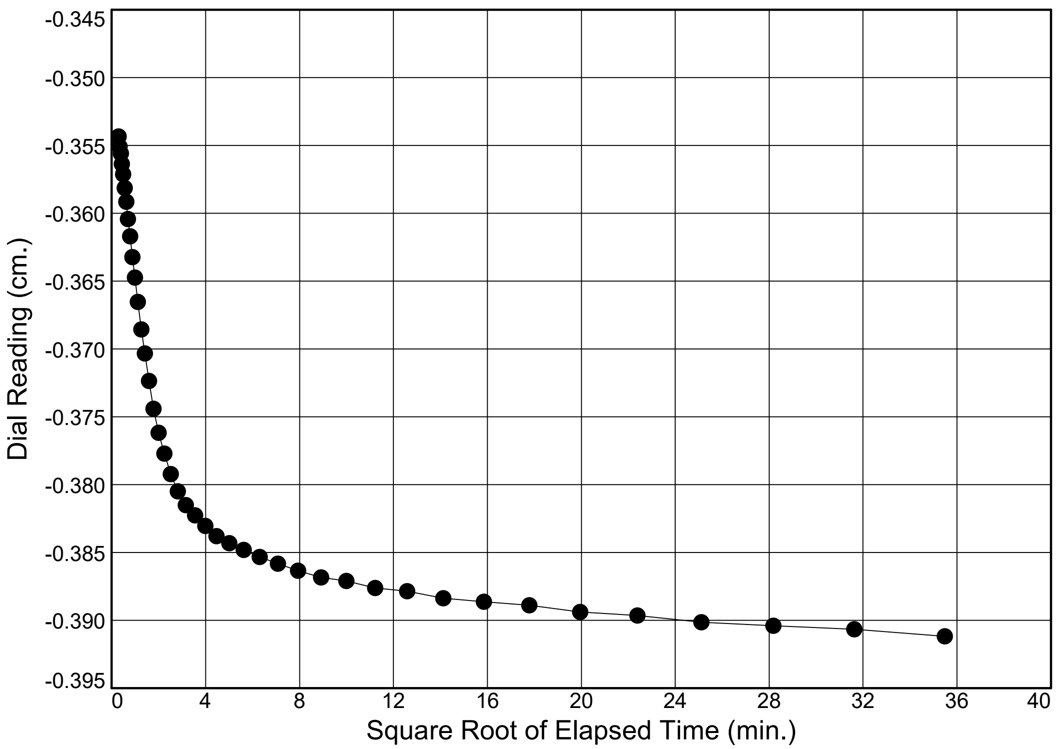
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

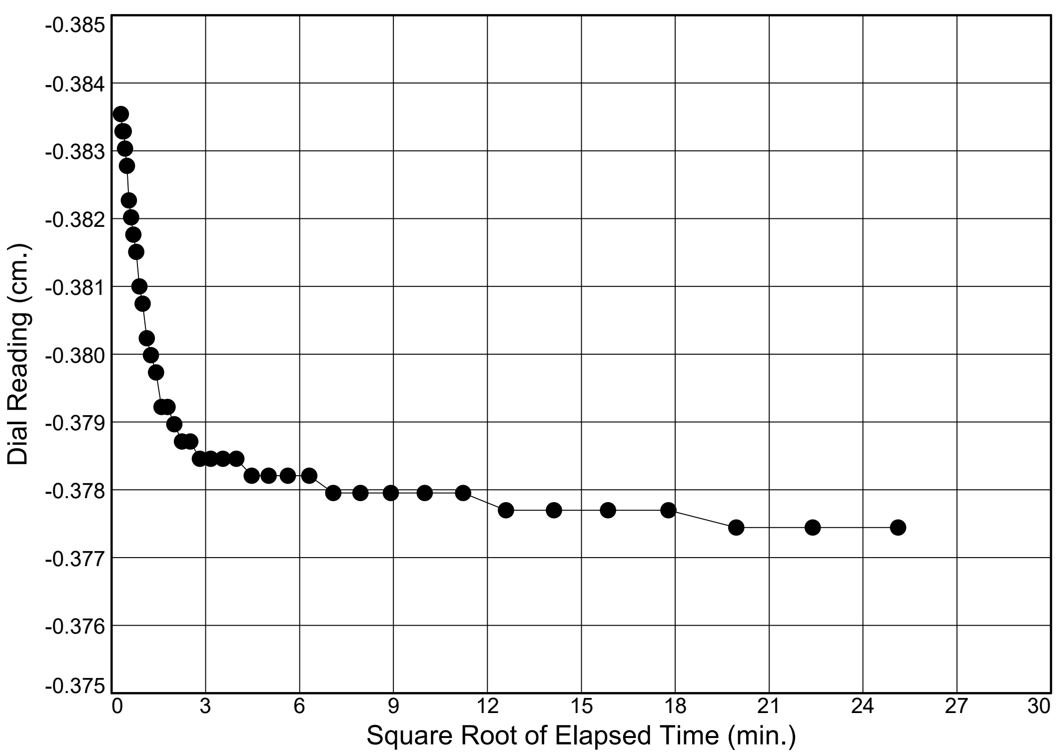
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15.0' Sample Number: 95.6-2 #39A



