



Terraprobe

Consulting Geotechnical & Environmental Engineering

Construction Materials Inspection & Testing

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
CALAMITY CREEK CULVERT
HIGHWAY 11
ASSIGNMENT No. 5013-E-0018
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. No. 5159-12-00, SITE 47-273C
GEOCRES NO. 31M-109**

PREPARED FOR: MMM Group Limited
2655 North Sheridan Way, Suite 300
Mississauga, Ontario
L5K 2P8

Attention: Mr. Trevor Small, M.Sc., P.Eng.

File No. 11-14-4066
April 11, 2016

©Terraprobe Inc.

Distribution:

3 Copies- MTO Project Manager (Northeastern Region)
1 Copy - MTO Pavements and Foundations Section
1 Copy - MMM Group Limited, Mississauga
1 Copy - Terraprobe Inc., Brampton

Terraprobe Inc.

Greater Toronto

11 Indell Lane
Brampton, Ontario L6T 3Y3
(905) 796-2650 Fax: 796-2250
brampton@terraprobe.ca

Hamilton – Niagara

903 Barton Street, Unit 22
Stoney Creek, Ontario L8E 5P5
(905) 643-7560 Fax: 643-7559
stoneycreek@terraprobe.ca

Central Ontario

220 Bavview Drive, Unit 25
Barrie, Ontario L4N 4Y8
(705) 739-8355 Fax: 739-8369
barrie@terraprobe.ca

Northern Ontario

1012 Kelly Lake Rd., Unit 1
Sudbury, Ontario P3E 5P4
(705) 670-0460 Fax: 670-0558
sudbury@terraprobe.ca

www.terraprobe.ca

TABLE OF CONTENTS

PART A – FOUNDATION INVESTIGATION REPORT	I
1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
3.0 INVESTIGATION PROCEDURES	1
3.1 Previous Investigation	1
3.2 Current Investigation	2
3.3 Borehole Data	2
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 Subsurface Conditions	3
4.2.1 Topsoil	4
4.2.2 Flexible Pavement	4
4.2.3 Fill – Sand and Gravel to Sand and Silt	4
4.2.4 Fill – Clayey Silt to Silty Clay	5
4.2.5 Silty Clay and Clayey Silt	5
4.2.6 Silty Clay (Varved)	6
4.2.7 Clayey Silt to Silty Clay Till	9
4.2.8 Bedrock	9
4.3 Ground Water Levels	10
5.0 MISCELLANEOUS	12
PART B – FOUNDATION DESIGN REPORT	II
6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	13
6.1 General	13
6.2 Installation Methods	14
6.2.1 Open Cut Excavation	14
6.2.2 Pipe Jacking with a Slurry or EPB Shield TBM	15
6.2.3 Micro Tunnelling (MT)	15
6.3 Assessment of Tunnelling Alternatives	15
6.4 Preferred Tunnelling Alternative	16
6.5 Settlement	17
6.6 Instrumentation and Monitoring	18
6.7 Open Cut Excavation	19
6.7.1 Vertical Alignment	19



6.8	Culvert Bedding, Cover and Trench Backfill	19
6.8.1	Trench Clay Plugs and Cut-off Collars	19
6.9	Erosion Protection	20
6.10	Embankments	20
6.10.1	Embankment Stability.....	20
6.10.2	Embankment Construction	22
6.10.3	Embankment Settlement	22
6.11	Temporary Protection Systems	22
6.12	Basal Stability.....	23
6.13	Excavations	24
6.14	Ground Water Control	24
6.15	Additional Studies.....	24
7.0	CLOSURE	25

REFERENCES

LIST OF TABLES

Table 1	Constructibility Review of Tunnelling Alternatives
Table 2	Feasibility of Tunnelling Methodologies
Table 3	Evaluation of Installation Methods

LIST OF DRAWINGS

Drawing 1	Borehole Locations and Soil Strata
Drawing 2	Soil Strata – Centre Line Profile of Highway 11
Drawing 3	Soil Strata – Centre Line Profile of Calamity Creek Culvert
Drawing 4	Soil Strata – Section A-A'
Drawing 5	Soil Strata – Section B-B'

LIST OF APPENDICES

APPENDIX A Record of Borehole Sheets

List of Symbols and Abbreviations

Record of Terraprobe Borehole Sheets – BH1, BH2, BH3, BH4, BH5 and BH6.

Record of S&P Borehole Sheets – BH DB2, BH DB3, BH DB4, BH DB5.

APPENDIX B1

Terraprobe Field and Laboratory Test Results and Photographs

Figure B1-1	Grain Size Distribution – Sand Fill
Figure B1-2	Grain Size Distribution – Gravelly Sand to Sand and Silt Fill
Figure B1-3	Grain Size Distribution – Silty Clay Fill
Figure B1-4	Plasticity Chart – Silty Clay Fill
Figure B1-5	Grain Size Distribution – Silty Clay to Clay
Figure B1-6	Plasticity Chart – Silty Clay to Clay
Figure B1-7	Photographs of Varved Silty Clay to Clay
Figure B1-8	Silty Clay to Clay – Plot of Undrained Shear Strength versus Elevation



Figure B1-9 – B1-11	Grain Size Distribution – Varved Silty Clay to Clay (CI)
Figure B1-12 – B1-14	Plasticity Chart – Varved Silty Clay to Clay (CI)
Figure B1-15	Grain Size Distribution – Varved Silty Clay (CL)
Figure B1-16	Plasticity Chart – Varved Silty Clay (CL)
Figure B1-17	Silty Clay to Clay – Atterberg Limits and Water Contents versus Elevation
Figure B1-18 – B1-25	Silty Clay to Clay – One Dimensional Consolidation Test Results
Figure B1-26	Grain Size Distribution – Clayey Silt Till
Figure B1-27	Plasticity Chart – Clayey Silt Till
Figure B1-28 – B1-32	Photographs of Bedrock Core Samples

APPENDIX B2

S&P Laboratory Test Results

Figures B2	Grain Size Distribution – Borderline Silts and Silty Clays
Figure B2-1	Plasticity Chart – Borderline Silts and Silty Clays

APPENDIX C

Plot of Undrained Shear Strength versus Elevation

APPENDIX D

Slope Stability Models and Results



PART A – FOUNDATION INVESTIGATION REPORT

**CALAMITY CREEK CULVERT, SITE 47-273C
HIGHWAY 11
TOWNSHIP OF DYMOND, DISTRICT OF TIMISKAMING, ONTARIO
ASSIGNMENT No. 5013-E-0018, G.W.P. 5159-12-00**



1.0 INTRODUCTION

Terraprobe Inc. (Terraprobe) has been retained by MMM Group Limited (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of preliminary designs for the rehabilitation of structures identified in MTO's Request for Proposal (RFP) titled *"Preliminary Design, Rehabilitation/Replacement of Twelve Structures on Highway 11, 101, 577, 579, 634 & 668, in New Liskeard Area"*, Contract Number. 5013-E-0018.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's RFP, and in Section 5.7 of MMM's *Technical Proposal* for this assignment. This report presents the factual data on the subsurface conditions at the Calamity Creek Culvert, Site 47-273C on Highway 11, Township of Dymond, District of Timiskaming, Ontario.

The current investigation is supplemented with data obtained from a previous subsurface investigation carried out at this site, which is reported in the following document:

- Shaheen & Peaker Limited, "Exploratory Boreholes, W.P. 147-98-00, Agreement No. P05005A000062, SP3012, dated December 14, 1999.

2.0 SITE DESCRIPTION

The site (with coordinates of N 5,269,400; E 404,535) is located on Highway 11, approximately 2.9 km north of the highway's intersection with Highway 65 in the Township of Dymond, Ontario. The key plan on the Borehole Locations and Soil Strata Drawing, (Drawing 1) provides an overview of the site location.

The existing structure is a 235± m long concrete box culvert with a non-linear alignment consisting of five segments/bends and its cross-section opening is 3.05 m wide and 2.45 m high. A 50 m section of the culvert's interior was refaced by MTO in 2007 and the cross-section opening of this section is 2.65 m wide and 2.01 m high. The highway crosses above the culvert via an approximately 18± m high embankment that transitions into cut slopes 150± m north and 60± m south of the culvert.

The terrain is generally rolling to gently undulating with vegetation consisting mainly of grass and shrubs and occasional stands of deciduous and coniferous streets along the banks of the creek. Calamity Creek flows from east to west.

3.0 INVESTIGATION PROCEDURES

3.1 Previous Investigation

The site was previously investigated by Shaheen & Peaker Limited (S&P) in October 1999. Four boreholes numbered DB2, DB3, DB4 and DB5 were drilled and sampled to depths ranging from 21.9 m to 28.1 m below ground surface. Standpipe piezometers were installed in Boreholes DB3 and DB5, to permit longer term ground water level monitoring. The approximate locations of these S&P boreholes are shown on Drawing 1.

3.2 Current Investigation

The fieldwork for the current investigation was carried out between August 25 and September 04, 2014. Six boreholes numbered Borehole 1 to 6 were drilled and sampled to depths ranging from 15.2 m to 30.3 m below ground surface, and their approximate locations are shown on Drawing 1. Terraprobe's staff staked out the borehole locations in the field relative to on-site features and MMM surveyors established Control Points HCP 102 and HCP 103 with geodetic elevations of 213.982 m and 214.165 m respectively. The data from these control points were used by Terraprobe's staff to determine the ground surface elevations and coordinates of the Terraprobe boreholes.

The boreholes were drilled with truck and track-mounted CME 55 drill rigs supplied and operated by specialist drilling contractors and Terraprobe's staff observed and recorded the drilling, sampling and in situ testing operations and logged the boreholes and rock cores.

Samples of the overburden soils were generally obtained at intervals of 0.75 m and 1.5 m depth using a 50 mm outer diameter (O.D.) split-spoon sampler in conjunction with the Standard Penetration Testing (SPT) procedures as specified in ASTM Method D 1586¹. Relatively undisturbed samples of the clay soils were also collected with thin-walled Shelby Tube samplers. In the clay deposits an MTO 'N' vane was used to perform in-situ field vane tests, in order to determine the undrained shear strength of the soil. The bedrock was cored by NQ-size diamond coring techniques.

Ground water conditions in the open boreholes were observed during the drilling operations and standpipe piezometers were installed in Boreholes 1 and 6 to permit longer term ground water level monitoring. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The recovered soil and rock samples were subjected to Visual Identification (VI) and select soil samples were also subjected to a laboratory testing programme consisting of natural moisture content, grain size distribution analyses, Atterberg limits determinations and one-dimensional consolidation testing in accordance with MTO and/or ASTM Standards as appropriate.

3.3 Borehole Data

The Terraprobe and applicable S&P borehole data are summarized in the following tables.

Terraprobe Borehole Details

Borehole No.	MTM NAD 83 Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BH1	5 269 457.4	404 593.1	201.8	16.3
BH2	5 269 441.2	404 537.9	214.2	29.3
BH3	5 269 374.3	404 536.5	213.7	30.3
BH4	5 269 354.3	404 541.0	213.9	30.0
BH5	5 269 354.8	404 496.3	203.5	20.6
BH6	5 269 290.3	404 454.7	197.7	15.2

1 ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

S&P Borehole Details

Borehole No.	Station	Offset Distance (m)	Estimated Ground Surface Elevation (m)	Borehole Depth (m)
DB2	17+590	3.5 Lt.	214.3	28.1
DB3	17+630	3.1 Rt.	213.9	26.6
DB4	17+679	2.9 Lt.	213.8	21.9
DB5	17+710	4.5 Rt.	214.1	26.1

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The site lies in the Little Clay Belt² Physiographic Region, which is characterized by glaciofluvial, and glaciolacustrine deposits of clay, sand and till. The fine grained glaciolacustrine clay beds were deposited in Glacial Lake Barlow-Ojibway and form the Little Clay Belt. The Till³ within the area is stony to bouldery and adjacent to paleozoic rocks has a clayey silt texture that is calcareous, containing numerous paleozoic clasts.

The bedrock unit within the project limits consist of the Thornloe Formation of Middle Silurian Age⁴. The Thornloe Formation consists of limestone, dolomite and sandstone.

4.2 Subsurface Conditions

Reference is made to the Record of Borehole Sheets in Appendix A. Details of the encountered soil and bedrock stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawings. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

The stratigraphic boundaries shown on the Record of Boreholes and on the interpreted stratigraphic section are inferred from non-continuous soil sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

In summary, the site is generally underlain by a flexible pavement, embankment fill consisting of very loose to very dense sand and gravel to sand and silt and soft to hard clayey silt. The native overburden deposits consist of soft to very stiff silty clay and clayey silt, firm to stiff varved silty clay, and firm to hard clayey silt till that are further underlain by dolomitic limestone bedrock.

2 Gupta, V.K., and Wadge, D.R. 1980: Bouguer Gravity and Generalized Geological Map Temagami-Englehart Area, Districts of Timiskaming, Nipissing and Sudbury; Ontario Geological Survey, Prelim. Map P.2296, Geophys. Ser., Scale 1:100 000. Survey and compilation 1977, 1978, 1979.

3 Morton, J.D., King, R.C.F. and Kalin, M.W. 1979: Quaternary Geology of the New Liskeard Area, District of Timiskaming; Ontario Geological Survey Prelim. Map P.2291, Geological Ser., Scale 1:50 000. Geology 1972, 1977.

4 Ministry of Natural Resources, Map 2301, Harley and Dymond Townships, Timiskaming District, Scale 1:31 680, 1974.

4.2.1 Topsoil

Topsoil ranging from 100 mm to 150 mm in thickness was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

4.2.2 Flexible Pavement

Boreholes drilled through Highway 11 encountered a flexible pavement consisting of 140 mm to 360 mm thick asphalt concrete underlain by granular fill consisting of sand and gravel and sand. In Boreholes 3, DB3 and DB5, a buried pavement was encountered consisting of 70 mm to 300 mm thick asphalt concrete that is further underlain by a layer of gravelly sand to sand and gravel. The locations, thicknesses and base elevations of the granular base fill are summarized in the following table.

Pavement Granular Borehole Data

Borehole No.	Fill Thickness (mm)	Buried Pavement Fill Thickness (mm)	Fill Base Elevation (m)
BH2	630	-	213.3
BH3	530	150	212.4
BH4	540	-	213.0
DB2	160	-	214.0
DB3	50	170	213.2
DB5	420	-	213.4

Standard Penetration tests carried out in the gravelly sand and sand fill measured SPT N-values of 31 to more than 50 blows for 0.3 m of penetration indicating a dense to very dense relative density. The natural water content of two samples of the granular fill is 3% and 11% by weight.

The grain size distribution curve of a sample of the sand fill is presented on Figure B1-1 in Appendix B1. The results show a grain size distribution consisting of 15% gravel, 64% sand, 16% silt and 5% clay size particles.

4.2.3 Fill – Sand and Gravel to Sand and Silt

Fill material ranging in composition from sand and gravel to sand and silt were encountered in the roadway embankment. The locations, thicknesses, depths and base elevations of the fill are summarized in the following table.

Sand and Gravel to Sand and Silt Fill Borehole Data

Borehole No.	Fill Thickness (m)	Fill Depth (m)	Fill Base Elevation (m)
BH2	6.1	7.0	207.2
BH3	7.7	9.0	204.7
BH5	1.9	2.1	201.4
DB2	4.2	4.5	209.8
DB4	8.9	9.1	204.7

Standard Penetration tests performed in this fill material measured SPT N-values ranging from 2 to 62 blows for 0.3 m of penetration indicating a very loose to very dense relative density. The natural water content of samples of this fill material range from 7% to 28% and in Borehole 2 a higher water content of 46% was obtained where peat inclusions were found in the fill.

Five samples of this gravelly sand to sand and silt were subjected to grain size distribution tests and the results are presented in Figure B1-2 in Appendix B1. These results show a grain size distribution consisting of 4% to 26% gravel, 45% to 54% sand, 16% to 37% silt and, 4% to 14% clay size particles. A boulder was also encountered in this fill material in Borehole 3.

4.2.4 Fill – Clayey Silt to Silty Clay

Discontinuous layers of clayey silt to silty clay fill material were encountered within the embankment. The locations, thicknesses, depths and base elevations of the clayey silt to silty clay fill are summarized in the following table.

Clayey Silt to Silty Clay Fill Borehole Data

Borehole No.	Fill Thickness (m)	Fill Depth (m)	Fill Base Elevation (m)
BH3	4.6	13.6	200.1
BH4	6.6	7.5	206.4
DB3	5.6	6.3	207.6
DB5	4.3	5.0	209.1

Standard Penetration tests performed in the clayey silt to silty clay fill measured N-values ranging from 3 to 37 blows for 0.3 m of penetration indicating a soft to hard consistency. The natural water content of samples of the clayey silt to silty clay fill range from 13% to 29% by weight.

The grain size distribution plots of three samples of the silty clay fill are depicted on Figure B1-3 in Appendix B1. The results show a grain size distribution consisting of 6% to 15% gravel, 31% to 37% sand, 30% to 34% silt and, 23% to 26% clay sized particles.

Atterberg limits tests were also carried out on three samples of the silty clay fill and the results are presented in Figure B1-4 in Appendix B. These values indicate that the fill is a cohesive soil with low plasticity (CL). The results from the Atterberg limits tests are summarized below:

Liquid Limit:	25 to 28 %
Plastic Limit:	14 to 16 %
Plasticity Index:	10 to 13 %
Natural Moisture Content:	17 to 22 %

4.2.5 Silty Clay and Clayey Silt

In some of the boreholes, there exists a layer of silty clay soil below the existing embankment fill or the ground surface and, in Borehole DB4 clayey silt layers were also encountered. Summarized below are the locations, thicknesses, depths and base elevations of the silty clay and clayey silt deposits.

Clayey Silt to Silty Clay Borehole Data

Borehole No.	Silty Clay/Clayey Silt Thickness (m)	Silty Clay/Clayey Silt Depth (m)	Silty Clay/Clayey Silt Base Elevation (m)
BH1	1.3	1.4	200.4
BH3	0.7	14.3	199.4
BH4	2.6	10.1	203.8
BH5	3.5	5.6	197.9
BH6	1.9	2.1	195.6
DB3	5.2	11.5	202.4
DB4	5.7	14.8	199.0

Standard Penetration tests in the silty clay and clayey silt measured SPT N-values ranging from 2 to 27 blows per 0.3 m of penetration and, field vane tests measure in-situ undrained shear strengths ranging from 64 kPa to more than 100 kPa. Based on the SPT tests and the field vane tests, the clayey silt to silty clay is described as having a soft to very stiff consistency. The sensitivity of the silty clay varies from 2.6 to 10.0, indicating a low to medium sensitivity soil class (Canadian Foundation Engineering Manual [CFEM], 2006). The moisture contents of samples of the silty clay range from 32% to 41%.

The grain size distribution plots of five samples of the silty clay are depicted in Figure B1-5 in Appendix B1. These results show a grain size distribution consisting of 0% gravel, 0% to 2% sand, 21% to 47% silt and, 52% to 77% clay sized particles.

Three samples of the silty clay deposit were also subjected to Atterberg limits tests and the results are presented in Figure B1-6 in Appendix B1. These values indicate that the silty clay deposit is a cohesive soil ranging from intermediate plasticity (CI) to high plasticity clay (CH). The Atterberg limits test results are summarized below.

Liquid Limit:	36% to 52 %
Plastic Limit:	20% to 24 %
Plasticity Index:	16% to 28 %
Natural Moisture Content:	35% to 41 %

4.2.6 Silty Clay (Varved)

The site is underlain by a varved silty clay deposit. The deposit's structure consists of fine grained clay soils interlayered with silt ranging from 5 mm to 30 mm in thickness. Photographs illustrating the varved clay matrix are provided in Figure B1-7 in Appendix B1. The locations, thicknesses, depths and base elevations of the silty clay to clay deposit are summarized in the following table.

Varved Silty Clay Borehole Data

Borehole No.	Silty Clay Thickness (m)	Silty Clay Depth (m)	Silty Clay Base Elevation (m)
BH1	11.7	13.1	188.7
BH2	18.2	25.2	189.0
BH3	12.2	26.5	187.2
BH4	16.7	26.8	187.1

Borehole No.	Silty Clay Thickness (m)	Silty Clay Depth (m)	Silty Clay Base Elevation (m)
BH5	11.1	16.7	186.8
BH6	10.0	12.1	185.6
DB2	22.9	27.4	186.9
DB3	14.0	25.5	188.4
DB4	7.1*	21.9	191.9
DB5	21.1*	26.1	188.0

* Borehole termination depth.

The N-values of Standard Penetration tests carried out in the silty clay deposit range from 0 blows (weight of hammer) to 17 blows per 0.3 m of penetration. Field vane tests measured in-situ undrained shear strengths that range from 30 kPa to 98 kPa and occasional values exceed 100 kPa, as illustrated on Figure B1-8 in Appendix B1. Based on these results the consistency of the silty clay is described as generally firm to stiff with occasional very stiff zones. The sensitivity of the silty clay ranges from about 2.1 to 11.2, indicating a low to medium sensitivity soil class (Canadian Foundation Engineering Manual [CFEM], 2006).

The variation of undrained shear strength with elevation plot depicted in Figure B1-8, illustrates undrained shear strength values that mostly range between 50 kPa and 75 kPa. Outside of this range a few lower values between 30 kPa and 50 kPa and a few higher values between 75 kPa and 98 kPa were measured.

Samples of the silty clay soils were subjected to grain size distribution tests and the grain size distribution curves are illustrated on Figures B1-9 to B1-11 in Appendix B1. The test results show a grain size distribution consisting of 0% gravel, 0% sand, 23% to 53% silt and 47% to 77% clay sized particles.

Samples of the silty clay soils were also subjected to Atterberg limits tests and the results are plotted on the plasticity charts, Figures B1-12 to B1-14 in Appendix B1. The results indicate a cohesive deposit of intermediate plasticity (CI). The Atterberg limits test results are summarized below.

Liquid Limit:	36% to 48 %
Plastic Limit:	19% to 22 %
Plasticity Index:	15% to 26 %
Natural Moisture Content:	41% to 53 %

Grain size distribution tests were carried out on six samples of low plasticity silty clay layers existing within the varved silty clay matrix. The grain size distribution curves are shown on Figure B1-15 in Appendix B1. The grain size distribution of the silty clay consists of 0% gravel, 0% to 1% sand, 45% to 69% silt and; 30% to 55% clay sized particles.

Atterberg limits tests were also carried out on six samples of the low plasticity silty clay layers embedded within the varved silty clay matrix and the results are plotted on the plasticity chart, Figure B1-16 in Appendix B1. These values indicate low plasticity (CL) silty clay soils. The Atterberg limits test results are summarized below.

Liquid Limit:	28% to 32 %
Plastic Limit:	19% to 20 %
Plasticity Index:	9% to 13 %
Natural Moisture Content:	33% to 53 %



Seven S&P grain size distribution curves are included in Appendix B2. The data indicates a grain size distribution consisting of 0% gravel, 0% to 4% sand, 56% to 69% silt and; 31% to 43% clay sized particles.

The Atterberg limits test results of seven soil samples from the S&P investigation are plotted on the plasticity chart included in Figure B2-1 in Appendix B2. These values indicate borderline soils consisting of inorganic silts (ML-MI) and low plasticity (CL) to intermediate plasticity (CI) silty clay soils. The Atterberg limits test results are summarized below.

Liquid Limit:	31% to 42 %
Plastic Limit:	23% to 29 %
Plasticity Index:	7% to 15 %
Natural Moisture Content:	36% to 48 %

The Atterberg Limits tests results of the silty clay deposit are also plotted against elevation in Figure B1-17. These results illustrate that the natural moisture contents of the tested samples are typically higher than the liquid limits. The moisture content of thirty-eight samples of the silty clay varies between 33% and 53% and the unit weight of tested samples range from 17 kN/m³ to 18.2 kN/m³.

One-dimensional consolidation tests were performed on two samples of the silty clay and the results are presented in Figures B1-18 to B1-25 in Appendix B1. The results of the one-dimensional consolidation tests are summarized below.

One-Dimensional Consolidation Test Results

Borehole/Sample No.	Sample Depth/Elevation (m)	σ'_{vo} (kPa)	σ'_p (kPa)	C_c	C_r	e_o
BH1, Sample 4	3.3/198.5	39.5	257.0	0.472	0.085	1.38
BH3, Sample 22	17.0/196.7	265.2	248.0	0.382	0.053	1.02

Where:

σ'_{vo}	= effective overburden pressure
σ'_p	= Preconsolidation pressure;
C_c	= Compression index
C_r	= Recompression index; and
e_o	= Initial void ratio

Since the preconsolidation pressure of Borehole 1, Sample 4 (located outside the footprint area of the existing embankment) is higher than the effective overburden pressure; the silty clay deposit at this location is overconsolidated. However, below the embankment (Borehole 3, Sample 22), the soil is now normally consolidated because the effective overburden pressure in this area is nearly similar to the soil's preconsolidation pressure.