Load No.= 7
Load= 800.0 kPa
D_0 = -0.8913
D_{90} = -0.9611
D_{100} = -0.9688
T_{90} = 5.58 min.

C_v @ T_{90}
0.101 cm.^{2}/min.



Load No.= 8
Load= 200.0 kPa
D_0 = -0.9771
D_{90} = -0.9646
D_{100} = -0.9632
T_{90} = 1.93 min.

C_v @ T_{90}
0.287 cm.^{2}/min.

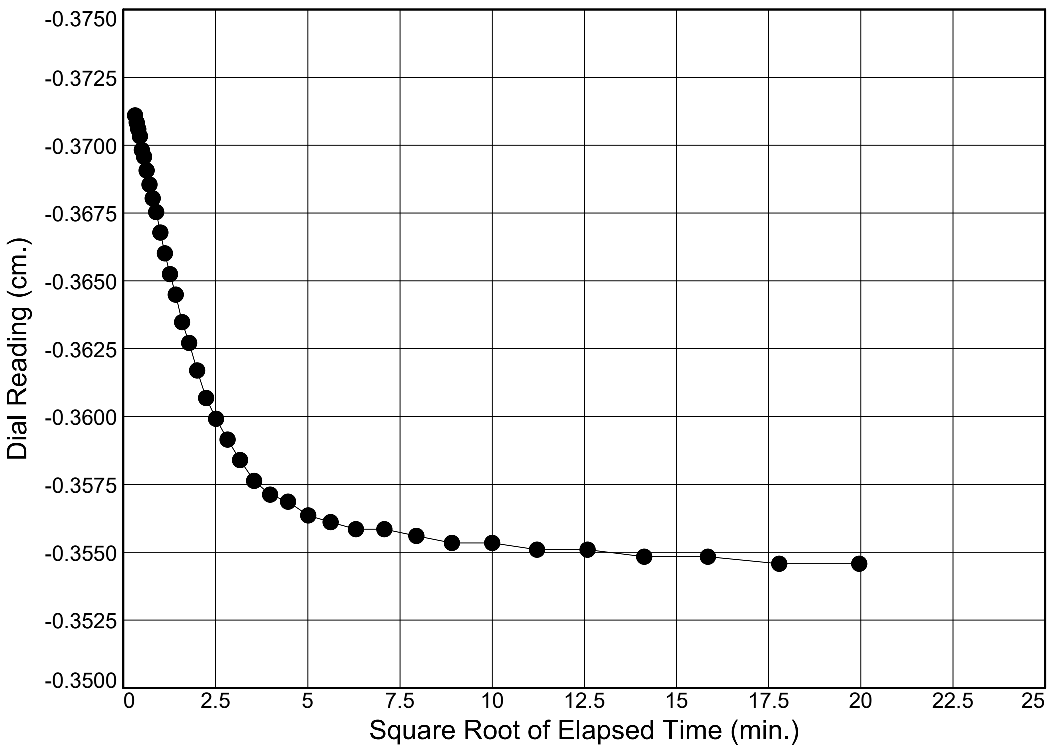
Figure

Solum Consultants Ltd.