4.2.7 Clayey Silt to Silty Clay Till

Till units ranging in composition from clayey silt to silty clay were encountered within the project limits. Summarized in the following table are the locations, thicknesses, explored depths and base elevations of the till.

Clayey Silt to Silty Clay Till Borehole Data

Borehole No.	Clayey Silt to Silty Clay Till Thickness (m)	Clayey Silt to Silty Clay Till Depth of Deposit (m)	Clayey Silt to Silty Clay Base Elevation (m)
BH1	0.2	13.3	188.5
BH2	1.0	26.2	188.0
BH3	0.7	27.2	186.5
BH5	0.8	17.5	186.0
DB2	0.7	28.1*	186.2
DB3	1.1	26.6*	187.3

* Borehole termination depth.

Standard Penetration tests carried out in this deposit generally measured N-values of more than 50 blows for less than 0.3 m of penetration and in Borehole 5, an SPT N-value of 5 blows per 0.3 m of penetration was recorded. Based on these N-values the Clayey Silt to Silty Clay till is described as hard with occasional firm zones. The natural water content of samples from this deposit range from 9% to 16% by weight.

A grain size distribution test was carried out on a sample of the clayey silt till and the results illustrated in Figure B1-26, Appendix B1 show a grain size distribution consisting of 9% gravel, 29% sand, 47% silt and 15% clay sized particles. Till soils can also be expected to contain random cobble and boulder inclusions.

An Atterberg Limits test was also carried out on a sample of the clayey silt till and the results are plotted on the plasticity chart shown on Figure B1-27 in Appendix B1. These results indicate that the till is a cohesive soil with low plasticity (CL). The results from the Atterberg Limits test are summarized below:

Liquid Limit:	17 %
Plastic Limit:	12 %
Plasticity Index:	5 %
Natural Water Content:	15 %

4.2.8 Bedrock

The overburden soils are underlain by dolomitic limestone bedrock. Some of the S&P boreholes encountered refusal to further augering probably on bedrock. Summarized below are the depths to bedrock and the bedrock surface elevations.



Bedrock Borehole Data

Borehole No.	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
BH1	13.3	188.5
BH2	26.2	188.0
BH3	27.2	186.5
BH4	26.8	187.1
BH5	17.5	186.0
BH6	12.1	185.6
DB2	28.1*	186.2*
DB3	26.6*	187.3*

* Inferred depth to bedrock and top of bedrock elevation.

The dolomitic limestone bedrock is described as slightly to moderately weathered, thinly to thickly bedded and its colour is grey to whitish grey. Photographs of the bedrock core samples are provided in Figures B1-28 to B1-32 in Appendix B1. Summarized below are the Rock Quality Designation, Rock Mass Quality, Total Core Recovery and Solid Core Recovery.

Rock Core Sample Data

Borehole No.	Rock Quality Designation (RQD)	Rock Mass Quality ⁵	Total Core Recovery (TCR)	Solid Core Recovery (SCR)
BH1	37% and 86%	Poor to Good	100%	92% and 100%
BH2	86% and 94%	Good to Excellent	100%	97%
BH3	61% and 94%	Fair to Excellent	100%	97% and 100%
BH4	83% and 100%	Good to Excellent	100%	95% and 100%
BH5	80% and 85%	Good	100%	95% and 100%
BH6	88% and 95%	Good to Excellent	100%	97% and 100%

4.3 Ground Water Levels

The ground water conditions were observed in the boreholes during and upon completion of drilling. Standpipe piezometers were installed in two Terraprobe boreholes with tip of screens founded at the overburden/bedrock interface. After the first water level readings were observed to be above ground surface, the piezometric water levels were manually lowered below ground surface and allowed to stabilize prior to recording the new water levels; to verify the presence of excess hydrostatic pressure at the overburden/bedrock interface. The ground water levels measured in the S&P piezometers are also summarized in the following table:

⁵ Deere et al., 1967.

Ground Water Level Data

Borehole No. & Location	Date	Water Levels	
		Depth (m)	Elevation (m)
BH1 (Inlet)	September 17, 2014	-0.1*	201.9
	October 28, 2014	-0.5*	202.3
	November 24, 2014	-0.6*	202.4
BH6 (Outlet)	September 17, 2014	-0.3*	198.0
	October 28, 2014	-0.4*	198.1
	November 24, 2014	-0.4*	198.1
DB3 (Highway)	October 13, 1999	13.8	200.1
	October 14, 1999	13.8	200.1
DB5 (Highway)	October 14, 1999	12.5	201.6

♦ Water level above ground surface.

The ground water levels in Boreholes 1 and 6 are above ground surface, indicating the presence of excess hydrostatic pressure in the soil zone overlying the bedrock. The variation in ground water elevations in Borehole 1 and 6 also indicates the presence of a hydraulic gradient. On the east side of the highway (near the culvert inlet) the piezometric head elevation is $202.4 \pm$ m, decreasing to elevations of $200.1 \pm$ m and $201.6 \pm$ m below the highway. The piezometric head continues to fall on the west side of the highway and at the culvert outlet its elevation is $198.1 \pm$ m.

The ground water level in the upper overburden deposits will follow the ground surface topography. In the footprint area of the highway embankment a deep ravine existed. The ground water level on the north and south slopes of the buried ravine is estimated (from soil moisture contents) to range from elevations $205 \pm$ m and $206 \pm$ m in Boreholes 4 and 2 respectively, falling further down slope to about elevation $198.5 \pm$ m in Borehole 3. The ground water level on the buried ravine slope is expected to fall towards the free water level in the creek which is at elevation $196.5 \pm$ m below the highway.

At Borehole 1 the ground water level in the upper overburden deposits is also estimated (from soils moisture contents) at an elevation of $199 \pm$ m falling easterly to elevations $198.5 \pm$ m and $196 \pm$ m in Boreholes 5 and 6 respectively.

The ground water levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year. The ground water level will also be controlled by the free water level in the creek which varies from 196.8 m at the culvert inlet to 192.8 m at the culvert outlet.



5.0 MISCELLANEOUS

The investigation was carried out using drilling equipment supplied and operated by Landcore Drilling of Chelmsford, Ontario. The field operations were organized by Mr. Satyajit Manani, C.E.T. and the routine laboratory and one-dimensional consolidation testing were carried out at Terraprobe's Brampton laboratory and the Mississauga laboratory of Golder Associates.

This report was prepared by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and Associate with Terraprobe; with assistance provided by Mr. Hussein Ahmed, P.Eng. and Ms. Sepideh D-Monfared, MEng. Mr. Michael Tanos, P.Eng., Terraprobe's Designated MTO Contact conducted an independent quality control review.

Terraprobe Inc.



Rehman Abdul

R. Abdul, P.Eng.
Associate, Senior Geotechnical Engineer



Michael Tanos

Michael Tanos, P.Eng.
Designated MTO Contact



PART B – FOUNDATION DESIGN REPORT

**CALAMITY CREEK CULVERT, SITE 47-273C
HIGHWAY 11
TOWNSHIP OF DYMOND, DISTRICT OF TIMISKAMING, ONTARIO
ASSIGNMENT No. 5013-E-0018, G.W.P. 5159-12-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This report presents interpretation of the geotechnical data in the factual report and presents preliminary geotechnical design recommendations to assist the design team to select a preferred alternative for a culvert replacement. The discussion and recommendations presented in this report are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigations. These geotechnical recommendations are for planning and preliminary design purposes only, as part of the assessment of the feasibility and constructability of potential alternatives.

When designing culverts, the economic analysis usually includes factors such as estimated service life, construction cost, maintenance cost, replacement cost, risk of failure, and risk of property damage. Fish passage is also an important factor that affects the choice of culvert type.

The material choice includes steel, concrete, high density polyethylene and polyvinyl chloride. Some factors that are to be considered when choosing the material type include:

- Steel and plastic culverts have the advantage of simpler and quicker construction, which is especially advantageous in remote areas. Steel also has added advantage of often being at least partly salvageable;
- A well designed concrete culvert is extremely durable under a wide range of conditions;
- Precast concrete and smooth walled plastic pipes provide more efficient inlets than sharp edged inlets on metal culverts;
- The greater roughness of corrugated interiors may be an advantage for fish passage and for other situations where barrel or outlet velocities must be reduced; and
- Flexible pipe culverts may have an advantage over concrete box culverts in certain unfavourable foundation soil conditions.

The most economical culvert is neither the one with the lowest initial cost nor the culvert with the longest service life. Short and long term costs should be considered in both the original designs and in repairs or replacements.

The existing structure is a 235± m long concrete box culvert with a non-linear alignment consisting of five segments/bends and its cross-section opening is 3.05 m wide and 2.45 m high. A 50 m section of the culvert's interior was refaced by MTO in 2007 and the cross-section opening of this section is 2.65 m wide and 2.01 m high. The upstream and downstream invert elevations of the existing culvert are 196.77 m and 194.15 m respectively. The highway crosses above the culvert via an approximately 18± m high embankment that transitions into cut slopes 150± m north and 60± m south of the culvert.

Alternatives considered for the culvert rehabilitation/replacement include:

- Refacing the existing culvert (Alternative 1);
- Refacing the existing culvert and installing twin 1.8 m internal diameter (ID) relief culverts (Alternative 2);
- Refacing the existing culvert and installing a 2.1 m internal diameter (ID) relief culvert (Alternatives 3 and 4);

- Replacing the existing culvert with a 3.0 m internal diameter concrete culvert installed by trenchless techniques (Alternative 5A);
- Replacing the existing culvert with a 3.0 m internal diameter concrete culvert installed in supported open cut excavations (Alternative 5B);
- Replacing the existing culvert with twin 2.1 m internal diameter concrete culverts installed by trenchless techniques (Alternative 6); and
- Replacing the existing culvert (by trenchless techniques) with twin 1.8 m internal diameter concrete culverts and installing a 1.8 m internal diameter relief culvert (Alternative 7).

6.2 Installation Methods

The diameter and length of the culvert and the anticipated subsurface conditions along the culvert alignment limit the available trenchless installation techniques that would be economically viable. Each method considered has advantages, disadvantages or limitations and these are discussed further below.

Ground behaviour will be, in part, dependent on the installation method adopted and this preliminary design report provides guidance on the influence of ground behaviour on some possible installation methods.

Open cut and trenchless installation methods were evaluated and the preliminary recommendations for the selection of a preferred method took into consideration the risks and consequences of each alternative, relative construction costs, as well as the need to minimize traffic disruptions and reduce user delay costs during construction. The trenchless alternatives are generally costlier compared to open-cut excavations, and there is always a possibility that excavations may be required to retrieve tunnelling equipment if adverse subsurface conditions are encountered. Alternative installation methods include the following:

- Open Cut Excavation;
- Pipe Jacking with a Slurry or Earth Pressure Balance (EPB) Shield Tunnel Boring Machine (TBM); and
- Micro Tunnelling (MT).

6.2.1 Open Cut Excavation

An open cut excavation involves a trench excavation and excavation sidewall support (temporary protection systems); dewatering, bedding placement, pipe installation followed by cover material placement and trench backfilling. The open cut method offers the best control of gradient and alignment of the culvert, reduces the potential for delays resulting from encountering obstructions and provides the least risk of unanticipated damage to the active roadways.

The major disadvantages with open cut installation can be the requirement for proper construction staging to minimize traffic disruption; the need for large and deep excavations; and the potential for post construction settlement of the backfill materials. Pipe installation should be undertaken in accordance with Ontario Provincial Standard Specification (OPSS) 421 (Pipe Culvert Installation in Open Cut). The open cut excavation method is feasible at all locations and design recommendations for this methodology are provided in Section 6.7.

6.2.2 Pipe Jacking with a Slurry or EPB Shield TBM

Pipe jacking involves pushing an oversized liner (pipe) horizontally into the ground by jacking from a thrust pit to a reception pit. Although there is no theoretical limit to the jacked length practical engineering considerations and economics may impose restrictions. Construction tolerances are comparable with other tunnelling methods and the pipe jacking method generally requires less overbreak than segmental tunnels and provides ground support thereby reducing potential ground movement.

A range of excavation methods (similar to those employed in other forms of tunnelling) are available for removing the soil from inside the pipe as it is advanced and, the tunnel face support can be designed for a wide variety of ground conditions. When TBM equipment is used, persons are required in the tunnel to operate the equipment and remove the spoil. Given the wide range of ground conditions, an open face tunnelling operation with a TBM is not recommended because of the potential for high ground loss which will in turn induce large surface settlement and sinkholes.

We recommend using a sealed face support method that is capable of pressurizing the face of the excavation to prevent flowing soils from entering the tunnel. Face support can be provided by equipping the TBM with either an Earth Pressure Balance (EPB) shield or a slurry shield.

6.2.3 Micro Tunnelling (MT)

Micro tunnelling is a method of installing pipes behind a steerable remote controlled shield that is pressurized with a bentonitic fluid to minimize ground losses. The process is essentially remote controlled pipe jacking, where all operations are controlled from the surface, cuttings are removed by the circulating slurry and the necessity for personnel to enter the bore is eliminated. Micro tunnelling is a precise method of tunnelling and there is relatively little settlement of the ground, if the face pressure and cutting tools are appropriate for the ground conditions and are maintained over the length of the drive.

Micro tunnelling can be applied to a wide range of ground conditions, from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. However, construction risks increase where a micro tunnel drive is required to advance through a variety of ground types. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including handling of obstructions such as cobbles and boulders.

6.3 Assessment of Tunnelling Alternatives

To reduce the risk of subsidence or heave, tunnelling installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence or heave increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario, the general practice is to maintain a minimum depth of cover equivalent to 2 to 3 tunnel diameters.

There are inherent risks and consequences involved with trenchless installations that could include some or all the following:



- Obstructions within the tunnel reach that could increase the level of construction effort. Adequate equipment such as mandrels, pneumatic breakers or chisels, and augers are required to break and remove obstructions. If such efforts prove futile, an open cut excavation would be required to remove the obstruction;
- Inability to correct for line and grade within the design tolerances. If misalignment occurs, it may be necessary to abandon the pipes in the ground and grout the open section. Alternatively, an open cut excavation may be the most efficient way of completing the installation and salvaging any misaligned casings. Based on the existing data the risk of misalignment is not significant. However, further explorations will be required to carry out a more refined risk assessment; and
- Tunnelling equipment will be installed (entry pit location) and removed (exit pit location) in areas of locally steep slopes at the bottom of an approximately 13± m high embankment. These site constraints and potential accessibility issues must be taken into consideration by the Contractor.

Table 1 following the text of this report, provides a summary of the culvert details e.g. tunnel inverts, pipe dimensions, the range of depths of overburden cover at the borehole locations, the Depth of Cover to Tunnel Diameter Ratio and; the subsurface conditions encountered in the boreholes from ground surface to the respective pipe inverts.

The SPT N-values and the coefficient of uniformity (which is an indication of how well the soil is graded, and is expressed as the ratio of the particle size at which 60% of the particles are finer than to the particle size at which 10% are finer than), assist in classifying the soil behaviour according to the Tunnelman's Ground Classification System (Terzaghi, 1950, modified by Heur, 1974). This system is commonly used to describe the potential behaviour of an unsupported tunnel face during excavation and it uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slow ravelling, fast ravelling, squeezing, cohesive running, running, flowing and swelling. Efforts to predict soil behaviour must also be tempered by experience and engineering judgement.

The soil conditions within the tunnel horizon are classified in Table 2 following the text of this report. The soil conditions generally range from "slow ravelling" to "squeezing" to "running". The tunnelling alternatives that are considered to be feasible and practical are also included in Table 2. A comparison of the advantages, disadvantages, relative costs and risks associated with the various installation methods is presented in Table 3 following the text of this report.

6.4 Preferred Tunnelling Alternative

The tunnelling alternatives described in Section 6.2 are ranked on a numerical scale in order of preference with one (1) being assigned to the most preferred alternative and two (2) being assigned to the least preferred option. The preferred alternative was selected based on installation costs, the number of installations that could be completed with the same type of equipment, the availability of construction equipment and local construction knowledge.

Alternative	Proposed Pipe Inside Diameter (mm)	New Culvert	Relief Culvert	Ranking of Tunnelling Alternatives	
				MT	Pipe Jacking with a TBM
Alternative 2	1,800 Twin Culverts	NO	YES	1	2
Alternative 3	2,100	NO	YES	1	2
Alternative 4	2,100	NO	YES	1	2
Alternative 5A	3,000	YES	NO	2	1
Alternative 6	2,100 Twin Culverts	YES	NO	1	2
Alternative 7	1,800 Twin Culverts	YES	NO	1	2
	1,800	NO	YES	1	2

From a geotechnical perspective, culvert installation by microtunnelling is recommended. It is the most feasible alternative for six of the seven alternatives. If twin culverts are installed, the spacing between culverts needs to be selected to mitigate interference between the installed culvert and the culvert being installed. The horizontal spacing (measured at the tunnel spring line), shall be equal to or greater than $2\pm$ m for twin 1800 mm diameter installations and $2.5\pm$ m for twin 2100 mm diameter installations. The advantages, disadvantages, risks and consequences of the installation methods are provided in Table 3.

6.5 Settlement

The zone of influence of soils disturbed by the tunnelling operations will be about 2 tunnel diameters and construction of the tunnel will result in ground movements that will produce a settlement trough above and ahead of the tunnel.

After a tunnel is constructed, the transverse settlement trough that develops can be described by a Gaussian distribution curve as:

$$S = S_{\max} \exp \left(\frac{-x^2}{2i^2} \right)$$

Where S = settlement observed at a distance x from the tunnel axis;
 S_{\max} = maximum settlement above the tunnel axis;
x = horizontal distance from the tunnel axis; and
i = horizontal distance from the tunnel axis to the inflexion point on the settlement trough

The settlement trough induced by tunnelling can be characterized by means of two parameters namely the volume of settlement per unit length of tunnel (V_s) and the horizontal distance from the tunnel axis to the inflexion point (i).

The volume of the settlement trough (V_s) is difficult to evaluate as this parameter is dependent on construction methods and workmanship. This parameter (V_s), is usually compared to the volume of ground loss produced at the tunnel level and is expressed as a percentage of the theoretical volume of excavated soils (V_t).

Correlations by Mair and Taylor (1997)⁶ concluded that the parameter i can be reasonably estimated using the following expression:

$$i = K Z$$

Where K = is the trough width parameter and its value is a function of ground type; and
 Z = depth to the tunnel centre line.

The equations outlined above were used to estimate the settlement due to tunnelling below the highway. Trough width parameters of 0.5, 0.6 and 0.7 were used for tunnels in soft clays and 0.25 for tunnels in non-cohesive soils. The estimated maximum range of settlement at the tunnel centreline for a 2% volume of ground loss is approximately 10 mm to 15 mm. This estimate is based on the assumption that the work will be carried out by experienced tunnellers with great care and good workmanship. However, excessive ground loss and settlement can occur if uncontrolled contact is made with the upper layer of silty sand fill or when unusual conditions are encountered, such as boulder removal or contact with water-bearing sand lenses.

6.6 Instrumentation and Monitoring

Active roadway surfaces shall be monitored before, during and after construction. A precondition survey should also be carried out prior to construction to document the existing conditions of the pavement and any nearby structures for the purpose of determining any restoration that may be required due to construction impacts. During detail design an instrumentation and monitoring program shall be developed for this project consistent with the *"Guidelines for Foundation Engineering Tunnelling Specialty for Corridor Encroachment Permit Application (MTO, 2008)"*, modified as appropriate to also cover open cut installations and the inclusion of instrumentation monitoring arrays. The instrumentation and monitoring program is required to:

- Document the effects of the installation on the overlying roadway;
- Obtain prior warning of ground movements that could occur due to construction methods and equipment or unforeseen ground condition;
- Verify the Contractor's compliance with the settlement limits imposed in the Contract; and,
- Allow adjustments to be made to the culvert installation methodology such that the established settlement limits are not exceeded.

For trenchless installations, the overburden soils above the tunnel alignment should be monitored for movement during construction by using in-ground monitoring points and surface settlement points. The in-ground monitoring points provide the best advance indicators of subsurface disturbance and the potential for settlement/heave at the ground surface due to the tunnelling operations. For open cut excavations the crest of temporary cuts adjacent to existing roadway and temporary protection systems should be monitored for movement.

⁶ Mair, R. J. and Taylor, R. N. (1997). Bored tunnelling in the urban environment, Theme Lecture, Plenary Session 4, 14th International Conference on Soil Mechanics and Foundation Engineering, Hamburg, 6-12 September.

6.7 Open Cut Excavation

6.7.1 Vertical Alignment

A replacement culvert can be installed in a supported open cut excavation provided that a suitable construction staging plan can be designed and implemented. The subsurface conditions that are anticipated to be encountered for the various alternatives are summarized as follows:

Approximate Elevation of Excavation Base	Subsurface Conditions at Trench Bottom	Remarks
Alternative 5B		
195.6±m to 193.0±m	Stiff Silty Clay (Varved). Estimated water level elevation is 199 m at inlet, 198.5 m below and on the east side the highway and 196 m at culvert outlet.	Adequate pipe support. Keep excavation dry by pumping from properly filtered sumps as and where required. Keep length of trench as short as practical.
Alternative 5A, 6 and 7		
193.3±m to 193.0±m	Stiff Silty Clay (Varved). Estimated water level at elevation 196 m.	Adequate pipe support. Keep excavation dry by pumping from properly filtered sumps as and where required. Keep length of trench as short as practical.

6.8 Culvert Bedding, Cover and Trench Backfill

The geometry of the bedding and cover arrangement surrounding the culvert should conform to OPSD 802.032 (Rigid Pipe Bedding – Earth Excavation) or OPSD 802.034 (Rigid Pipe Bedding In Embankment) as appropriate. Bedding and cover material should consist of OPSS Granular “A” material. Additional bedding requirements that may be imposed by the supplier must also be followed. The bedding and cover material should be placed in 200 mm thick loose lifts and compacted to at least 95 % of the materials Standard Proctor Maximum Dry Density (SPMDD) using suitable compaction equipment.

To achieve the specified compaction, soils used for backfill must neither be too wet nor too dry of their optimum moisture content. Soils that are too wet (such as the silty clay to clay) cannot be used immediately because the material will have to be dried to a moisture content of 2± % of optimum. If the construction operations are time sensitive, the use of imported earth fill may be considered. Soils that are dry of optimum can be used immediately provided that the material is moisture conditioned (i.e. water added) to achieve a moisture content of 2± % of optimum. The existing embankment fill can be re-used for backfill provided the soils are free of organics and other deleterious material. Backfill should be placed in 300 mm thick lifts and compacted to at least 95 % SPMDD.

6.8.1 Trench Clay Plugs and Cut-off Collars

Clay plugs or cutoff collars are usually installed in trenches to minimize the lateral flow of groundwater through the granular bedding and cover material. Clay plugs should be placed in the trenches at 50 m intervals (or less) along the full length of the trench. The plug should be 1 m thick measured along the pipe, and should completely replace the granular bedding and cover material surrounding the pipe. The clay plugs should be compacted to at least 95% SPMDD. Material used for the clay plugs should contain not less than 15% particles finer than 2 microns and the compacted mass should have a coefficient of permeability less than 10^{-6} cm/s as specified in OPSS 1205..

Alternatively, cut off collars consisting of unshrinkable fill can be installed around the pipe to achieve the same effect. Collars should not be placed closer than 1 m to a pipe joint and precautions should be taken to ensure that at least 95% SPMDD compaction is achieved on the soil backfill placed around the collars. Watertight connections should be made between the collar and the pipe.

6.9 Erosion Protection

Erosion protection should be provided at the culvert inlets and outlets (including the slopes and sides). At the inlet area a clay seal can be provided such that water is channelled through the culvert and does not seep through the backfill around and underneath the structure. The clay seal should extend to cover all the granular backfill materials, should be a continuous layer around the culvert, should have a minimum compacted thickness of 0.6 m, and should extend at least 1 m above the high water level. The clay seal should also be protected by a layer of rip-rap. Material used for the clay seal should conform to the requirements stipulated in OPSS 1205. Concrete cut-off and head walls can also be used as an alternative to a clay seal to protect the granular fill around the culvert from erosion.

Design of an erosion protection scheme for the stream bed in the inlet and outlet areas will depend on hydrologic, hydraulic and/or other concerns. Typically, rip-rap protection should be provided to these areas. The rip-rap layer should cover all surfaces on the embankment slopes with which creek water is likely to be in contact.

We recommend that a qualified Hydraulics Engineer be consulted to design the specifics of the channel, culvert outlet and inlet (i.e. thickness and extent of protection) and scour depth. Footings must also be placed below the scour depth.

6.10 Embankments

6.10.1 Embankment Stability

The global, internal and surficial stability of the embankment will depend on the slope geometry and also to a large degree on the material used to construct the embankment. For the purpose of embankment stability analyses, the commercially available slope stability program Slide 6.0 developed by Rocscience Inc. was used.

The Morgenstern-Price and Spencer methods for stability analysis were employed and a minimum target factor of safety of 1.3 was established. Stability analyses were carried out for the following cases:

- Existing embankment with side slope geometries of 1.8H:1V (west side) and 1.9H:1V (east side) and embankment heights of 10.5 m (west side) and 5.5 m (east side);
- Reconstructed embankment with a minimum side slope geometry of 2H:1V and no mid-height berm;
- Reconstructed embankment with a minimum side slope geometry of 2H:1V and a 2 m wide mid-height berm on the west side where the embankment height is equal to or greater than 8 m;
- Stability of a reconstructed embankment with a minimum side slope geometry of 2H:1V during and immediately after a 100 year storm event for a design High Water Level of 203 m.

The soil parameters used for the slope stability analyses and the factors of safety that were obtained are provided in the following table. The slope stability models depicting the corresponding factors of safety are provided in Figures D1, D2 and D3 in Appendix D.

Slope Stability Design Parameters and Results

Material Type	Unit Weight	Total Stress Analysis*		Effective Stress Analysis	
	γ (kN/m ³)	ϕ (degrees)	c (kPa)	ϕ' (degrees)	c' (kPa)
Embankment Fill – Gravelly Sand to Sand	19	32	0	32	0
Embankment Fill – Silty Clay	18	28	0	28	0
New Embankment Fill	19	32	0	32	0
Silty Clay	19	0	35	28	0
Silty Clay (Varved)	17	0	60	28	0
Clayey Silt Till	21	0	200	33	0
<i>Design Factors of Safety</i>					
Existing Embankment		Not Applicable		1.1 to 1.4	
Reconstructed Embankment – 2H:1V and no mid height berm		1.3		1.3	
Reconstructed Embankment – 2H:1V with mid height berm		1.3		1.3	
Reconstructed Embankment – 2H:1V during storm event		1.3 to 1.4		Not Applicable	
Reconstructed Embankment – 2H:1V after storm event		Not Applicable		1.3 to 1.4	

* Refer to Figure C1 in Appendix C for undrained shear strength data.

Our analyses indicate that:

- The existing embankment geometry does not comply with MTO's requirement for a mid-height berm on the west side slope between Sta.17+640 and Sta. 17+680 where the embankment height is equal to or greater than 8 m and the east side slope geometry is steeper than 2H:1V between Sta. 17+620 and Sta. 17+700;
- Between Sta.17+640 and Sta. 17+680 the stability analysis of the existing west side slope yielded target factors of safety that range between 1.0 and 1.1 which is lower than the required target factor of safety of 1.3. Between Sta. 17+620 and Sta. 17+700 the stability analysis of the existing east side slope yielded target factors of safety that range between 1.0 and 1.2;
- A target factor of safety of at least 1.3 is attainable if the embankment's west and east side slopes are reconstructed at 2H:1V. For the west side slope a target factor of safety of 1.3 is achievable with and without a mid-height berm;
- A target factor of safety of at least 1.3 is attainable for a 2H:1V embankment side slope geometry during and immediately after a 100 year storm event for a design High Water Level of 203 m.

Based on the global stability analyses we recommend reconstructing the existing embankment with a minimum side slope geometry of 2H:1V. Where earth fill embankments are equal to or higher than 8 m, a mid-height berm should be incorporated in the design. The berm should:

- extend for the length through which the embankment height exceeds 8 m;
- be at least 2 m wide; and
- have a 2% positive side slope to shed run-off water.

6.10.2 Embankment Construction

Materials used for embankment construction should be placed in lifts not exceeding 300 mm (before compaction), and each lift should be uniformly compacted to at least 95 % of the material's SPMD. Embankment construction should be carried out in accordance with OPSS.PROV 501 and OPSS.PROV 206. Borrow material must meet the requirements of OPSS.PROV 212 and bonding between existing fill and new fill should be carried out by benching in accordance with OPSD 208.010.

Proper erosion control measures should be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS 805 and embankment slopes must be reinstated with permanent erosion protection in accordance with OPSS 803 and OPSS.PROV 804.

6.10.3 Embankment Settlement

Since the highway grade will not be raised and, reconstructing the embankment to achieve a side slope geometry of 2H:1V will not impart significant additional loads on the underlying silty clay deposits; settlement of the underlying silty clay deposits will be negligible and the new culvert/s will not experience detrimental settlement due to the embankment widening. However, embankments constructed with local granular or earth fill will settle during construction (fill compression) and; the magnitude of this settlement is expected to be about 1% of the fill height.

Widening the existing embankment to achieve the desired 2H:1V side slope will cause settlement of the underlying soils in the footprint area of the embankment side slope and toe. The total settlement due to embankment widening and mid-height berm construction is not expected to exceed 175 mm and this settlement will be essentially complete shortly after construction.

6.11 Temporary Protection Systems

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary protection systems should be designed in accordance with OPSS.PROV 539 and the designs should be carried out by a licensed Professional Engineer experienced in shoring design.

The shape of the soil pressure distribution diagram behind a temporary protection system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The protection system can be restrained, fixed or flexible and the sequence of work will alter the shape of the pressure diagram during the various construction phases.

Earth pressure computations must also take into account the ground water level. Above the ground water level, earth pressure is computed using the bulk unit weight of the retained soil. Below the ground water level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). In this case, the performance level should be Level 2 – Angular Distortion 1:200 but shall not be more than 25 mm. Where limited shoring movement (Performance Level 1A or 1B) is required the design should be based on the at rest earth pressure coefficient (K_o). For “kick out” design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p). It should be noted that the lateral earth pressure

coefficients chosen for design require certain movements for the active and passive conditions to be mobilized.

The appropriate lateral earth pressure parameters for use in the design temporary protection systems are provided in the following table. The lateral earth pressure coefficients are based on the assumption that the ground surface behind the temporary protection system is horizontal. Where the retained ground is sloping, the lateral earth pressure coefficients must be adjusted to account for the slope and, these earth pressure coefficients can be estimated from the equations provided on Figures C6.17 and C6.18 of the CHBDC 2006.

Temporary Protection System Design Parameters

Stratigraphic Unit	Friction Angle ϕ (degrees)	Unit Weight γ (kN/m)	Active Earth Pressure Coefficient	At - Rest Earth Pressure Coefficient	Passive Earth Pressure Coefficient
			K_a	K_o	K_p
Fill – Gravelly Sand to Sand	32	19	0.30	0.47	3.25
Fill – Silty Clay	28	18	0.36	0.53	2.77
Silty Clay	28	19	0.36	0.53	2.77
Silty Clay (Varved)	28	17	0.36	0.53	2.77
Clayey Silt Till	33	21	0.29	0.46	3.39

The commercially available slope stability program Slide 6.0 (developed by Rocscience Inc.) was used to perform preliminary global stability analyses for vertically supported open excavations. The Morgenstern-Price and Spencer methods of stability analysis were employed. The stability analyses indicate that:

- Alternative 5B – along the highway centre line, sheet piles will have to be driven into the silty clay till or to bedrock in order to achieve a target factor of safety of 1.3 with respect to global stability. For preliminary design purposes assume a sheet pile length of 26.7 m measured from the ground surface of Highway 11; and
- Alternative 5A, 6 and 7 – supported open cut excavations in the outlet area of the new culvert will require extending sheet piles to about 191.4 m i.e. 1.8 m below the base of the excavation in order to achieve a target factor of safety of 1.3 with respect to global stability.

6.12 Basal Stability

The type of base failure condition depends on the subsurface conditions beneath the excavation bottom and this type of failure can occur if one or all of the following conditions are encountered:

- Relatively impermeable deposits at the excavation base that are underlain by water-bearing permeable deposits with a sufficiently high hydrostatic head resulting in basal uplift; and
- Weak cohesive soils below the excavation base resulting in base heave due to the stress imposed by the vertical height of the retained overburden.

Excavations should be designed such that the base is stable at each successive stage during excavation. Basal stability should be reviewed during detail design and, it is also imperative for the Contractor's licensed Professional Engineer to check for basal stability when the supported open excavation geometry and dimensions are finalized.

6.13 Excavations

All excavations must be carried out in accordance with the guidelines outlined in the *Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects*. Where workers must enter excavations extending deeper than 1.2 m, the trench walls must be suitably sloped and/or braced in accordance with the OHSA. Within the envisaged depths of temporary excavations (i.e. up to elevation 267.0 m), the OHSA soil classifications are:

- Embankment fill – Type 3 soils; and
- Silty Clay to Clay – Type 4 soils.

The side slopes of temporary excavations may be formed no steeper than 1H:1V for Type 3 soils and 3H:1V or flatter for Type 4 soils. Excavations should be undertaken in accordance with OPSS 902.

6.14 Ground Water Control

Surface water and ground water control will be necessary to enable construction below the ground water table. We recommend temporarily diverting the flow of creek water away from the construction area. Around the perimeter of the excavation, a cofferdam and an interceptor perimeter trench should also be installed to prevent surface water from entering the excavation.

The design, installation, operation and maintenance of the dewatering system is the Contractor's responsibility. A suitable dewatering system that can be employed is gravity drainage and pumping from strategically placed filtered sumps.

6.15 Additional Studies

It is recommended that the following issues be considered during the future detail design studies.

- Confirm and further refine the preliminary geotechnical recommendations based on the selected option and carry out additional detail level foundation investigations along the tunnel alignment;
- Complete a more rigorous tunnelling assessment of the preferred alignment;
- Carry out detail level stability analyses of the embankment design configuration;
- Prepare non-standard specifications for the proposed tunnelling methodology;
- Prepare a settlement monitoring and instrumentation plan and non-standard specifications for settlement monitoring and instrumentation including items such as review and alert levels and reading frequency before, during and after construction.



7.0 CLOSURE

This report was prepared by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and Associate with Terraprobe; with assistance provided by Mr. Hussein Ahmed, P.Eng. and Ms. Sepideh D-Monfared, MEng. Mr. Michael Tanos, P.Eng., Terraprobe's Designated MTO Contact conducted an independent quality control review.

Terraprobe Inc.



Rehman Abdul

R. Abdul, P.Eng.
Associate, Senior Geotechnical Engineer



Michael Tanos

Michael Tanos, P.Eng.
Designated MTO Contact



REFERENCES

- Bowles, J.E., 1984. *Physical and Geotechnical Properties of Soils*, Second Edition. McGraw Hill Book Company, New York.
- Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.
- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6 06. 2006.* CSA Special Publication, S6.1 06. Canadian Standard Association.
- Chandler, R. J. 1988. *The In Situ Measurement of the Undrained Shear Strength of Clays Using the Field Vane, STP 1014, Vane Shear Strength Testing in Soils: Field and Laboratory Studies*, American Society for Testing and Materials.
- Gupta, V.K., and Wadge, D.R. 1980: Bouguer Gravity and Generalized Geological Map Temagami-Englehart Area, Districts of Timiskaming, Nipissing and Sudbury; Ontario Geological Survey, Prelim. Map P.2296, Geophys. Ser., Scale 1:100 000. Survey and compilation 1977, 1978, 1979.
- Kulhawy, F. H., and Mayne, P. W. 1990. *Manual on Estimating Soil Properties for Foundation Design, Report EL-6800*, Electric Power Research Institute Inc.
- Mair, R. J. and Taylor, R. N. (1997). Bored tunnelling in the urban environment, Theme Lecture, Plenary Session 4, 14th International Conference on Soil Mechanics and Foundation Engineering, Hamburg, 6-12 September.
- Ministry of Natural Resources, Map 2301, Harley and Dymond Townships, Timiskaming District, Scale 1:31 680, 1974.
- McClenaghan, M.B. 1990. *Summary of results from the Black River – Matheson (BRiM) reconnaissance surface till sampling program*. Ontario Geological Survey, Open File Report 5749, p. 197.
- Morton, J.D., King, R.C.F. and Kalin, M.W. 1979: Quaternary Geology of the New Liskeard Area, District of Timiskaming; Ontario Geological Survey Prelim. Map P.2291, Geological Ser., Scale 1:50 000. Geology 1972, 1977.
- Terzaghi, K. (1950). *Geologic aspects of soft ground tunneling*. John Wiley & Sons, New York.

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 206	Construction Specification For Grading.
OPSS.PROV 212	Construction Specification For Earth Borrow.
OPSS 421	Construction Specification For Pipe Culvert In Open Cut.
OPSS.PROV 501	Construction Specification For Compacting.
OPSS.PROV 539	Construction Specification For Temporary Protection Systems.
OPSS 803	Construction Specification For Sodding.
OPSS.PROV 804	Construction Specification For Seed and Cover.
OPSS 805	Construction Specification For Temporary Erosion And Sediment Control Measures.
OPSS 902	Construction Specification For Excavating and Backfilling – Structures.
OPSS 1205	Material Specification For Clay Seal.

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching Of Earth Slopes.
OPSD 802.032	Rigid Pipe Bedding, Cover and Backfill, Type 4 Soil – Earth Excavation
OPSD 802.034	Rigid Pipe Bedding and Cover In Embankment, Original Ground: Earth or Rock



TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS¹

CLASSIFICATION		BEHAVIOUR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support, and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand and gravel when not highly overstressed.
Raveling	Slow raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table, slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
	Fast raveling		
Squeezing		Ground squeezes or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of raveling at excavation surface and squeezing at depth behind surface
Running	Cohesive running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (approximately 30° – 35°). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand, or weak cementation in any granular soil, may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behavior is cohesive-running.
	Running		
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances, completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

¹ Modified by Heuer (1974) from Terzaghi (1950)



TABLE 1
CONSTRUCTIBILITY REVIEW OF TUNNELLING ALTERNATIVES

Alternative No.	Proposed Pipe Inside Diameter (mm)	New Culvert	Relief Culvert	Proposed Culvert Length (m)		Culvert Invert Elevations		Depth of Overburden Cover (m) ¹	Depth of Cover to Tunnel Diameter Ratio	Anticipated Subsurface Conditions Within The Zone of Tunnelling	Estimated Groundwater Depth Relative to Pipe Invert
				Open Cut Excavation	Tunnel Boring Methods	Upstream (m)	Downstream (m)				
Alternative 2	1,800 Twin Culverts	NO	YES	-	70 ±*	205.0±*	204.0±*	0.0 to 7.3±	0.0 – 3.4	Embankment fill - very loose gravelly sand to silty sand and firm silty clay, Firm silty clay and Stiff varved silty clay.	5.5 m± to 6.5 m± below.
Alternative 3	2,100	NO	YES	-	185 ±*	200.3±*	199.0±*	0.0 to 11.9±	0.0 – 4.8	Embankment fill – very loose sand and silt and firm silty clay, Firm to very stiff silty clay and stiff varved silty clay.	0.5 m± to 3.0 m± below to 5.5 m± above.
Alternative 4	2,100	NO	YES	-	200 ±*	198.5±*	197.0±*	0.0 to 13.3±	0.0 – 5.3	Embankment fill – very stiff silty clay, Soft to very stiff silty clay, Firm to stiff varved silty clay.	0.0 m± to 1.0 m± below to 6.5 m± above.
Alternative 5A	3,000	YES	NO	28 ±	190 ±	196.3±	193.7±	0.0 to 15.6±	0.0 – 4.3	Soft to firm silty clay, Firm to stiff varved silty clay.	2.3 m± to 9.7 m± above.
Alternative 6	2,100 Twin Culverts	YES	NO	28 ±	190 ±	196.3±	193.7±	0.0 to 16.5±	0.0 – 6.6	Soft silty clay, Firm to stiff varved silty clay.	2.3 m± to 9.7 m± above.
Alternative 7	1,800 Twin Culverts	YES	NO	28 ±	190 ±	196.3±	193.7±	0.0 to 17.1±	0.0 – 8.0	Soft silty clay, Firm to stiff varved silty clay.	2.3 m± to 10.0 m± above.
	1,800	NO	YES	-	70 ±*	206.0±*	204.0±*	0.0 to 6.4±*	0.0 – 3.0*	Embankment fill – very loose silty sand and loose to compact gravelly sand to silty sand and firm silty clay, Firm silty clay, Stiff varved silty clay.	0.0 m± to 5.5 m± below*

♦ Denotes relief culvert preliminary design information.
1. Minimum overburden cover measured at the culvert inlet/outlet and maximum overburden cover measured under the road's centre line.

TABLE 2
FEASIBILITY OF TUNNELLING METHODOLOGIES

Alternative No Applicable Stratigraphic Section	Proposed Pipe Diameter (mm)	Depth of Overburden Cover (m) ¹	Reference Borehole Number	Soil Conditions ² (Ground surface to pipe invert)	Fines Content ³	SPT N-Values [Undrained Shear Strength (kPa)]	Coefficient of Uniformity ⁴	Soil Behaviour	Pipe Jacking With TBM	Microtunnelling
Alternative 2 CL Profile of Calamity Creek Culvert	1,800	0.0 to 7.3±	BH2	Varved Silty Clay*	100*, 100*, 100*	2, 3, 0 [54]	_.5	Squeezing	No	Yes
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	5, 5, 4	47*, >50*	Running to Slow Ravelling		
				Fill- Silty Clay**	57**	6**	>50**			
Alternative 3 Section A-A'	2,100	0.0 to 11.9±	BH1	Silty Clay*	100*	5, 5	_.5	Slow ravelling to squeezing	Yes	Yes
				Varved Silty Clay	-	3 [56, 56, 58]	_.5			
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Slow ravelling		
				Fill- Silty Clay**	57**, 54**	6, 7, 5, 6, 5, 17	>50**			
				Silty Clay	-	16	_.5			
			BH4	Fill - Sand	-	50/100 mm	_.5	Squeezing		
				Fill- Silty Clay*	60*	7, 9, 13, 30, 8, 6, 3, 7	_.5			
				Silty Clay**	98**, 99**	7, 4, 5	_.5			
				Varved Silty Clay***	-	0 [56, 62, 60]	_.5			
			BH5	Fill-Sand and Silt*	51*	7, 12, 2	>50*	Running to slow ravelling		
				Silty Clay**	99**	2, 4, 13 [72, >100]	_.5			
Alternative 4 Section A-A'	2,100	0.0 to 13.3±	BH1	Silty Clay*	100*	5, 5	_.5	Slow ravelling to squeezing	Yes	Yes
				Varved Silty Clay**	100**	3 [38,72]	_.5			
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Slow ravelling to squeezing		
				Fill- Silty Clay**	57**, 54**	6, 7, 5, 6, 5, 17	_.5			
				Silty Clay	-	16	_.5			
				Varved Silty Clay***	100***	4, 0 [72]	_.5			
			BH4	Fill - Sand	-	50/100 mm	_.5	Squeezing		
				Fill- Silty Clay*	60*	7, 9, 13, 30, 8, 6, 3, 7	_.5			
				Silty Clay**	98**, 99**	7, 4, 5	_.5			
				Varved Silty Clay***	-	0, 0 [60, 76, 68]	_.5			
			BH5	Fill-Sand and Silt*,	51*	7, 12, 2	>50*	Slow ravelling to squeezing		
				Silty Clay**	99**	2, 4, 13 [72, >100]	_.5			
				Varved Silty Clay***	-	- [64,68]	_.5			
			BH6	Silty Clay *	99*	3	_.5	Slow ravelling		

1. Minimum overburden cover measured at the culvert inlet/outlet and maximum overburden cover measured under the road's centre line
2. Soil conditions from ground surface to pipe invert; bold soil conditions indicate soil conditions within tunnel horizon.
3. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve and ♦ denotes fines content for respective soil type.
4. Coefficient of uniformity of soil within and above the tunnel horizon reported for coarse grained soils only. Not applicable for fine grained soils.
5. No tests performed within that area of interest or the Coefficient of Uniformity parameter is not applicable for that specific soil type.

TABLE 2 (Continued)

FEASIBILITY OF TUNNELLING METHODOLOGIES

Alternative No Applicable Stratigraphic Section	Proposed Pipe Diameter (mm)	Depth of Overburden Cover (m) ¹	Reference Borehole Number	Soil Conditions ² (Ground surface to pipe invert)	Fines Content ³	SPT N-Values	Coefficient of Uniformity ⁴	Soil Behaviour	Pipe Jacking With TBM	Microtunnelling
Alternative 5A Section A-A'	3,000	0.0 to 15.6±	BH1	Silty Clay*	100*	5, 5	.5	Squeezing	Yes	Yes
				Varved Silty Clay**	100**, 100**, 100**	3, 0 [72, 56, 56 58]	.5			
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Squeezing		
				Fill- Silty Clay**	57**, 54**	6, 7, 5, 6, 5, 17	.5			
				Silty Clay	-	16	.5			
				Varved Silty Clay***	100***, 100***, 100***	4, 0, 0 [60, 62, 56, 66]	.5			
			BH4	Fill - Sand	-	50/100 mm	.5	Squeezing		
				Fill- Silty Clay*	60*	7, 9, 13, 30, 8, 6, 3, 7	.5			
				Silty Clay**	98**, 99**	7, 4, 5	.5			
				Varved Silty Clay***	100***	0, 0, 1 [56, 60, 66, 70]	.5			
			BH5	Fill-Sand and Silt*,	51*	7, 12, 2	>50*	Slow ravelling to squeezing		
				Silty Clay**	99**	2, 4, 13	.5			
				Varved Silty Clay***	100***	0 [56, 64, 42, 56]	.5			
			BH6	Silty Clay *	99*	3, 4, 2	.5	Slow ravelling to squeezing		
				Varved Silty Clay**	100**	0 [44, 52, 48, 56]	.5			
Alternative 6 Section A-A'	2,100	0.0 to 16.5±	BH1	Silty Clay*	100*	5, 5	.5	Squeezing	Yes	Yes
				Varved Silty Clay**	100**, 100**, 100**	3, 0 [56, 56, 58]	.5			
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Squeezing		
				Fill- Silty Clay**	57**, 54**	6, 7, 5, 6, 5, 17	.5			
				Silty Clay	-	16	.5			
				Varved Silty Clay***	100***, 100***, 100***	4,0, 0 [62, 56, 66]	-			
			BH4	Fill - Sand	-	50/100 mm	.5	Squeezing		
				Fill- Silty Clay*	60*	7, 9, 13, 30, 8, 6, 3, 7	.5			
				Silty Clay**	98**, 99**	7, 4, 5	.5			
				Varved Silty Clay***	100***	0, 0, 0, 1 [60, 66, 70]	.5			
			BH5	Fill-Sand and Silt*,	51*	7, 12, 2	>50*	Slow ravelling to squeezing		
				Silty Clay**	99**	2, 4, 13	.5			
				Varved Silty Clay***	100***	0 [64, 42, 56]	.5			
			BH6	Silty Clay *	99*	3, 4, 2	.5	Slow ravelling to squeezing		
				Varved Silty Clay**	100**	0 [44, 52, 48]	.5			

1. Minimum overburden cover measured at the culvert inlet/outlet and maximum overburden cover measured under the road's centre line

2. Soil conditions from ground surface to pipe invert; bold soil conditions indicate soil conditions within tunnel horizon.

3. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve and ♦ denotes fines content for respective soil type.

4. Coefficient of uniformity of soil within and above the tunnel horizon reported for coarse grained soils only. Not applicable for fine grained soils.

5. No tests performed within that area of interest or the Coefficient of Uniformity parameter is not applicable for that specific soil type.