Dial Reading vs. Time

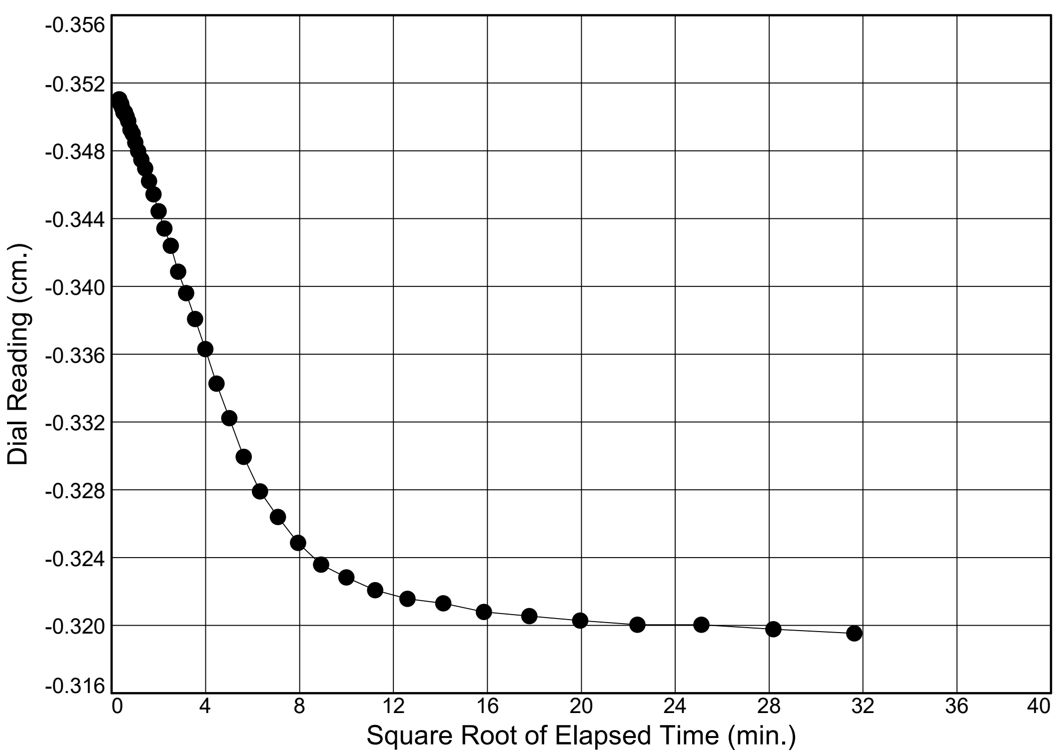
Project No.: 61021019.00
Project: Geo. Inv. for Culvert Sites

Depth: 15.0' Sample Number: 95.6-2 #39A



Load No.= 9
Load= 50.0 kPa
D_0 = -0.9467
D_{90} = -0.9135
D_{100} = -0.9098
T_{90} = 6.90 min.

C_v @ T_{90}
0.082 cm.^{2}/min.



Load No.= 10
Load= 12.5 kPa
D_0 = -0.8951
D_{90} = -0.8252
D_{100} = -0.8174
T_{90} = 63.03 min.

C_v @ T_{90}
0.009 cm.^{2}/min.

Figure

Solum Consultants Ltd.

SOLUM™
CONSULTANTS LTD.
GEOTECHNICAL & MATERIAL
TESTING LABORATORY

STANDARD LABORATORY TERMS AND CONDITIONS

1.0 Description of Services to be Performed by Solum Consultants Ltd. (Solum)
Solum shall provide geotechnical and material laboratory testing services on samples in accordance with these terms and conditions and executed Laboratory Testing Request Forms. Solum shall perform its work in accordance with accepted laboratory standards and accepted standard operating procedures. Solum reserves the right to modify methods as necessary based upon experience and/or current scientific literature. If the Client requests a manner of analysis that varies from standard operating or recommended procedures, the Client shall not hold Solum responsible for the results. Such variations of analysis will be noted on the reports. Solum reserves the right to subcontract laboratory testing if a particular test cannot be performed by Solum.

2.0 Reports, Confidentiality and Third Parties
Laboratory reports provided by Solum will be composed of a cover page, tables and figures if applicable. Reports will be e-mailed in PDF format to the individual(s) specified on the Laboratory Testing Request Forms. Laboratory reports may also be faxed or mailed to the Client upon request. Except as required by law, Solum shall not disclose testing results or reports to any party other than the Client, unless the Client, in writing, requests information to be provided to a third party. Solum shall abide by any additional confidentiality requirements requested by the Client provided that such requirements are provided to Solum at or before execution of the testing.
Information provided by Solum is intended for Client use only. Any use by a third party, of reports or documents authored by Solum, or any reliance on or decisions made by a third party based on the findings described in said documents, are the sole responsibility of such third parities, and Solum accepts no responsibility of damages suffered by any third party as a result of decisions made or actions conducted.

3.0 Laboratory Testing Request Form (Chain of Custody)
The laboratory testing request form must be completed by the Client and be accompanied with the samples. Other form of COC may be accepted; however, the condition of Solum COC is still applied. Testing will not commence until the laboratory testing request form has been completed. If requested by the Client, Solum shall provide a copy of the laboratory testing request form with the report.
No persons other than the designated representatives for each Laboratory Testing Request Form are authorized to act regarding changes to the testing request form. Any changes or amendments of the laboratory testing request form must be in writing and be completed by the originator.