TABLE 2 (Continued)

FEASIBILITY OF TUNNELLING METHODOLOGIES

Alternative No Applicable Stratigraphic Section		Proposed Pipe Diameter (mm)	Depth of Overburden Cover (m) ¹	Reference Borehole Number	Soil Conditions ² (Ground surface to pipe invert)	Fines Content ³	SPT N-Values	Coefficient of Uniformity ⁴	Soil Behaviour	Pipe Jacking With TBM	Microtunnelling
Alternative 7	Section A-A' (New Culvert)	1,800	0.0 to 16.6±	BH1	Silty Clay*	100*	5, 5	_.5	Squeezing	No	Yes
					Varved Silty Clay**	100**, 100**, 100**	3, 0 [56, 56, 58]	_.5			
				BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Squeezing		
					Fill- Silty Clay**	57**, 54**	6, 7, 5, 6, 5, 17	>50**			
					Silty Clay	-	16	_.5			
					Varved Silty Clay***	100***, 100***, 100***	4,0, 0 [62, 56, 66]	_.5			
				BH4	Fill - Sand	-	50/100 mm	_.5	Squeezing		
					Fill- Silty Clay*	60*	7, 9, 13, 30, 8, 6, 3, 7	_.5			
					Silty Clay**	98**, 99**	7, 4, 5	_.5			
					Varved Silty Clay***	-	0, 0, 0, 1 [60, 66, 70]	_.5			
				BH5	Fill-Sand and Silt*,	51*	7, 12, 2	>50*	Squeezing		
					Silty Clay**	99**	2, 4, 13	_.5			
	Varved Silty Clay***	100***	0 [56, 64, 42]		_.5						
	BH6	Silty Clay *	99*	3, 4, 2	_.5	Squeezing to fast ravelling					
		Varved Silty Clay**	100**	0 [44, 52]	_.5						
CL Profile of Calamity Creek Culvert (Relief Culvert)		0.0 to 6.4±*	BH2	Fill- Sand to Silty Sand*	21*, 46*, 48*	72, 62, 11, 5, 4, 4, 4, 2, 4	>50*	Running to squeezing	No	Yes	
				Varved Silty Clay***	100**, 100**	2, 3, 0	-				
			BH3	Fill- Gravelly Sand to Silty Sand*	20*, 34*	75, 31, 21,48, 7, 16, 15, 5, 13, 5, 5, 4	47*, >50*	Running			

1. Minimum overburden cover measured at the culvert inlet/outlet and maximum overburden cover measured under the road's centre line

2. Soil conditions from ground surface to pipe invert; bold soil conditions indicate soil conditions within tunnel horizon.

3. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve and ♦ denotes fines content for respective soil type.

4. Coefficient of uniformity of soil within and above the tunnel horizon reported for coarse grained soils only. Not applicable for fine grained soils.

5. No tests performed within that area of interest or the Coefficient of Uniformity parameter is not applicable for that specific soil type.

TABLE 3
EVALUATION OF INSTALLATION METHODS

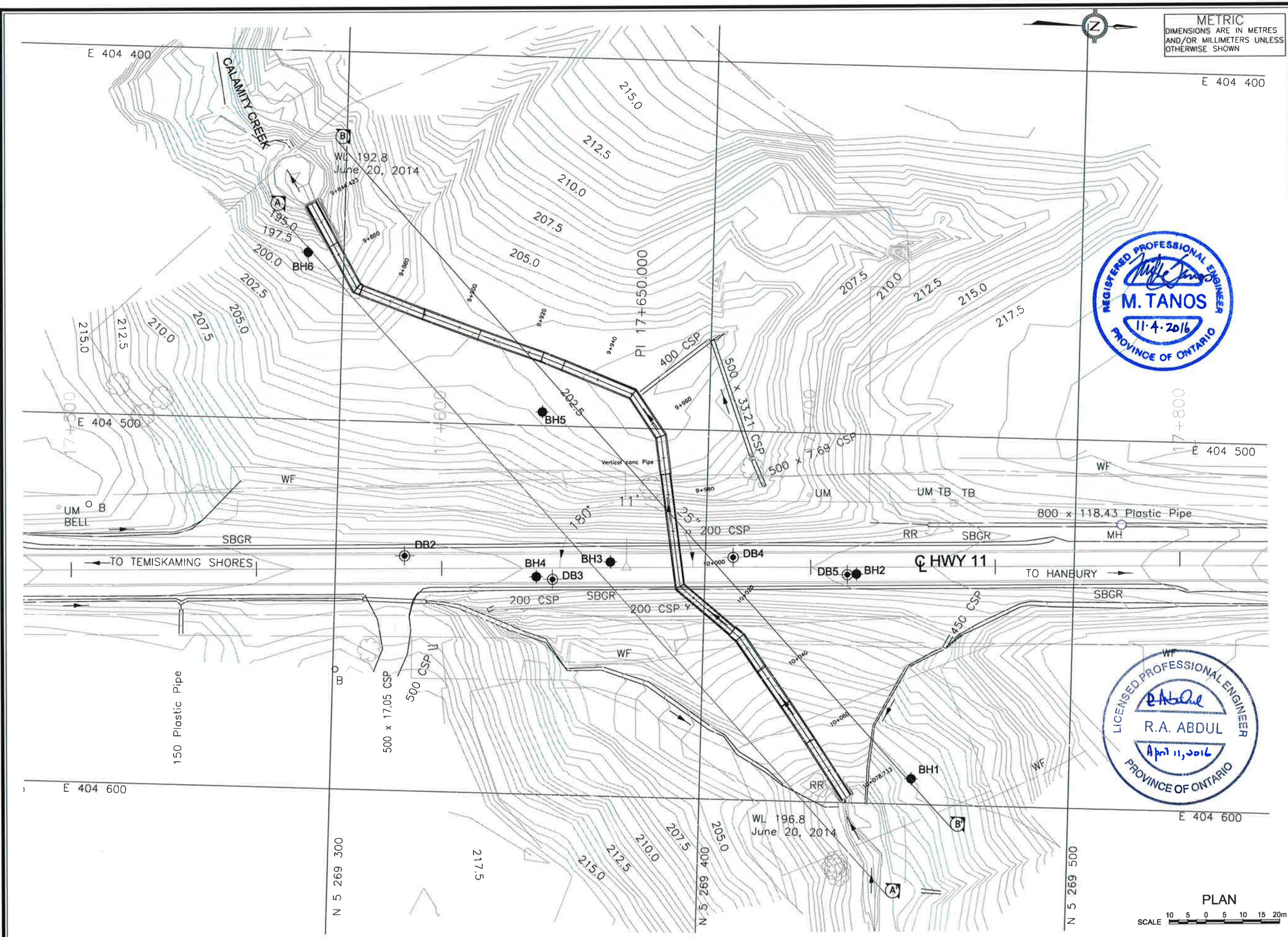
Installation Method	Ranking*	Advantages	Disadvantages	Risk/Consequences
Open Cut (OPSS 421)	Not Ranked	Best control of gradient and alignment. Reduced potential for delays due to obstructions. Least risk of unanticipated impact to active highway. Equipment and skilled construction workforce readily available. Suitable for all alternatives.	Requires construction staging in order to maintain traffic on roadways which could result in minor delays to traffic. Large and deep excavations required at some sections of the alignments. Temporary protection systems are required as well as dewatering.	Increased traffic disruption.
Micro Tunnelling (MT)	1	Minimal traffic disruption. Does not require groundwater lowering since machine can counterbalance earth and water pressures, thereby reducing the risk of ground losses during tunnelling. Suitable for all alternatives.	Probable lack of availability of more than one machine with a 3 m diameter bore in Ontario. Less expensive than Pipe Jacking with TBM. High mobilization cost for short crossings. Requires a skilled construction workforce. Requires intermediate jacking stations for relatively long installations.	Time delay in obtaining a suitable diameter machine is likely. Time delay in renting or purchasing a 3 m diameter machine and mobilizing to Northern Ontario. Potential for culvert misalignment and construction delays where culverts are installed in separate bores.
Pipe Jacking With TBM	2	Minimal traffic disruption. Equipment and skilled construction workforce readily available. Does not require groundwater lowering since machine can counterbalance earth and water pressures, thereby reducing the risk of ground losses during tunnelling.	Relatively large work area required for jacking pit. Most expensive compared to other methods. High mobilization cost for short crossings. Requires a skilled construction workforce. Requires intermediate jacking stations for relatively long installations. Not suitable for Alternative 7 because of the small pipe diameter.	Time delay in obtaining a suitable diameter machine is likely.

* Ranking considered from a foundations perspective.

DRAWINGS



\\PDServer1-Project Files\11-Geo\2014\11-14-066 New Likard Area\11-14-066 Calamity Creek Culvert Area\11-14-066 Calamity Creek Culvert Figure-- (2015-06) dwg. kural



GWP No 5159-12-00

HWY 11
CALAMITY CREEK CULVERT
BOREHOLE LOCATIONS AND SECTION PLAN

MMM Group Limited

2655 North Sheridan Way, Suite 303
Mississauga, ON Canada L5K 2P8
t: 905.823.8500, f: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650

KEY PLAN

LEGEND

Bore Hole

Dynamic Cone Penetration Test

Bore Hole And Cone

Bore Hole (Shaheen & Pecker Limited)

Blows/0.3m (Std Pen Test, 475 J/blow)

Blows/0.3m (60' Cone, 475 J/blow)

WL at Time of Investigation

WL in Piezometer

Piezometer

Rock Quality Designation

Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
1	201.8	5 269 457.4	404 593.1
2	214.2	5 269 441.2	404 537.9
3	213.7	5 269 374.3	404 536.5
4	213.9	5 269 354.3	404 541.0
5	203.5	5 269 354.8	404 496.3
6	197.7	5 269 290.3	404 454.7

DB2	Sta. 17+590 O/S 3.5m LT.
DB3	Sta. 17+630 O/S 3.1m RT.
DB4	Sta. 17+679 O/S 2.9m LT.
DB5	Sta. 17+710 O/S 4.5m RT.

NOTE

The drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview.

Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions

REFERENCE

Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B3040011001, DTM3040011001, received September 11, 2014

REVISIONS			
DATE	BY	DESCRIPTION	

HWY. 11	PROJECT No. 11-14-4066	GEORES NO.: 31M-109
SUBM'D. HA	CHKD. RA DATE: April 2016	SITE: 47-273C
DRAWN: KC	CHKD. RA APPD: MT	DWG. 1

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETERS UNLESS
OTHERWISE SHOWN

GWP No 5159-12-00

HWY 11
CALAMITY CREEK CULVERT
CL PROFILE HIGHWAY 11 AND SOIL STRATA

MMM Group Limited
2855 North Sheridan Way, Suite 300
Mississauga, ON Canada L5K 2P8
t: 905.823.8500, f: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
11 Indall Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND	
	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
	Bore Hole (Shaheen & Peaker Limited)
	Blows/0.3m (Std Pen Test, 475 J/blow)
	Blows/0.3m (60' Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer
	90% Rock Quality Designation
	A/R Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
1	201.8	5 269 457.4	404 593.1
2	214.2	5 269 441.2	404 537.9
3	213.7	5 269 374.3	404 536.5
4	213.9	5 269 354.3	404 541.0
5	203.5	5 269 354.8	404 496.3
6	197.7	5 269 290.3	404 454.7

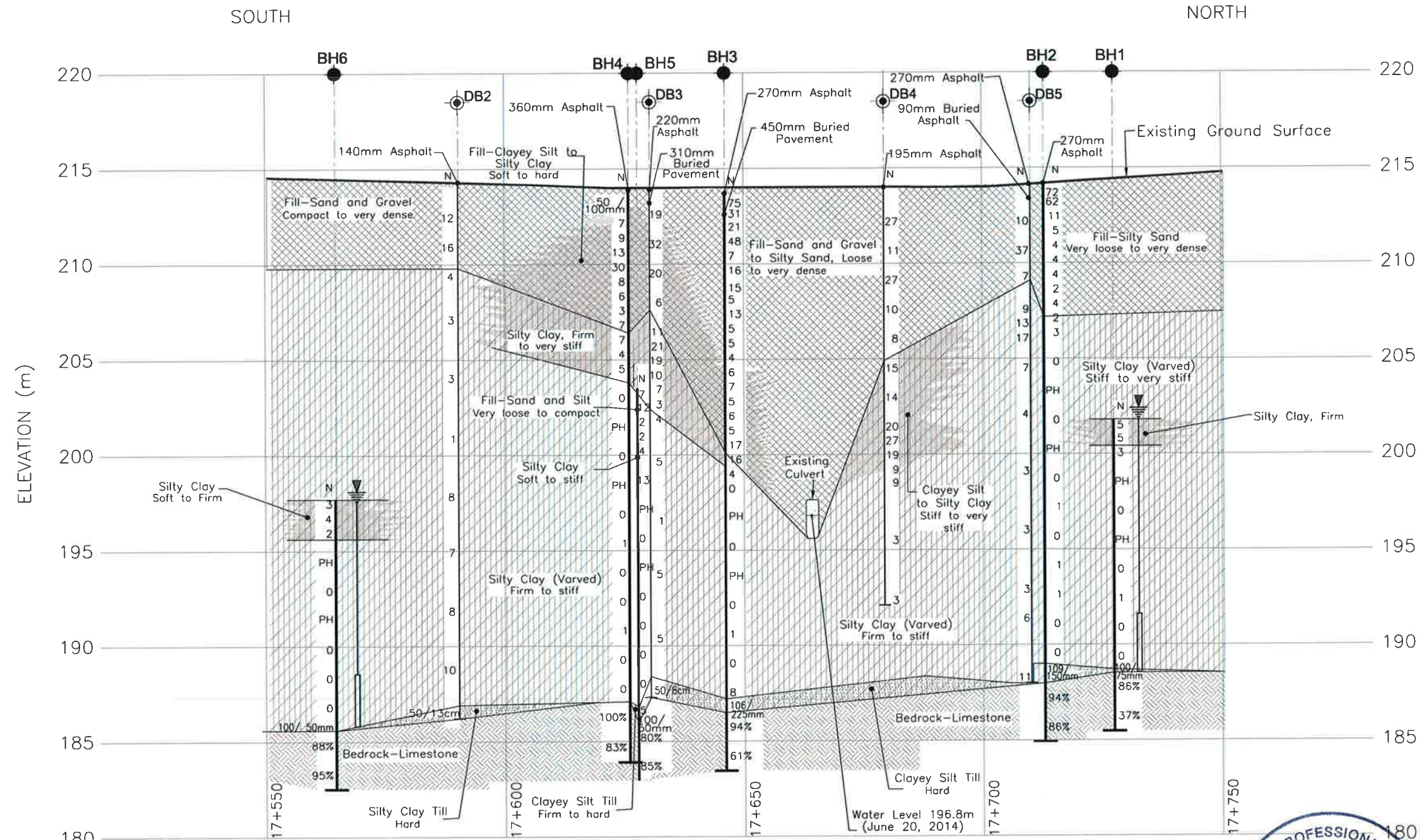
DB2	Sta. 17+590 O/S 3.5m LT.
DB3	Sta. 17+630 O/S 3.1m RT.
DB4	Sta. 17+679 O/S 2.9m LT.
DB5	Sta. 17+710 O/S 4.5m RT.

NOTE
This drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE
Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B3040011001, DTM3040011001, received September 11, 2014

REVISIONS		
DATE	BY	DESCRIPTION

HWY. 11	PROJECT No. 11-14-4066	GEOCRES NO.: 31M-109
SUBM'D. HA	CHKD. RA	DATE: April 2016
DRAWN: KC	CHKD. RA	APPD: MT
		SITE: 47-273C
		DWG. 2



CL PROFILE HIGHWAY 11

HORIZ. SCALE 10 5 0 5 10 15 20m
VERT. SCALE 2.5 0 2.5 5m



\\PDS\Server1\Project Files\11-Gwp\2014\11-14-4066 New Liskeard Area\11-14-4066 Calamity Creek Culvert Figure- (2015-04) dwg. kml

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETERS UNLESS
OTHERWISE SHOWN

GWP No 5159-12-00

HWY 11
CALAMITY CREEK CULVERT
PROFILE OF CULVERT AND SOIL STRATA

SHEET

MMM Group Limited
2055 North Sheridan Way, Suite 300
Mississauga, ON Canada L5K 2P8
t: 905.823.8500, f: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering & Testing
11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test
- Bore Hole And Cone
- Bore Hole (Shaheen & Peaker Limited)
- Blows/0.3m (Std Pen Test, 475 J/blow)
- Blows/0.3m (60" Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer
- Piezometer
- 90% Rock Quality Designation
- Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
1	201.8	5 269 457.4	404 593.1
2	214.2	5 269 441.2	404 537.9
3	213.7	5 269 374.3	404 536.5
4	213.9	5 269 354.3	404 541.0
5	203.5	5 269 354.8	404 496.3
6	197.7	5 269 290.3	404 454.7

DB2	Sta. 17+590 O/S 3.5m LL
DB3	Sta. 17+630 O/S 3.1m LL
DB4	Sta. 17+679 O/S 2.9m LL
DB5	Sta. 17+710 O/S 4.5m LL

NOTE

This drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

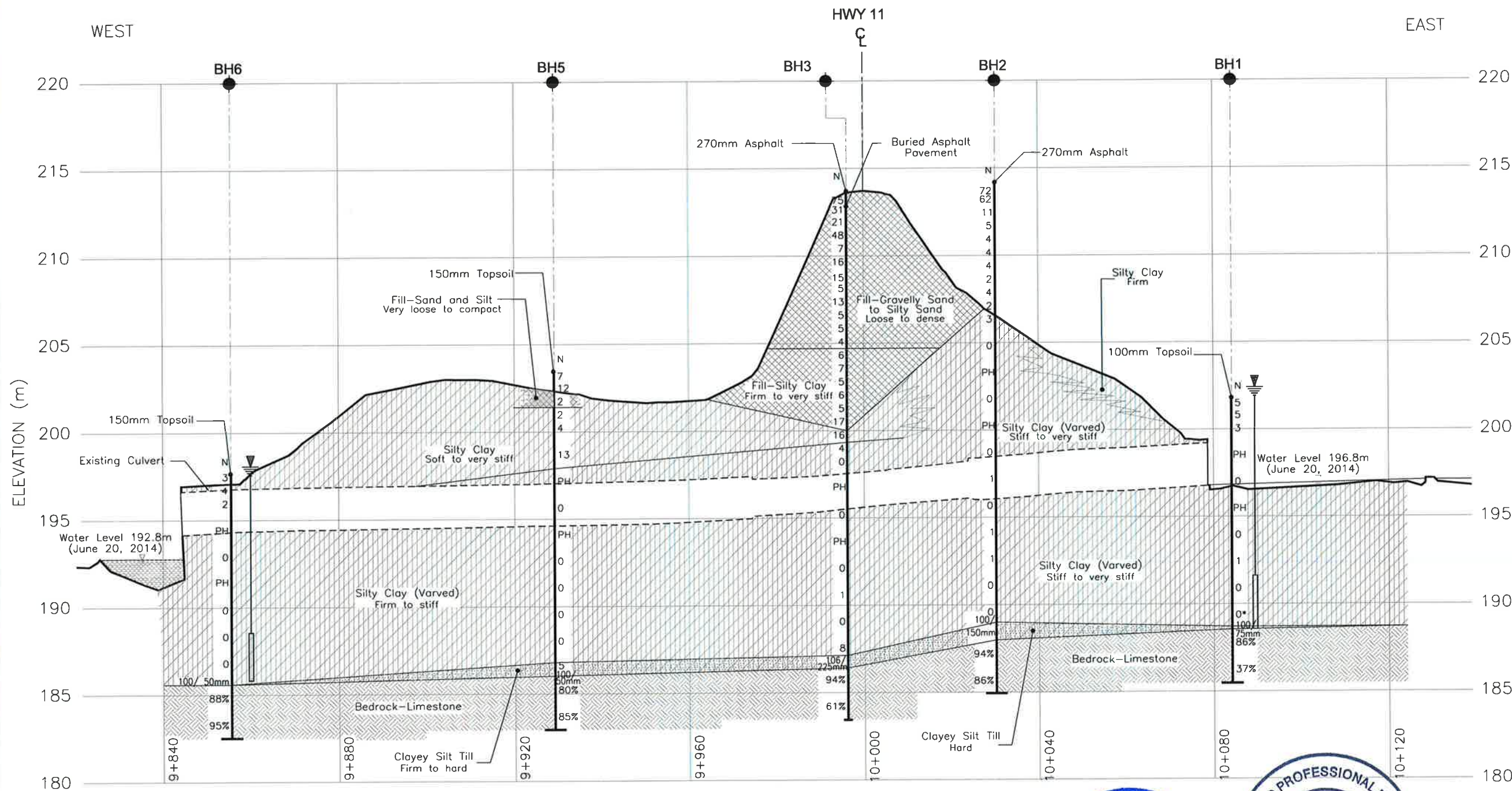
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B3040011001, DTM3040011001, received September 11, 2014

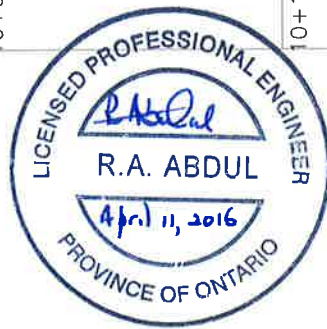
REVISIONS	DATE	BY	DESCRIPTION

HWY: 11	PROJECT No: 11-14-4066	GEORES NO.: 31M-109
SUBM'D: HA	CHKD: RA	DATE: April 2016
DRAWN: KC	CHKD: RA	APPD: MT
		SITE: 47-273C
		DWG: 3



PROFILE OF CALAMITY CREEK CULVERT

HORIZ. SCALE 10 5 0 5 10 15 20m
VERT. SCALE 2.5 0 2.5 5m



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETERS UNLESS
OTHERWISE SHOWN

GWP No 5159-12-00

HWY 11
CALAMITY CREEK CULVERT
CROSS SECTION A-A' AND SOIL STRATA

SHEET

MMM Group Limited
2855 North Sheridan Way, Suite 300
Mississauga, ON Canada L5K 2P8
T: 905.823.8500, F: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test
- Bore Hole And Cone
- Bore Hole (Shaheen & Peaker Limited)
- Blows/0.3m (Std Pen Test, 475 J/blow)
- Blows/0.3m (60' Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer
- Piezometer
- Rock Quality Designation
- Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
1	201.8	5 269 457.4	404 593.1
2	214.2	5 269 441.2	404 537.9
3	213.7	5 269 374.3	404 536.5
4	213.9	5 269 354.3	404 541.0
5	203.5	5 269 354.8	404 496.3
6	197.7	5 269 290.3	404 454.7

DB2	Sta. 17+590 O/S 3.5m LL
DB3	Sta. 17+630 O/S 3.1m Rt.
DB4	Sta. 17+679 O/S 2.9m LL
DB5	Sta. 17+710 O/S 4.5m Rt.

NOTE
This drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.

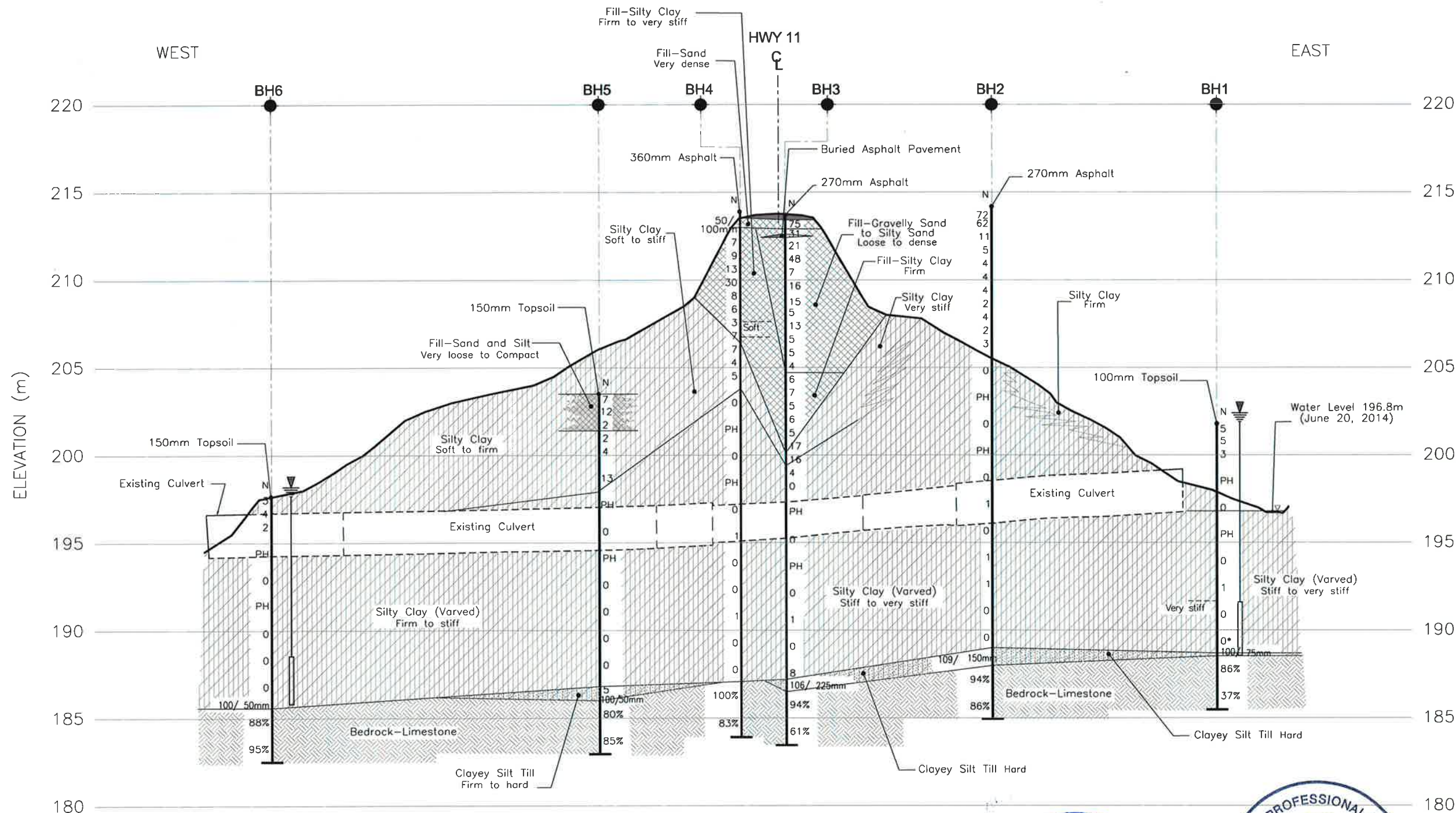
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE
Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B3040011001, DTM3040011001, received September 11, 2014

REVISIONS	DATE	BY	DESCRIPTION

HWY. 11	PROJECT No. 11-14-4066	GEORES NO.: 31M-109
SUBM'D. HA	CHKD. RA	DATE: April 2016
DRAWN: KC	CHKD. RA	APPD: MT
		SITE: 47-273C
		DWG. 4



SECTION A-A'

HORIZ. SCALE 10 5 0 5 10 15 20m
VERT. SCALE 2.5 0 2.5 5m



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETERS UNLESS
OTHERWISE SHOWN

GWP No 5159-12-00

HWY 11
CALAMITY CREEK CULVERT
CROSS SECTION B-B' AND SOIL STRATA

SHEET

MMM Group Limited
2855 North Sheridan Way, Suite 300
Mississauga, ON Canada L5K 2P8
T: 905.823.8500, F: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test
- Bore Hole And Cone
- Bore Hole (Shaheen & Peaker Limited)
- 'N' Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60' Cone, 475 J/blow)
- WL at Time of Investigation
- WL in Piezometer
- Piezometer
- 90% Rock Quality Designation
- A/R Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
1	201.8	5 269 457.4	404 593.1
2	214.2	5 269 441.2	404 537.9
3	213.7	5 269 374.3	404 536.5
4	213.9	5 269 354.3	404 541.0
5	203.5	5 269 354.8	404 496.3
6	197.7	5 269 290.3	404 454.7

DB2	Sta. 17+590 O/S 3.5m LL
DB3	Sta. 17+630 O/S 3.1m RL
DB4	Sta. 17+679 O/S 2.9m LL
DB5	Sta. 17+710 O/S 4.5m RL

NOTE

This drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

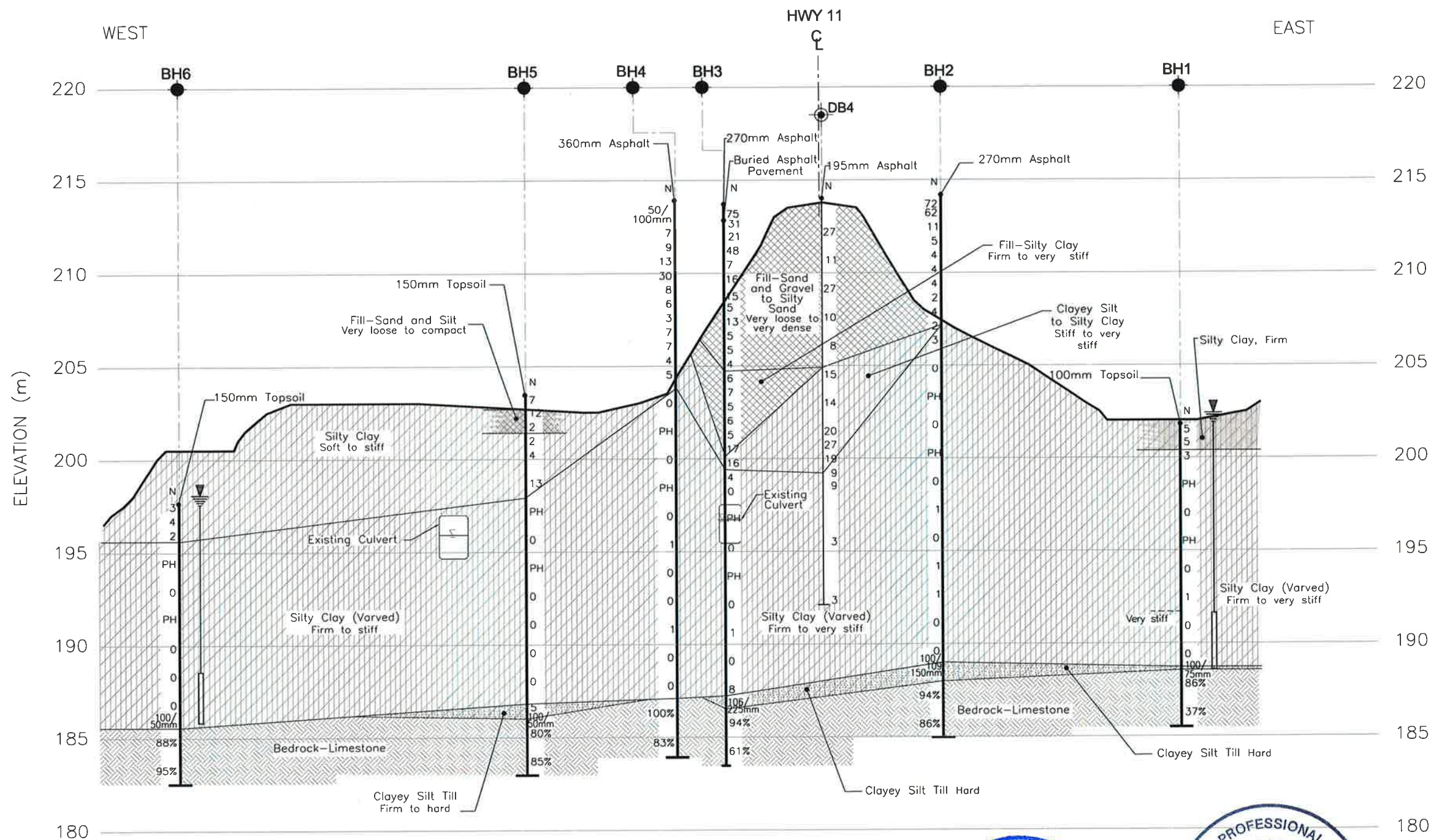
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B3040011001, DTM3040011001, received September 11, 2014.

REVISIONS	DATE	BY	DESCRIPTION

HWY: 11	PROJECT No: 11-14-4056	GEORES NO: 31M-109
SUBM'D: HA	CHKD: RA	DATE: April 2016
DRAWN: KC	CHKD: RA	APPD: MT
		SITE: 47-273C
		DWG: 5



SECTION B-B'

HORIZ. SCALE 10 5 0 5 10 15 20m
VERT. SCALE 2.5 0 2.5 5m



APPENDIX A

Record of Borehole Sheets



LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report.

This report was prepared for the express use of the Ministry of Transportation, its retained design consultants and MMM Group Limited. It is not for use by others. This report is copyright of Terraprobe Inc. and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Inc. The Ministry of Transportation, its retained design consultants and MMM Group Limited, are authorized users.

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg. FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{u} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_{α}	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	- °	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	- °	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_r	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1.0%	VOID RATIO	e_{min}	1.0%	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1.0%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1.0%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m ² /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $(w_L - w_p)$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_p)/I_p$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $(w_L - w)/I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1.0%	VOID RATIO IN LOOSEST STATE	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

Record of Terraprobe Borehole Sheets



RECORD OF BOREHOLE No 1

1 of 2

METRIC


G.W.P. 5159-12-00 LOCATION Coords: E:404593.1 N:5269457.4 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-9-4 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)						WATER CONTENT (%)		
								20 40 60 80 100						W _P W W _L		
								○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE								
201.8	GROUND SURFACE												GR SA SI CL			
	100mm TOPSOIL		1	SS	5											
	SILTY CLAY, trace sand, trace gravel, firm, brown, wet		2	SS	5		201						0 0 27 73			
200.4																
1.4			3	SS	3		200									
		firm														
		--														
	SILTY CLAY (Varved), containing 5mm to 20mm thick silt layers, stiff, grey, wet		4	TW	PH		199	9.5	3.3			53 53 LL=48	17.0	0 0 63 37 0 0 23 77		
							198	7.0	5.6							
			5	SS	0*		197					51 LL=47		0 0 27 73		
							196	5.8	5.5							
			6	TW	PH		195									
								6.0	5.6							
			7	SS	0*		194					42		0 0 37 63		
							193		8.9	5.2						
			8	SS	1		192									
								5.0								
		very stiff					191							0 0 56 44		
			9	SS	0*		190		5.6	4.6						
			10	SS	0*		189									
188.7								4.7								
13.1	CLAYEY SILT, sandy, trace gravel, hard, grey, moist (GLACIAL TILL)		11	SS	100 / 75mm		188							NQ Coring		
188.5	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered (13.3m-14.9m) to moderately weathered (14.9m-16.3m) medium to thickly bedded, grey to whitish grey, medium to high strength, vuggy (frequent vugs at 15.2m-16.3m)		1	RUN	NQ									RUN# 1 TCR=100% SCR=100% RQD=86%		
13.3			2	RUN	NQ		187							RUN# 2		

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)					WATER CONTENT (%)				
								20	40	60	80	100	W _p	W	W _L		
	(continued)																
185.5	BEDROCK-LIMESTONE , (Dolomitic), slightly weathered (13.3m-14.9m) to moderately weathered (14.9m-16.3m) medium to thickly bedded, grey to whitish grey, medium to high strength, vuggy (frequent vugs at 15.2m-16.3m)		2	RUN	NQ		186									GR=SA=SI=100% TCR=100% SCR=92% RQD=37%	

*(aq) - above ground.

<u>Date</u>	<u>Water Depth (m)</u>	<u>Elevation (m)</u>
Sep 17, 2014	-0.1 (ag)*	n/a
Oct 28, 2014	-0.5 (ag)*	n/a
Nov 24, 2014	-0.6 (ag)*	n/a

RECORD OF BOREHOLE No 2

1 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404537.9 N:5269441.2 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-25 - 2014-8-26 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV. DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100							W _p	W	W _L			
								SHEAR STRENGTH (kPa)										WATER CONTENT (%)		
214.2	GROUND SURFACE																			
213.9 0.3	270mm ASPHALTIC CONCRETE						214								15 64 16 5					
213.3 0.9	630mm FILL-SAND, some silt, some gravel, trace clay, very dense, brown, dry		1	SS	72										commence casing and washboring 8 46 34 12					
	Containing asphalt concrete layer, compact to very dense		2	SS	62															
			3	SS	11															
	...		4	SS	5															
	Fill, silty sand, some clay, trace gravel, very loose to loose, brown, moist to wet		5	SS	4															
	...		6	SS	4															
	containing sand and gravel		7	SS	4															
			8	SS	2															
	...		9	SS	4															
	containing a 25mm thick peat layer		10	SS	2															
			11	SS	3															
			12	SS	0*															
			13	TW	PH															
			14	SS	0*															
			15	TW	PH															
207.2 7.0																				
	SILTY CLAY (Varved), containing 5mm to 20mm thick silt layers, stiff to very stiff, grey, wet																			
						</														

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

August 25, 2014
August 26, 2014

RECORD OF BOREHOLE No 2

2 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404537.9 N:5269441.2 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-25 - 2014-8-26 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)				WATER CONTENT (%)					
								20 40 60 80 100				W _p	W	W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
(continued)							20 40 60 80 100	20 40 60 80 100	10 20 30	kN/m ³			GR SA SI CL				
189.0 25.2	SILTY CLAY (Varved), containing 5mm to 20mm thick silt layers, stiff to very stiff, grey, wet		16	SS	0*											0 0 38 62	
			17	SS	1												0 0 39 61
			18	SS	0*												
			19	SS	1												0 0 43 57
			20	SS	1												
			21	SS	0*												
188.0 26.2	CLAYEY SILT, sandy, trace gravel, hard, grey, moist (GLACIAL TILL)		22	SS	0*												
			23	SS	109 / 150mm												
184.9 29.3	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered, medium to thickly bedded, grey to whitish grey, high strength, vuggy		1	RUN	NQ										NQ Coring		
			2	RUN	NQ												RUN #1 TCR=100% SCR=97% RQD=94%
															RUN #2 TCR=100% SCR=97% RQD=86%		
END OF BOREHOLE																	


library: library - terraprobe gint.gib report: mto-terraprobe soil file: 11-14-4066 (47-273c) calamity creek.gpj

RECORD OF BOREHOLE No 2

3 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404537.9 N:5269441.2 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-25 - 2014-8-26 CHECKED BY R.A

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE								

Borehole filled with drill water upon completion of drilling.

*Sampler sinking under weight of hammer and/ or rods

RECORD OF BOREHOLE No 3

1 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404536.5 N:5269374.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS / CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-27 - 2014-8-28 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100							
								SHEAR STRENGTH (kPa)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)															
20 40 60 80 100 10 20 30															
213.7	GROUND SURFACE													GR SA SI CL	
213.4	270mm ASPHALTIC CONCRETE														
0.3	530mm FILL-SAND, some silt. some gravel, very dense, brown, dry		1	SS	75		213							commence casing and washboring	
212.9	300mm ASPHALTIC CONCRETE		2	SS	31										
0.8	150mm FILL-GRAVELLY SAND, trace silt, dense, brown, wet		3	SS	21		212								
212.6															
1.1			4	SS	48		211								
212.4	FILL, gravelly sand to silty sand, trace clay, containing crushed limestone fragments, loose to dense, brown, moist to wet														
1.3			5	SS	7		210								
			6	SS	16										
	455 diameter boulder						209								
			7	SS	15										
			8	SS	5		208								
			9	SS	13										
			10	SS	5		207								
			11	SS	5		206								
			12	SS	4		205								
204.7	FILL, silty clay, sandy, trace to some gravel, trace organics, firm, grey, moist to wet		13	SS	6										
9.0			14	SS	7		204								
			15	SS	5		203								
			16	SS	6		202								
			17	SS	5		201								
	containing wood fragments, very stiff		18	SS	17										
200.1	SILTY CLAY, trace sand, very stiff, brown, wet		19	SS	16		200								
13.6															
199.4			20	SS	4		199								
14.3															

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

library: library - terraprobe gint.gib report: mto-terraprobe soil file: 11-14-4066 (47-273c) calamity creek.gpj

METRIC

ELEV DEPTH (m)	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE										
								SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE							
							20 40 60 80 100		W _p W W _L						
							20 40 60 80 100		WATER CONTENT (%)	kN/m³	GR SA SI CL				
(continued)															
			21	SS	0*		198	4.2		44 ○	0 0 38 62				
								3.8							
			22	TW	PH		197	4.1	X	50 ○	0 0 45 55				
	SILTY CLAY (Varved), containing 10mm to 30mm thick silt layers, stiff, grey, wet						196	5.1							
								4.4							
			23	SS	0*		195			44 ○	August 27, 2014 August 28, 2014 0 0 43 57				
								4.4							
							194	3.6							
			24	TW	PH										
							193	3.8							
								3.4							
			25	SS	0*		192			42 ○	0 0 43 57				
								2.1							
							191	4.5							
			26	SS	1										
							190	2.9							
								3.4							
			27	SS	0*		189			○					
								4.6							
							188	3.2							
187.2 26.5	CLAYEY SILT, trace to some sand, trace gravel, occasional cobbles, hard, grey, moist (GLACIAL TILL)		29	SS	106 / 225mm		187	>+		○	NQ Coring				
186.5 27.2	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered to 29.3m, moderately weathered below, medium to thickly bedded, grey to whitish grey, medium to high strength, vuggy (frequent vugs at 29.3m-30.3m)		1	RUN	NQ		186				RUN #1 TCR=100% SCR=97% RQD=94%				
			2	RUN	NQ		185				RUN #2 TCR=100% SCR=100% RQD=61%				
							184								


+³, ×³: Numbers refer to Sensitivity **○^{3%}** STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

3 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404536.5 N:5269374.3 ORIGINATED BY S.M
 DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS / CASING AND WASH BORING/NQ CORING COMPILED BY A.A
 DATUM GEODETIC DATE 2014-8-27 - 2014-8-28 CHECKED BY R.A

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE								
	(continued)		2	RUN	NQ							
183.5 30.3												

END OF BOREHOLE

Borehole filled with drill water upon completion of drilling.

*Sampler sinking under weight of hammer and/ or rods.

Consolidation test performed on TW22

RECORD OF BOREHOLE No 4

1 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)					WATER CONTENT (%)				
213.9	GROUND SURFACE						20	40	60	80	100	W _P	W	W _L			
213.5	360mm ASPHALTIC CONCRETE																
0.4	540mm FILL, SAND, some silt, some gravel, trace clay, very dense, brown, drv		1	SS	50 / 100mm												
213.0	FILL, silty clay, trace sand to sandy, trace gravel, trace organics below 6.9m, occasional cobbles, firm to very stiff, brown, moist to wet		2	SS	7												
0.9			3	SS	9												
			4	SS	13												
			5	SS	30												
			6	SS	8												
			7	SS	6												
			8	SS	3												
			9	SS	7												
206.4			10	SS	7												
7.5	SILTY CLAY, trace sand, trace organics, firm, brown to grey, wet		11	SS	4												
			12	SS	5												
203.8																	
10.1	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, stiff, grey, wet		13	SS	0*												
			14	TW	PH												
			15	SS	0												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

August 26, 2014
August 27, 2014

RECORD OF BOREHOLE No 4

2 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)							WATER CONTENT (%)					
								20	40	60	80	100			W _p	W	W _L			
								○ UNCONFINED	● QUICK TRIAXIAL	+	FIELD VANE	×	LAB VANE							
								20	40	60	80	100	10	20	30	GR SA SI CL				
(continued)																				
SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, stiff, grey, wet																				
								16	TW	PH										
								17	SS	0*										
								18	SS	1										
								19	SS	0*										

Continued Next Page

END OF BOREHOLE

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

library: library - terraprobe gint.gls report: mto-terraprobe soil file: 11-14-4066 (47-273c) calamity creek.gpj

RECORD OF BOREHOLE No 4

3 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT NUMBER	TYPE			SHEAR STRENGTH (kPa)		W _p	W	W _L	γ	
						20 40 60 80 100						
						○ UNCONFINED + FIELD VANE		WATER CONTENT (%)				
						● QUICK TRIAXIAL × LAB VANE						
						20 40 60 80 100		10 20 30			kN/m ³	GR SA SI CL

(continued)

30.0

Borehole filled with drill water
upon completion of drilling.

*Sampler sinking under weight of
hammer and/ or rods

Insufficient sample available for
Atterberg limits test at SS12

RECORD OF BOREHOLE No 5

1 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404496.3 N:5269354.8 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-29 - 2014-9-3 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)							WATER CONTENT (%)		
								20 40 60 80 100							W _p	W	W _L
								○ UNCONFINED ● QUICK TRIAXIAL							+ FIELD VANE × LAB VANE		
203.5	GROUND SURFACE												kN/m ³	GR SA SI CL			
203.4 0.2	150mm TOPSOIL		1	SS	7		203										
	FILL, sand and silt, some clay, trace gravel, very loose to compact, brown, wet		2	SS	12						○						
			3	SS	2		202					○			4 45 37 14		
201.4 2.1	SILTY CLAY, trace sand, trace gravel, soft to stiff, brown, wet		4	SS	2		201										
	...		5	SS	4							○					
	containing organics						200										
			6	SS	13		199						41	○	0 1 33 66		
197.9 5.6	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, firm to stiff, grey, wet		7	TW	PH		198								Aug. 29, 2014		
															Sept. 2, 2014		
							197								commence casing and washboring		
			8	SS	0*		196						41	○	0 0 29 71		
							195										
			9	TW	PH												
			10	SS	0*		193						46	○	0 0 43 57		
							192										
			11	SS	0*		191								Sept. 2, 2014		
															Sept. 3, 2014		
							190										
			12	SS	0*								41	○	0 0 51 49		
							189										

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

library: library - terraprobe gint - md.gib report: mto-terraprobe soil file: 11-14-4066 (47-2730) calamity creek.gp

RECORD OF BOREHOLE No 5

2 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404496.3 N:5269354.8 ORIGINATED BY S.M
 DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
 DATUM GEODETIC DATE 2014-8-29 - 2014-9-3 CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100			W _p	W	W _L			WATER CONTENT (%)
								SHEAR STRENGTH (kPa)								
								○ UNCONFINED ● QUICK TRIAXIAL			+ FIELD VANE × LAB VANE					
	(continued)							20 40 60 80 100				10 20 30	kN/m ³	GR SA SI CL		
	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, firm to stiff, grey, wet		13	SS	0*		188									
186.8 16.7	CLAYEY SILT , sandy, trace gravel, firm to hard, grey, moist (GLACIAL TILL)		14	SS	5		187								9 29 47 15	
186.0 17.5	BEDROCK-LIMESTONE , (Dolomitic), slightly weathered, thinly to medium bedded, grey to whitish grey, high strength, vuggy		15	SS	100 / 50mm		186								NQ Coring	
			1	RUN	NQ		185								RUN #1 TCR=100% SCR=95% RQD=80%	
			2	RUN	NQ		184								RUN #2 TCR=100% SCR=100% RQD=85%	
183.0							183									

END OF BOREHOLE

Borehole filled with drill water upon
completion of drilling.

*Sampler sinking under weight of
hammer and/ or rods.

Insufficient sample available for
Atterberg limits test at SS6

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

RECORD OF BOREHOLE No 6

2 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404454.7 N:5269290.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-9-3 CHECKED BY R.A

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE								
182.5 15.2	(continued)		2	RUN	NQ		20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	10 20 30			kN/m ³	GR SA SI CL

END OF BOREHOLE

Borehole filled with drill water upon completion of drilling.

*Sampler sinking under weight of hammer and/ or rods.

Piezometer installation consists of a 25mm diameter schedule 40PVC pipe with a 3.0m slotted screen.

*(ag) - above ground.