4.0 Acceptance, Contamination and Disposal of Samples
Loss or damages to samples remains the responsibility of the Client until Solum representatives acceptance of samples by notation on the laboratory testing request form.
As to any samples that are suspected of containing hazardous substances, the Client will specify the suspected or known substance and level of contamination. This information is to be stated on the laboratory testing request form and be accompanied with the samples before testing can commence. Solum may refuse acceptance of samples if it determines they present a risk to health and safety.
Samples accepted by Solum shall remain the property and liability of the Client while in the custody of Solum. Solum will discard all non-contaminated samples after two weeks of submitting lab report or a month from the date of receiving the samples without additional retention period at a fixed disposal charge, or if requested by the Client, samples may be returned to the Client at no cost to Solum. If requested by client, Solum will store samples provided the client agrees to pay for the storage charge. Contaminated material may be returned/shipped to the Client at the Client's expense or Solum will discard samples with disposal rates varying for samples containing higher levels of contamination, refer to price list.
Soil samples requested to be stored will be stored inside the lab up to the expiration of storage period. Soil samples will be discarded upon the expiration date of the storage period unless client requests either extending storage period or return samples back to client at no cost to Solum.

5.0 Indemnification/Hold Harmless
Solum shall protect, indemnify and save harmless Client, and its directors, officers, employees, agents, representatives, invitees and subcontractors, and at Client's request, investigate and defend such entities form and against all claims, demands and causes of action, of every kind and character, without limitation, arising in favour of or made by third parties, on account of bodily injury, death or damage to or loss of their property resulting from any negligent act or wilful misconduct of Solum.
The Client shall protect, indemnify and save harmless Solum, and its directors, officers, employees, agents, representatives, invitees and subcontractors, and at Solum's request, investigate and defend such entities form and against all claims, demands and causes of action, of every kind and character, without limitation, arising in favour of or made by third parties, on account of bodily injury, death or damage to or loss of their property resulting from any negligent act or wilful misconduct of Client.

6.0 Limitation of Liability
The total liability of Solum or its staff whether based in contract or tort, will be limited to the lesser of the fees paid or actual damages incurred by the Client. Solum will not be responsible for any consequential or indirect damages even if caused by negligence of Solum. Solum will only be liable for damages resulting form negligence of Solum. All claims by the Client shall be deemed relinquished if not made within one year after the testing date. No warranty is either expressed or implied, or intended by any agreement or by furnishing oral or written reports or findings.

7.0 Termination of Testing Work Order
The Client may order work suspended or terminated upon seven days advance written notice. If work is suspended, Solum shall receive, upon resumption, an adjustment in the cost of services to compensate for additional costs incurred due to the interruption of services. Upon suspension or termination, Solum shall preserve samples provided that the Client agrees to pay the sample storage charge.

8.0 Pricing, Payments and Invoicing
Invoices will be based on most current Solum laboratory testing rates; rates may change without notice. Solum invoices shall be paid within thirty (30) days of receipt of the invoice. Amounts not paid when due shall bear interest at the rate of 18% per annum from the date due until the date of payment.

Appendix D

List of Laboratory Soil Testing Methods

Appendix D

List of Laboratory Soil Testing Methods

The following tests were performed on selected soil samples:

- Moisture content tests were performed in accordance with ASTM D2216-10, "*Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*."
- Atterberg Limit determinations in accordance with ASTM D4318-10, "*Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*."
- Sieve analysis in accordance with ASTM C136/C136M-14, "*Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*."
- Sieve and hydrometer analysis in accordance with ASTM D422 (withdrawn 2016), "*Standard Test Method for Particle-Size Analysis of Soils*."
- California Bearing Ratio in accordance with ASTM D1883-16, "*Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils*."
- Direct Shear Testing in accordance with ASTM D3080/D3080M-11, "*Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions*."
- Standard Proctor tests in accordance with ASTM D698-12e2, "*Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12400 ft-lbf/ft^3 (600 kN-m/m^3)).*"
- Oversize correction in accordance with ASTM D4718/D4718M-15, "*Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles*."
- One-dimensional consolidation test in accordance with ASTM D2435/D2435M-11, "*Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading*."
- Unconfined compressive strength of rock in accordance with ASTM D7012-14, "*Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures*."
- Soil pH determination was according to ASTM G51 - 95(2012), "*Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing*."
- Soil soluble chloride content in accordance with SM 4500-Cl E-97 OL, "*Colorimetric, manual or Automatic (Ferricyanide) Potentiometric Titration Method*."
- Soil soluble sulfate content in accordance with EPA 300.0 Rev. 2.1, "*Ion Chromatography Method*."

- Soil resistivity measurement in accordance with ASTM G187-12a, "*Standard Test Method for Measurement of Soil Resistivity Using the Two-Electrode Soil Box Method*."
- Organic content test in accordance with ASTM D2974 – 14, "*Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*."