WATER LEVEL READINGS

Date	Water Depth (m)	Elevation (m)
Sep 17, 2014	-0.3 (ag)*	n/a
Oct 28, 2014	-0.4 (ag)*	n/a
Nov 24, 2014	-0.4 (ag)*	n/a

Record of S&P Borehole Sheets



RECORD OF BOREHOLE No DB2

1 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17 + 590 O/S 3.5 m Lt. ORIGINATED BY T.B
 DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
 DATUM DATE 10.05.99 & 10.05.99 CHECKED BY P.M

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N* VALUES			20	40	60	80	100	W _p	W	W _L		
114.3	Ground Surface																
0.0	140 mm Asphalt																
0.1	160 mm Sand and gravel,																
0.3	brown, moist																
112.8	SAND: with trace gravel, coarse, brown																
1.5	FILL: sand with trace gravel, brown, moist, over sandy silt with trace clay, brown, moist medium sand, over silty clay, grey, moist (possible native)		1	SPT	12												
			2	SPT	16												
101.8	VARVED CLAY: rhythmic layers of dark grey silty clay to clay and light grey clayey silt to silt.		3	SPT	4												
4.5			4	SHELBY													
			5	SPT	3												
			6	SHELBY													
			7	SPT	3												
			8	SHELBY													
			9	SHELBY													
			10	SPT	1												

Continued Next Page

3 3

Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

+ 3, x 3; Numbers refer to Sensitivity

RECORD OF BOREHOLE No DB3

1 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17 + 630 O/S 3.1 m Rt. ORIGINATED BY T.B
 DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
 DATUM DATE 10.05.99 & 10.05.99 CHECKED BY P.M

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
213.9	Ground Surface													
0.0	220 mm Asphalt													
0.2	50 mm Sand and gravel, brown, moist													
0.4	70 mm Asphalt													
0.6	170 mm Sand and gravel													
0.7	70 mm Asphalt, over Sand and gravel		1	SPT	19									
	FILL: clayey silt with trace organics and some gravel sizes, grey, moist, very stiff, over (possible fill) grey, moist clayey silt with trace organics 25 mm thick layer of topsoil		2	SPT	32									
			3	SPT	20									
207.6			4	SPT	6									
6.3	SILTY CLAY: greenish, moist, stiff very soft		5	SPT	11									
			6	SPT	21									
			7	SPT	19									
			8	SPT	10									
	with layers of organics becoming brown, very stiff fissured, stiff		9	SPT	7									
202.4	becoming wet at 10.7 m		10	SPT	3									
11.5	VARVED CLAY: rhythmic layers of dark grey silty clay to clay and light grey clayey silt to silt.		11	SPT	4									
			12	SHELB										
			13	SPT	5									

Continued Next Page

+ 3, x 3

Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DB4

1 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17+679 O/S 2.9 m Lt. ORIGINATED BY T.B
DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
DATUM DATE 10.05.99 & 10.05.99 CHECKED BY P.M

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
							SHEAR STRENGTH kPa					WATER CONTENT (%)			kN/m ³	GR SA SI CL
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
							20	40	60	80	100	20	40	60		
113.8	Ground Surface															
0.0	195 mm Asphalt															
0.2	FILL: sand and gravel, moist															
		1	SPT	27												
		2	SPT	11												
		3	SPT	27												
	with trace clay	4	SPT	10												
		5	SPT	8												
104.7	CLAYEY SILT: with some sand and gravel, brown	6	SPT	15												
103.2	with some organics															
102.2	CLAYEY SILT: with some gravel and organics, brown, moist	7	SPT	14												
		8	SPT	20												
101.0	SILTY CLAY: grey, organics	9	SPT	27												
		10	SPT	19												
100.0	becoming brown with trace	11	SPT	9												

Continued Next Page

+ 3, × 3; Numbers refer to 20
Sensitivity 15-25 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DB4

2 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17+679 O/S 2.9 m Lt. ORIGINATED BY T.B
DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
DATUM DATE 10.05.99 & 10.05.99 CHECKED BY P.M

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100		
14.8	organics VARVED CLAY: rhythmic layers of dark grey silty clay to clay and light gray clayey silt to silt. Clay layers are approximately 25 mm thick with 12 mm thick silt layers, firm but readily separates on horizontal planes		12	SPT	9								
			13	SHELBY									
			14	SHELBY									
			15	SPT	3								
			16	SHELBY									
			17	SHELBY									
			18	SPT	3								
21.9	End of borehole Note: Borehole dry on completion												

RECORD OF BOREHOLE No DB5

1 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp O/S 4.5 m Rt. ORIGINATED BY T.B
DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
DATUM DATE 10.05.99 & 10.05.99 CHECKED BY P.M

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
0.0	Ground Surface																
0.3	270 mm Asphalt																
0.6	420 mm Sand and gravel, brown, moist																
0.7	90 mm Asphalt																
	Sand and gravel FILL: clayey silt with some gravel and fine sand, brown, moist		1	SPT	10												
			2	SPT	37												
			3	SPT	7												
	silty sand, with zones of some clay and gravel, trace organics																
5.0	VARVED CLAY: rhythmic layers of dark grey silty clay to clay and light grey clayey silt to silt.		4	SPT	9												
			5	SPT	13												
			6	SPT	17												
			7	SPT	7												
			8	SHELBY													
			9	SPT	4												
			10	SHELBY													
			11	SHELBY													
	Clay layers are approximately 25 mm thick with 6 mm thick silt layers, firm but readily separates on horizontal planes		12	SPT	3												

Continued Next Page

+ 3 x 5 Numbers refer to 20
Sensitivity 15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DB5

2 OF 2

METRIC

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp O/S 4.5 m Rt. ORIGINATED BY T.B
 DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers COMPILED BY G.T
 DATUM _____ DATE 10.05.99 & 10.05.99 CHECKED BY P.M

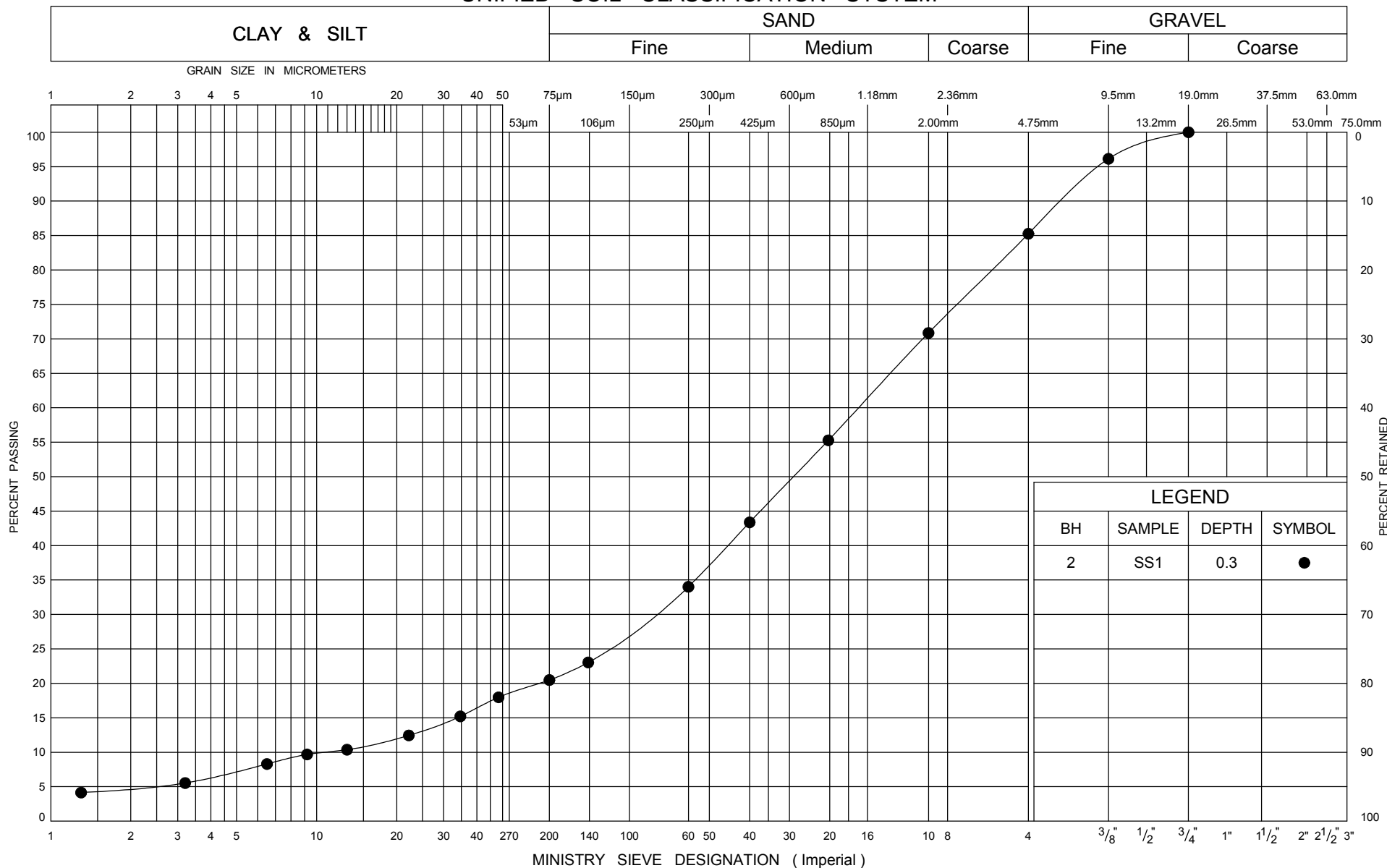
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
						20	40	60	80	100	W _p	W	W _L			
			13	SHELBY												
			14	SHELBY												
			15	SPT	3											
			16	SHELBY												
			17	SHELBY												
			18	SPT	3											
			19	SHELBY												
			20	SPT	6											
			21	SHELBY												
			22	SPT	11											
188.0	Clay layers are approximately 25 mm thick with 12 mm thick silt layers, firm but readily separates on horizontal planes															
26.1	End of borehole Note: Water level in piezometer at 12.5 m on 10.14.99															

+ 3 x 3 Numbers refer to Sensitivity 20 15 10 (%) STRAIN AT FAILURE

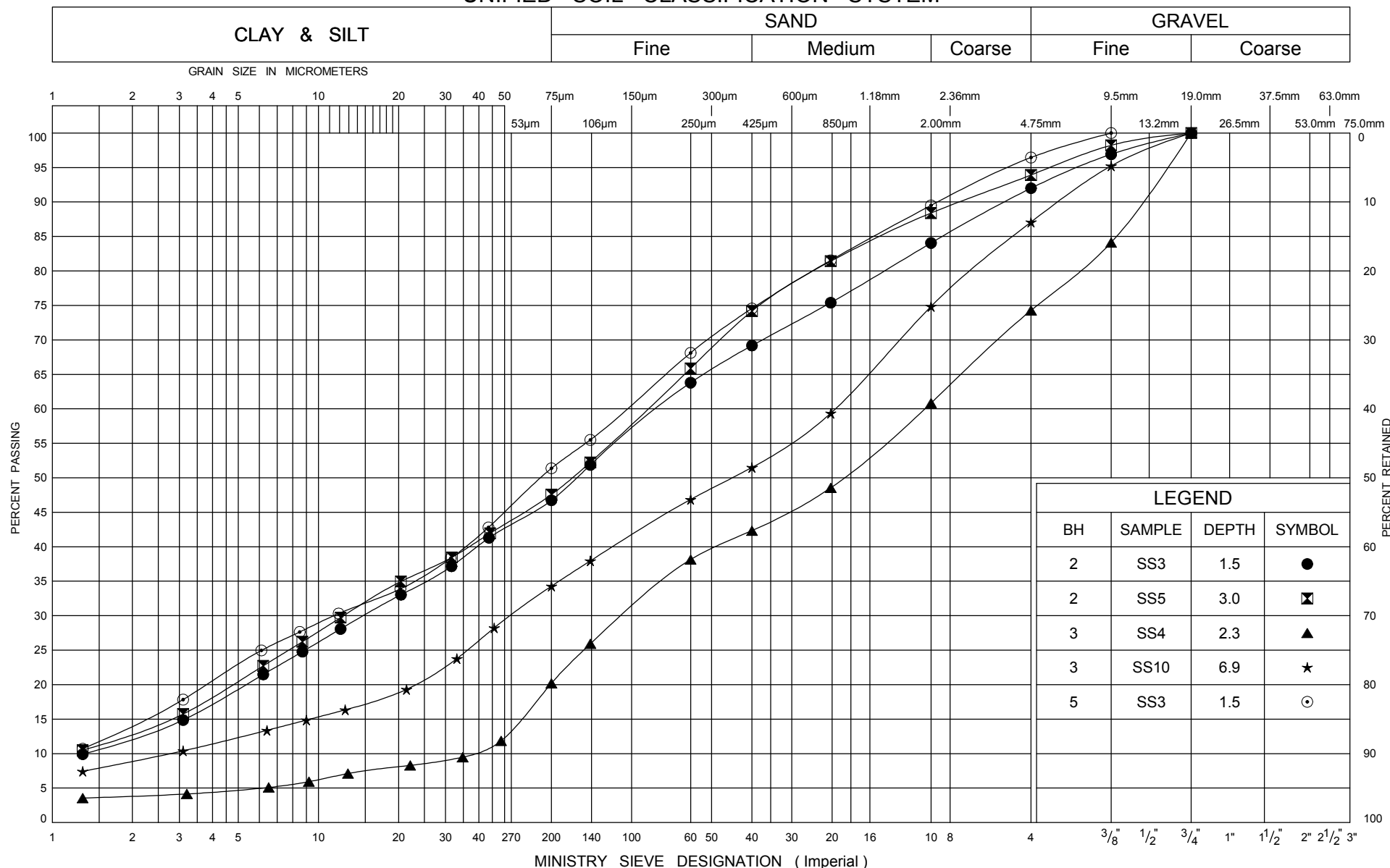
APPENDIX B1
Terraprobe
Field & Laboratory Test Results
&
Photographs



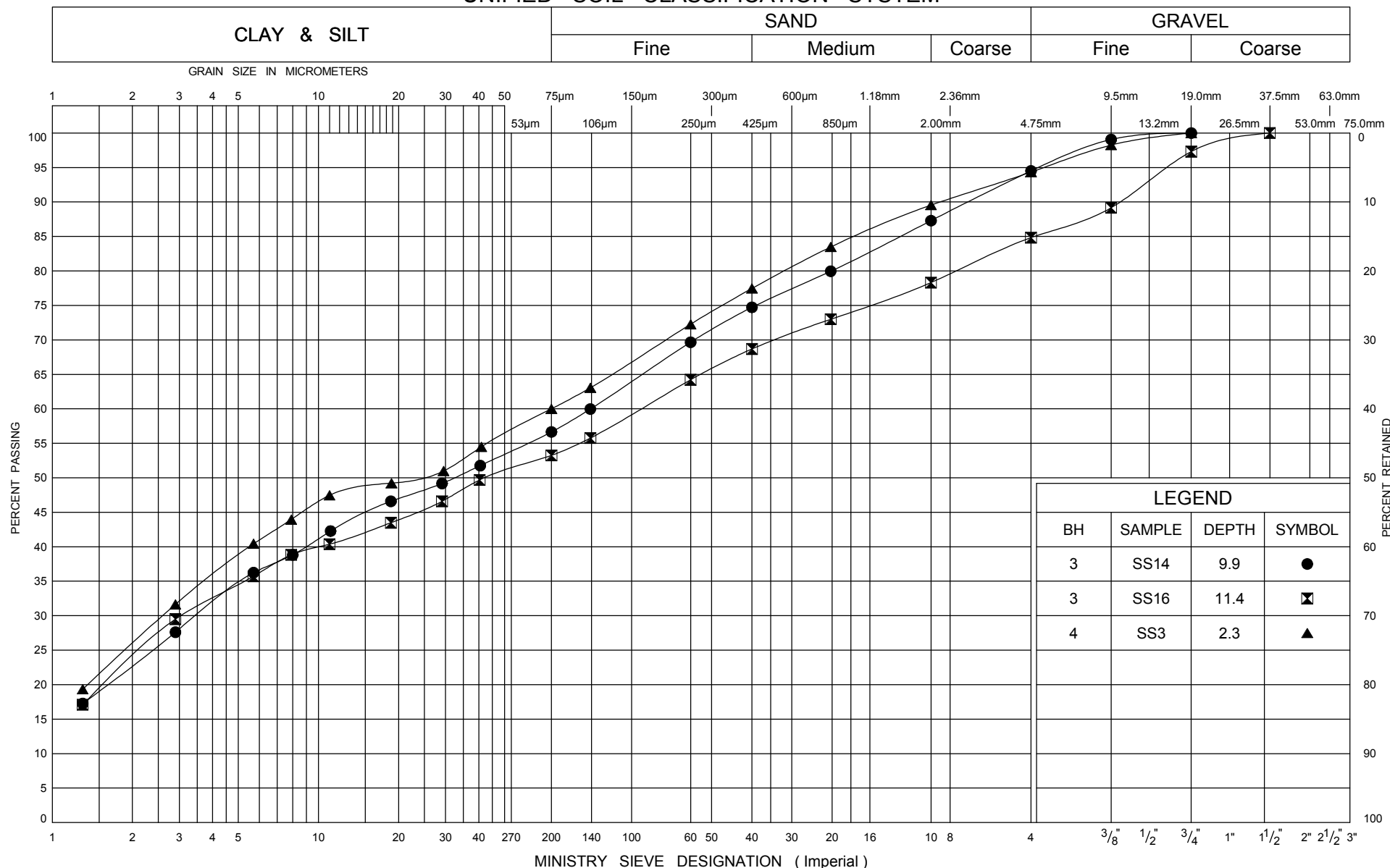
UNIFIED SOIL CLASSIFICATION SYSTEM



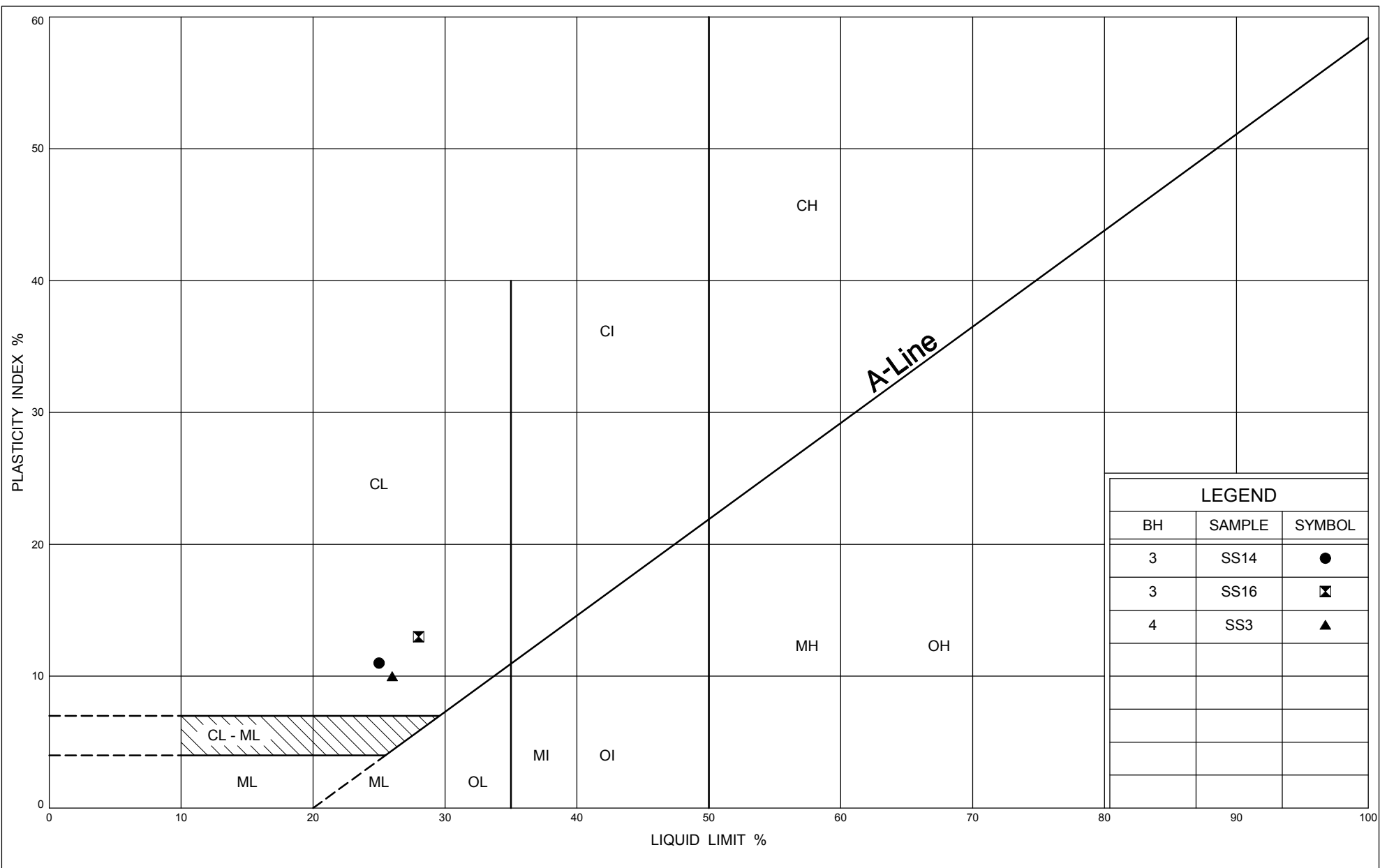
UNIFIED SOIL CLASSIFICATION SYSTEM



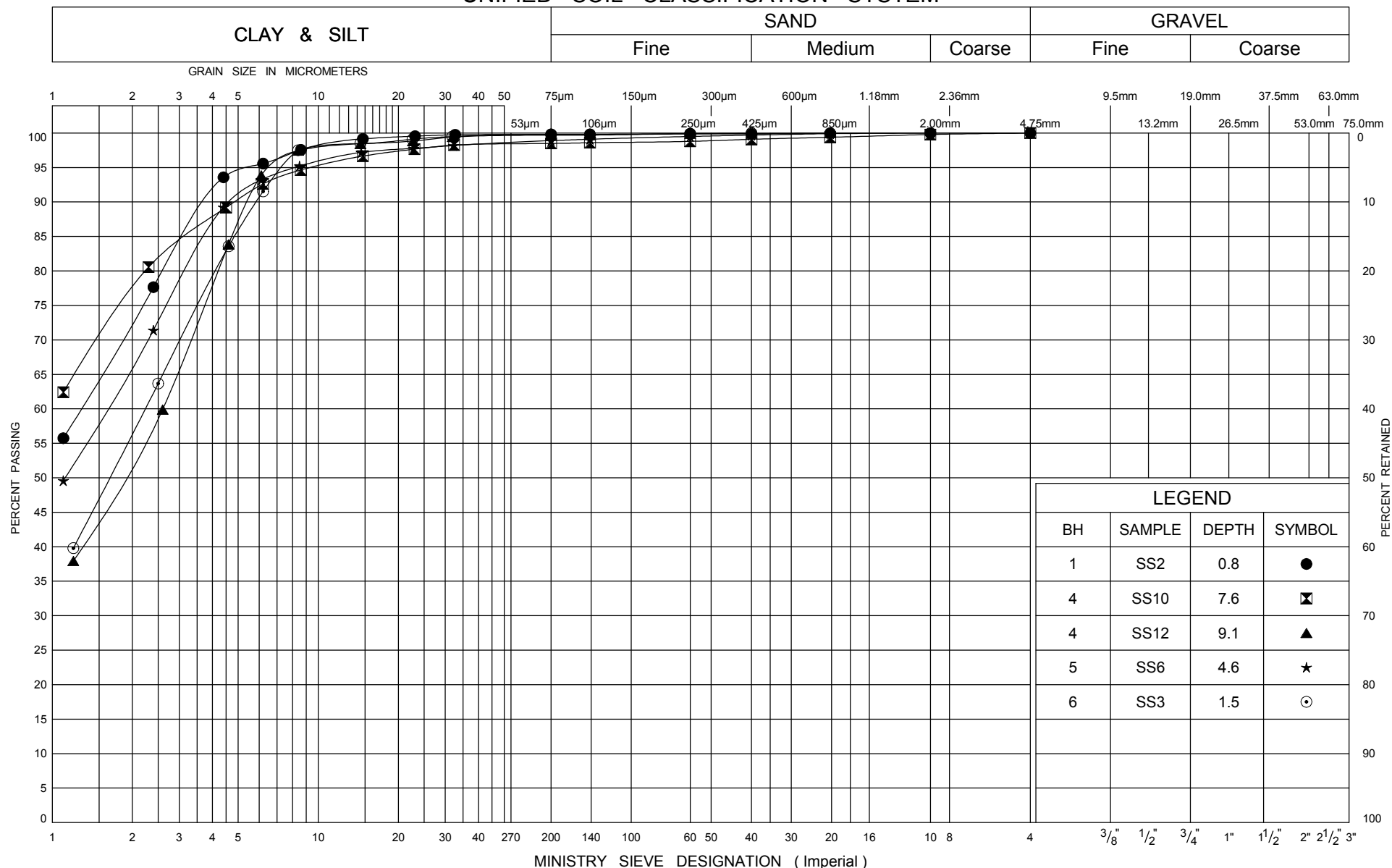
UNIFIED SOIL CLASSIFICATION SYSTEM



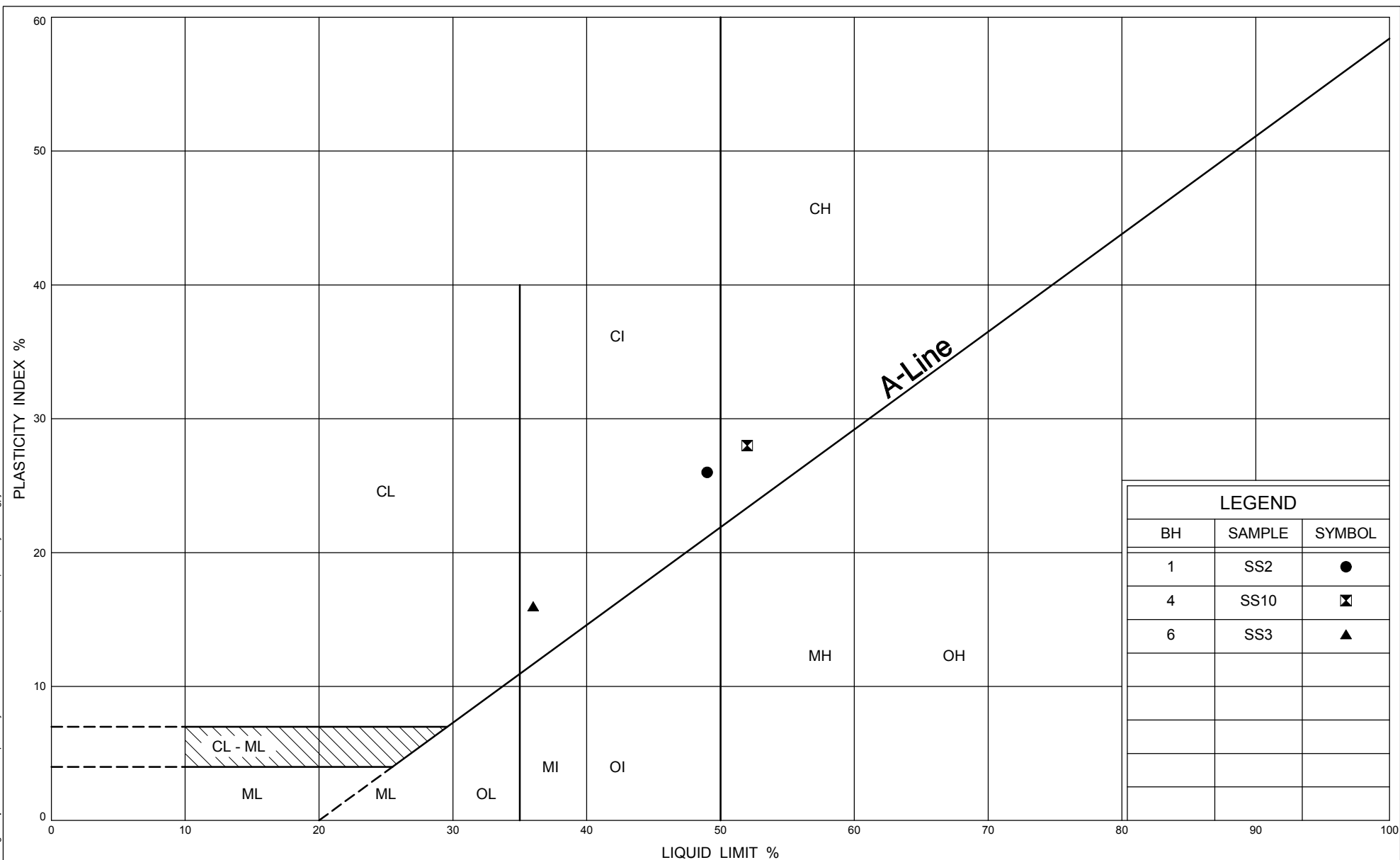
library: library - terraprobe.gint - md.glb report: mto-terra-plasticity chart file: 11-14-4066 (47-273c) calamity creek.gpj



UNIFIED SOIL CLASSIFICATION SYSTEM



library: library - terraprobe.gint - md.glb report: mto-terra-plasticity chart file: 11-14-4066 (47-273c) calamity creek.gpj



Ministry of
Transportation

PLASTICITY CHART SILTY CLAY

FIG No B1-6

G W P 5159-12-00

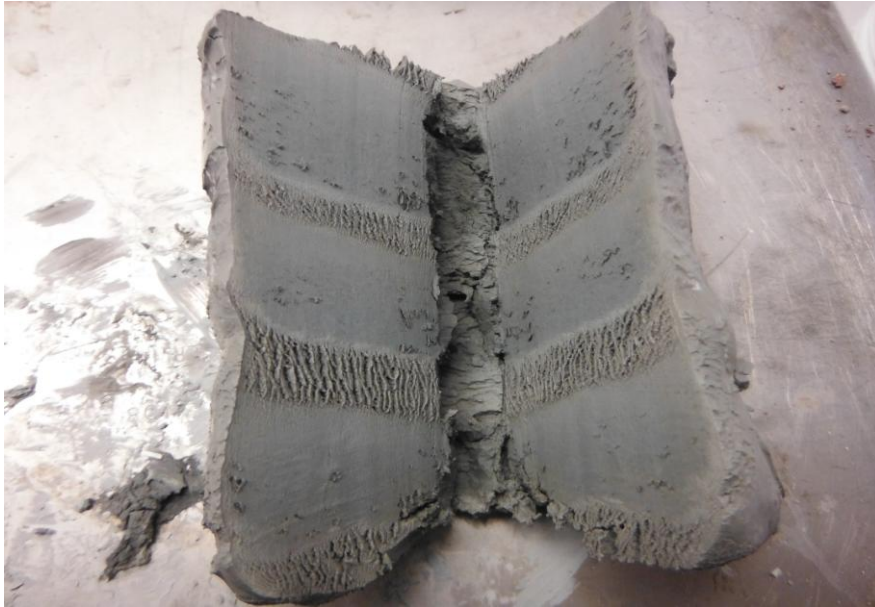
Calamity Creek Culvert Site 47-273C

VARVED SILTY CLAY TO CLAY SAMPLES

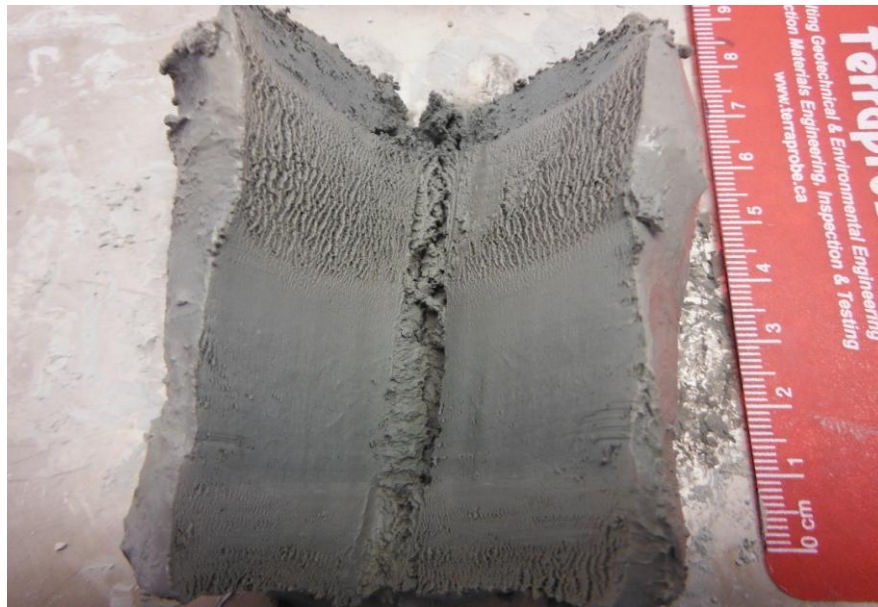
FIGURE B1-7

CALAMITY CREEK CULVERT- Site 47-273C

Silty Clay (Varved)



BH2 SS12



BH5 SS12

Project No. : 11-14-4066

Date : January, 2015



Terraprobe Inc.

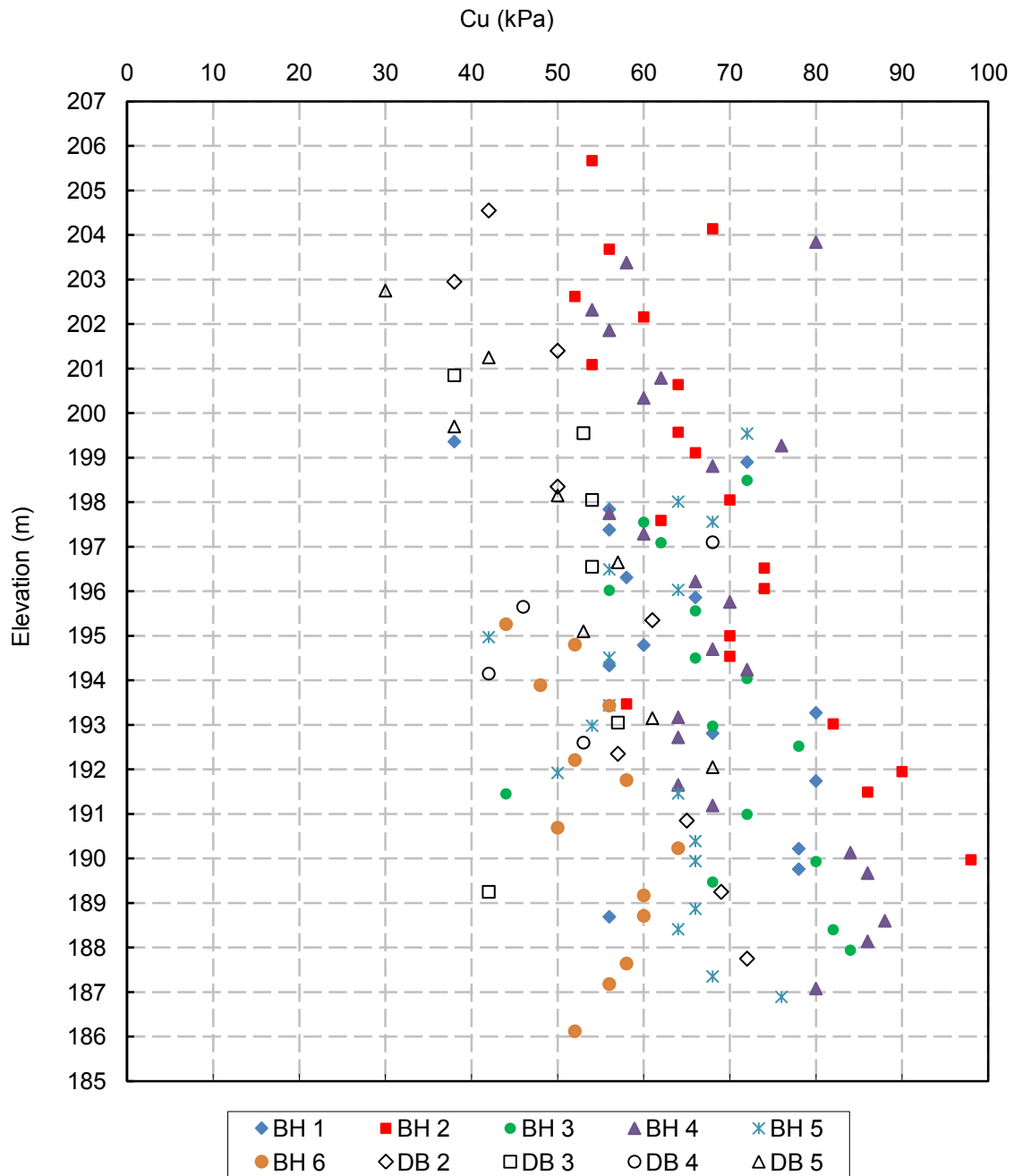
Prepared by : SD

Checked by : RA

UNDRAINED SHEAR STRENGTH

FIGURE B1-8

CALAMITY CREEK CULVERT Site 47-273C Silty Clay (Varved)



BH 1 to 6 – Terraprobe field investigation data.

DB 2 to 5 – SPL field investigation data.

Project No. : 11-14-4066

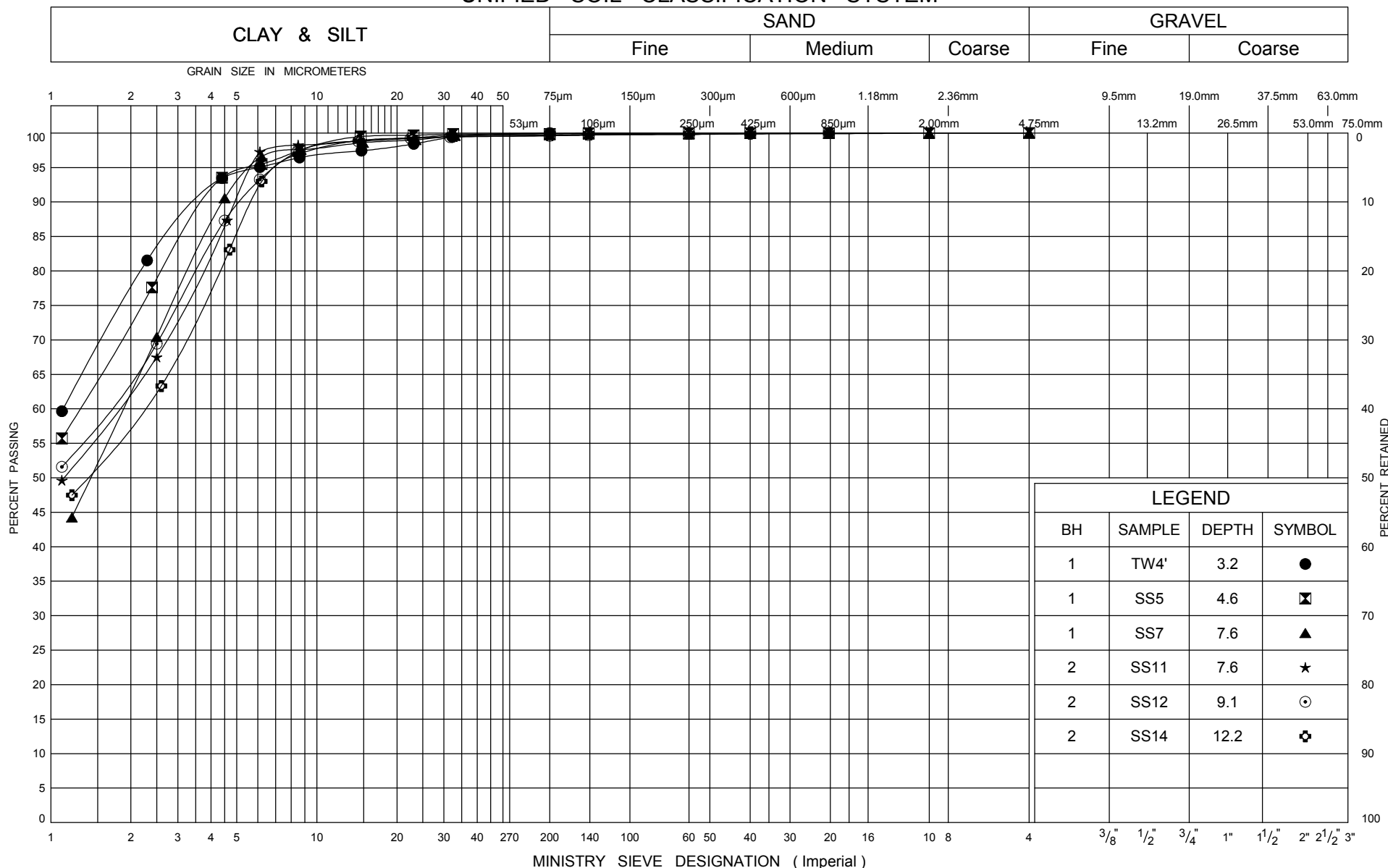
Date : January, 2015



Prepared by : SD

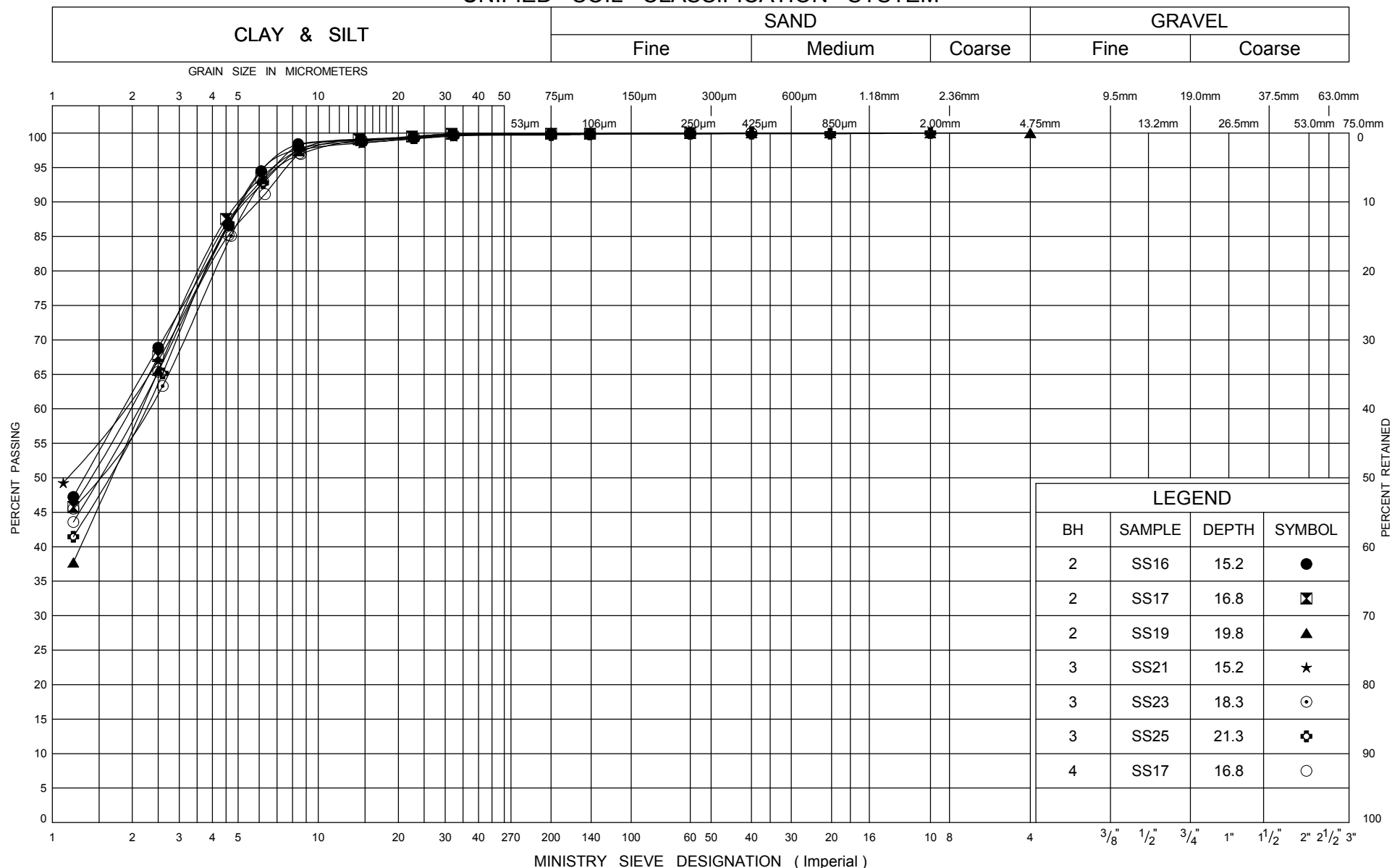
Checked by : RA

UNIFIED SOIL CLASSIFICATION SYSTEM

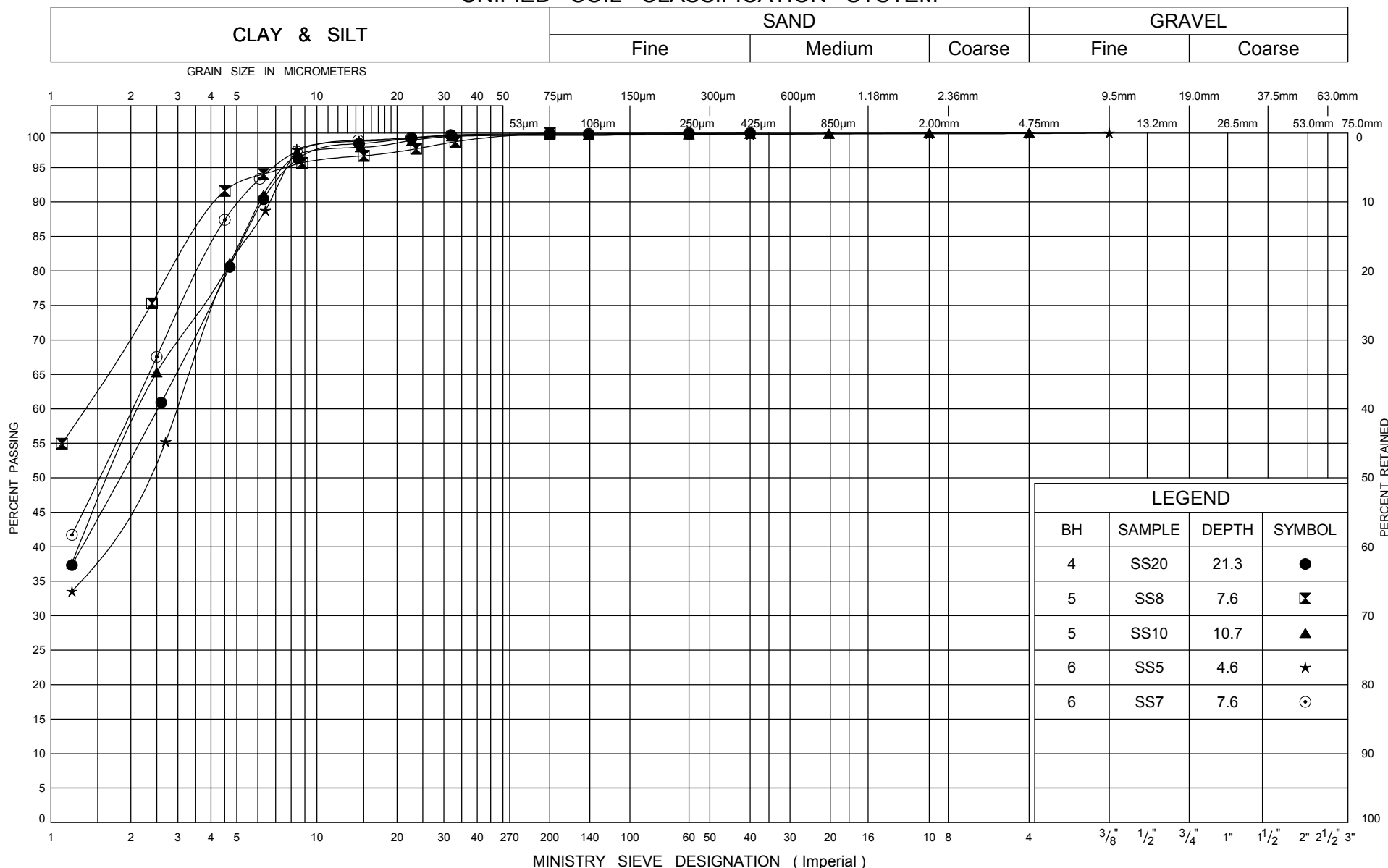


LEGEND			
BH	SAMPLE	DEPTH	SYMBOL
1	TW4'	3.2	●
1	SS5	4.6	⊠
1	SS7	7.6	▲
2	SS11	7.6	★
2	SS12	9.1	⊙
2	SS14	12.2	⊕

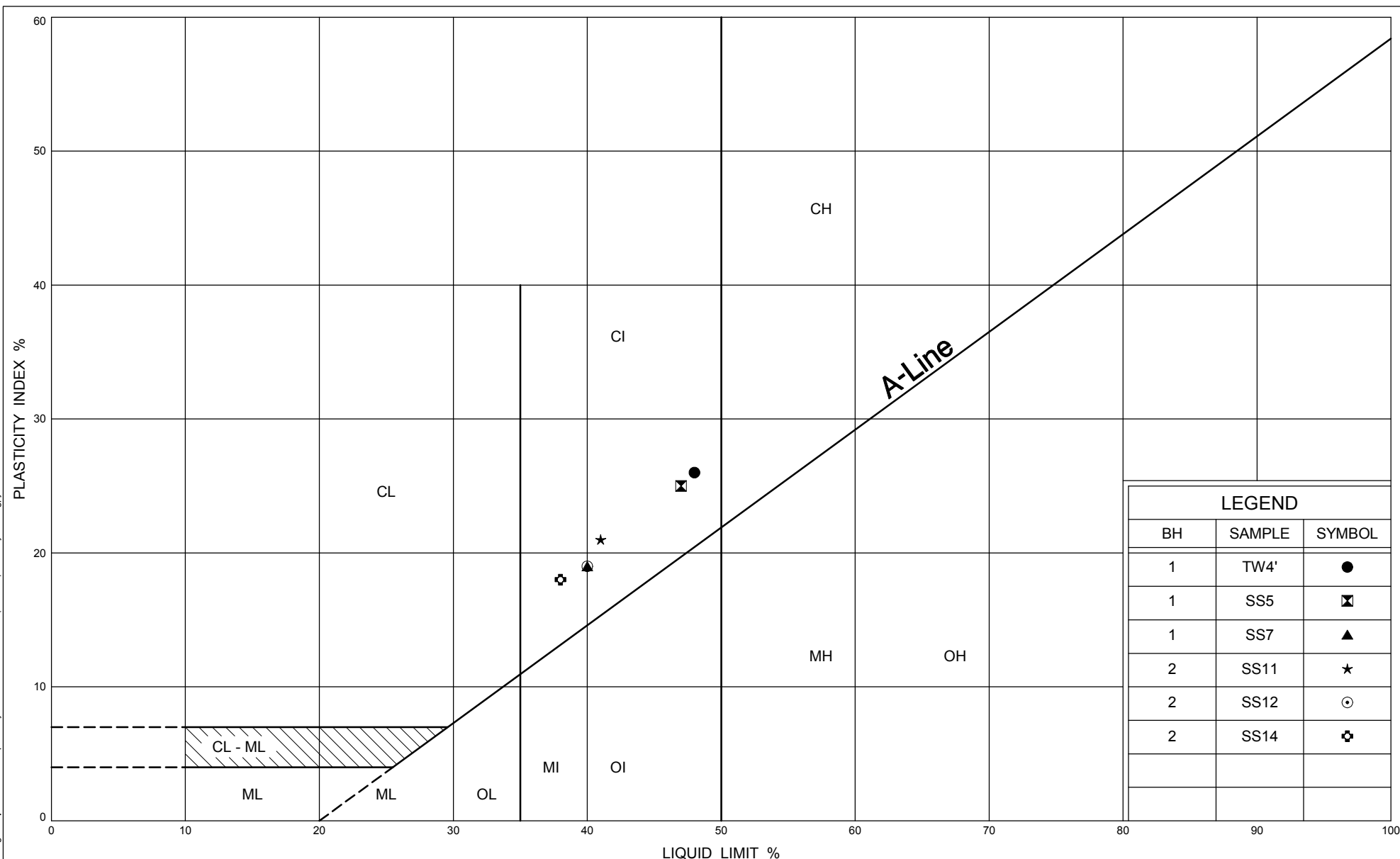
UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



library: library - terraprobe.gint - md.glb report: mto-terra-plasticity-chart file: 11-14-4066 (47-273c) calamity creek.gpj



Ministry of
Transportation

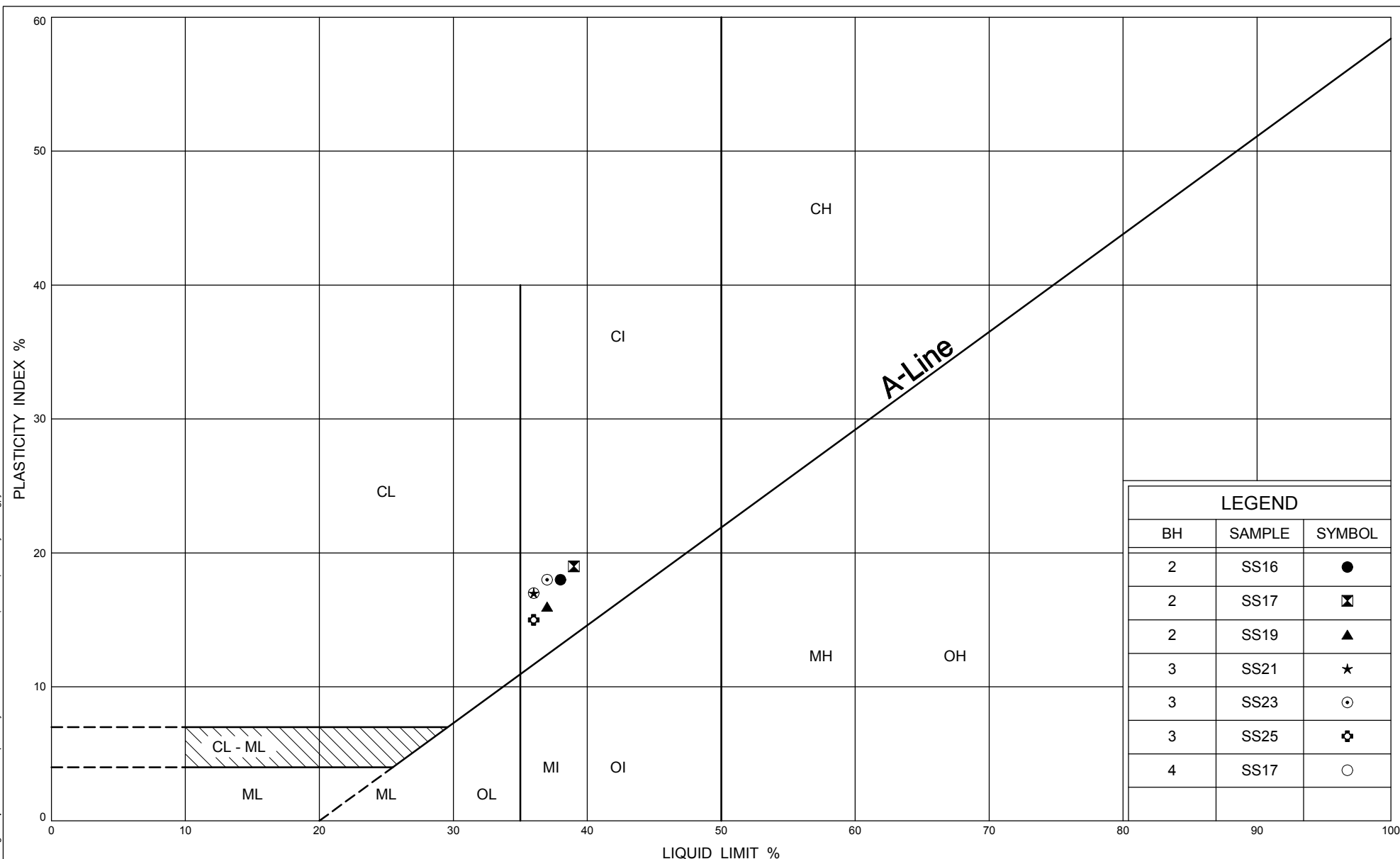
PLASTICITY CHART SILTY CLAY (VARVED)

FIG No B1-12

G W P 5159-12-00

Calamity Creek Culvert Site 47-273C

library: library - terraprobe.gint - md.glb report: mto-terra-plasticity-chart file: 11-14-4066 (47-273c) calamity creek.gpj



Ministry of
Transportation

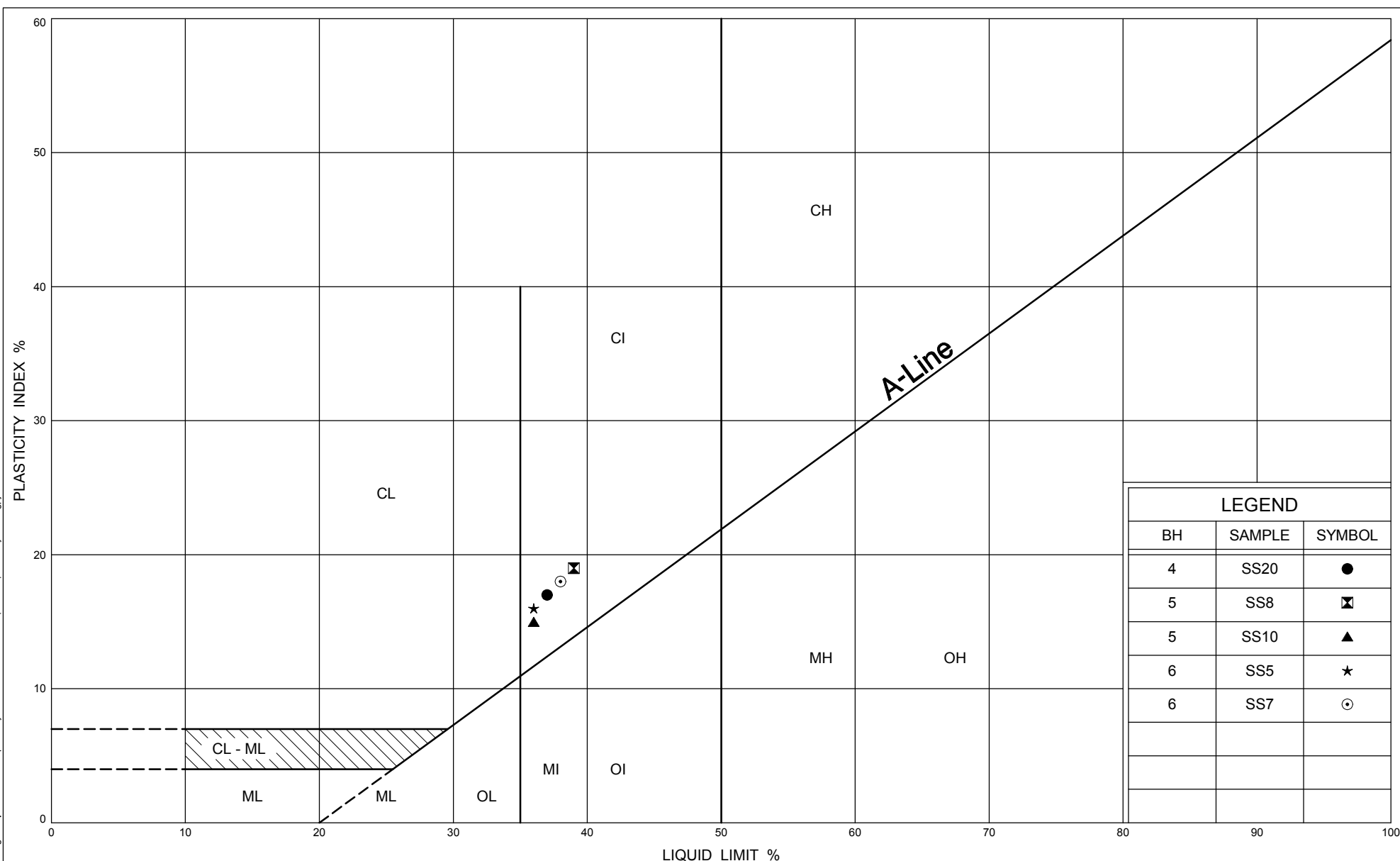
PLASTICITY CHART SILTY CLAY (VARVED)

FIG No B1-13

G W P 5159-12-00

Calamity Creek Culvert Site 47-273C

library: library - terraprobe.gint - md.glb report: mto-terra-plasticity-chart file: 11-14-4066 (47-273c) calamity creek.gpj



Ministry of
Transportation

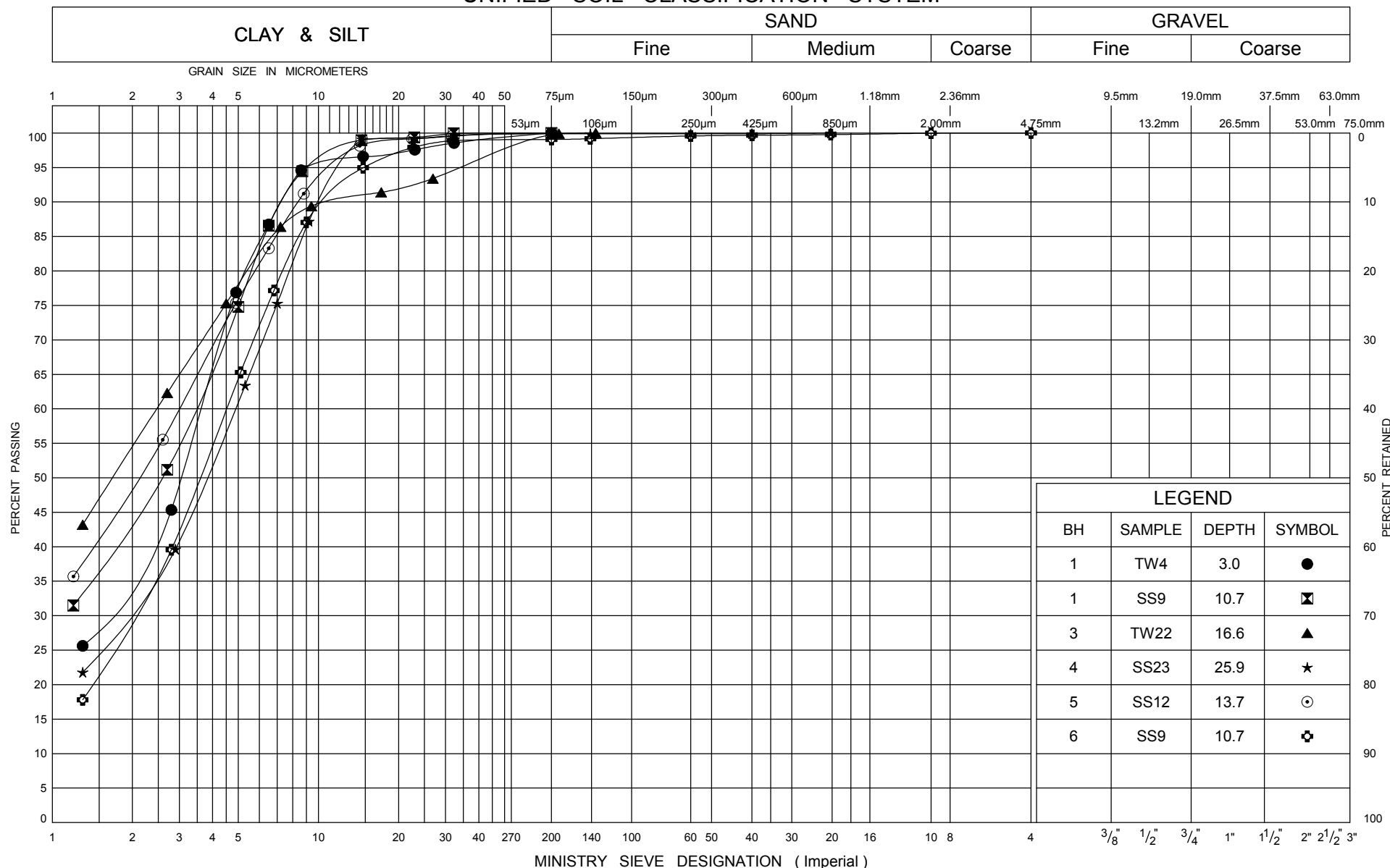
PLASTICITY CHART SILTY CLAY (VARVED)

FIG No B1-14

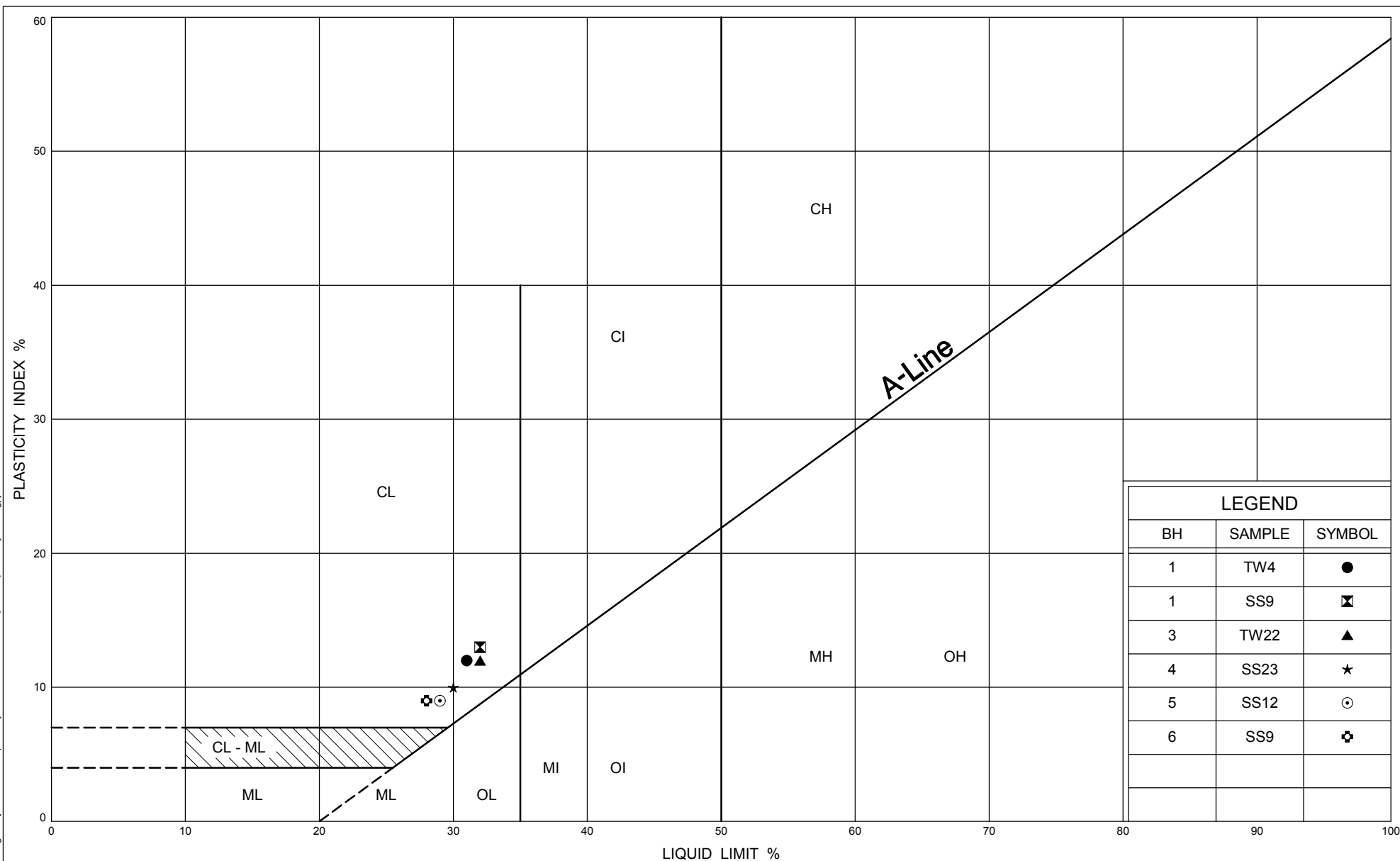
G W P 5159-12-00

Calamity Creek Culvert Site 47-273C

UNIFIED SOIL CLASSIFICATION SYSTEM



library: library - terraprobe.gint - md.glb report: mto-terra-plasticity-chart file: 11-14-4066 (47-273c) calamity creek.gpj



Ministry of
Transportation

PLASTICITY CHART SILTY CLAY (VARVED)

FIG No B1-16

G W P 5159-12-00

Calamity Creek Culvert Site 47-273C

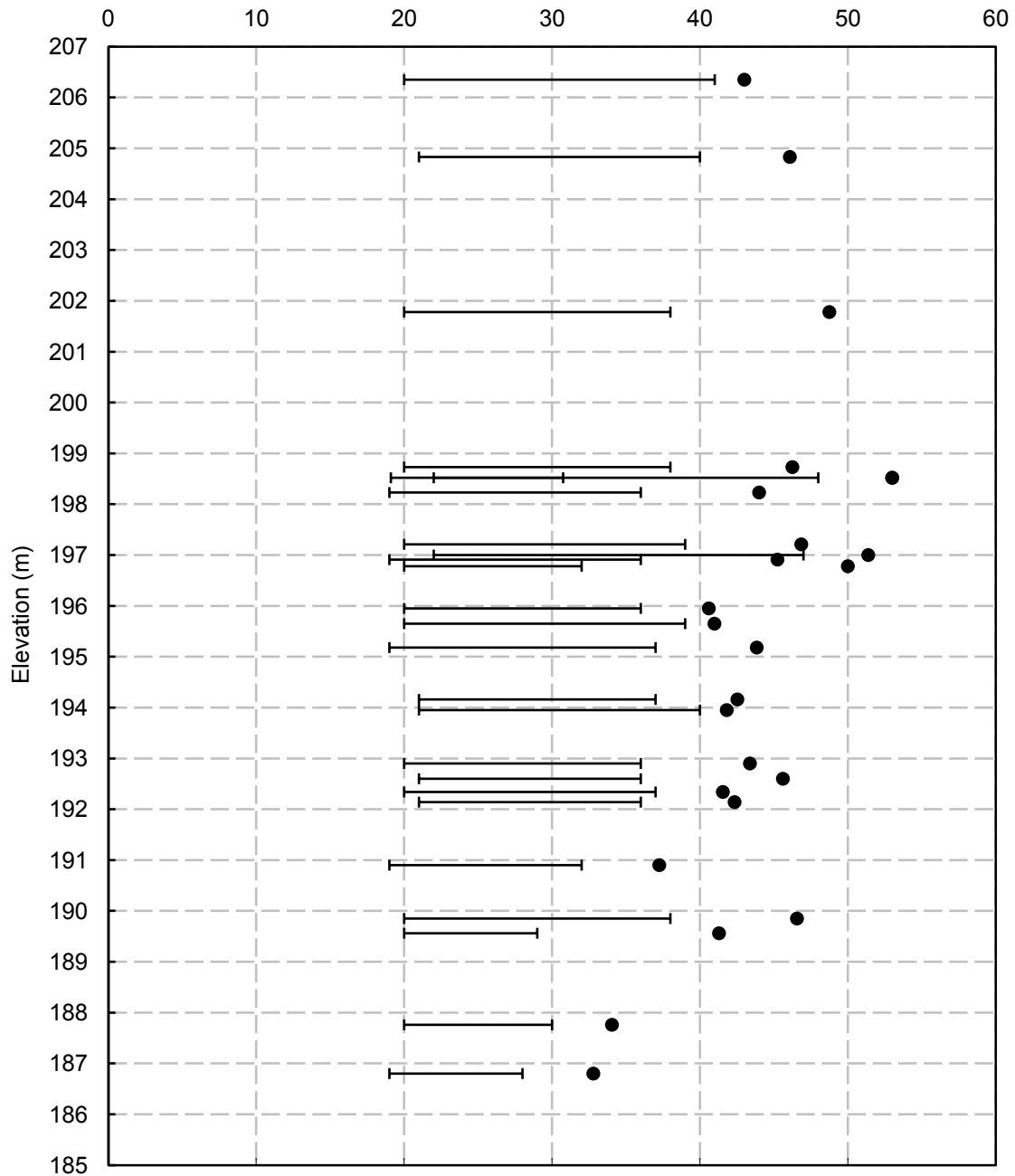
ATTERBERG LIMITS AND WATER CONTENTS

FIGURE B1-17

CALAMITY CREEK CULVERT Site 47-273C

Silty Clay (Varved)

Atterberg Limits & Water Contents (%)



Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likeard Area\1- Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\ed-P-Cc-Cr-Cu.xls

Project No. : 11-14-4066

Date : January, 2015




Prepared by : SD

Checked by : RA

CONSOLIDATION TEST SUMMARY

FIGURE B1-18

SAMPLE IDENTIFICATION							
Project Number	1414696 (2000)			Sample Number	TW22		
Borehole Number	3			Sample Depth, m	16.76-17.22		
TEST CONDITIONS							
Test Type	Laboratory Standard			Load Duration, hr	24		
Oedometer Number	9						
Date Started	10/01/2014						
Date Completed	10/16/2014						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.90			Unit Weight, kN/m ³	18.17		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m ³	13.23		
Area, cm ²	31.55			Specific Gravity, measured	2.72		
Volume, cm ³	60.04			Solids Height, cm	0.944		
Water Content, %	37.36			Volume of Solids, cm ³	29.77		
Wet Mass, g	111.22			Volume of Voids, cm ³	30.27		
Dry Mass, g	80.97			Degree of Saturation, %	99.9		
TEST COMPUTATIONS							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv, cm ² /s	mv m ² /kN	k cm/s
0.00	1.903	1.017	1.903				
6.51	1.896	1.010	1.900				
11.16	1.892	1.005	1.894	191	3.98E-03	5.20E-04	2.03E-07
21.00	1.888	1.001	1.890	427	1.77E-03	1.82E-04	3.16E-08
40.50	1.882	0.995	1.885	501	1.50E-03	1.64E-04	2.42E-08
79.35	1.870	0.981	1.876	360	2.07E-03	1.72E-04	3.49E-08
156.84	1.833	0.943	1.851	589	1.23E-03	2.47E-04	2.98E-08
311.96	1.767	0.873	1.800	667	1.03E-03	2.24E-04	2.26E-08
622.51	1.675	0.775	1.721	759	8.27E-04	1.56E-04	1.26E-08
1242.71	1.604	0.700	1.639	190	3.00E-03	6.02E-05	1.77E-08
2482.05	1.540	0.632	1.572	147	3.56E-03	2.72E-05	9.49E-09
1242.71	1.554	0.646	1.547				
311.96	1.585	0.680	1.569				
79.35	1.618	0.714	1.601				
21.00	1.650	0.749	1.634				
6.51	1.667	0.767	1.659				
Note: Consolidation loading and unloading schedule assigned by the client. k calculated using cv based on t ₉₀ values.							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.67			Unit Weight, kN/m ³	19.36		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m ³	15.10		
Area, cm ²	31.55			Specific Gravity, measured	2.72		
Volume, cm ³	52.60			Solids Height, cm	0.944		
Water Content, %	28.25			Volume of Solids, cm ³	29.77		
Wet Mass, g	103.84			Volume of Voids, cm ³	22.83		
Dry Mass, g	80.97						
Prepared By: RD				Golder Associates		Checked By: 	

Note: One dimensional consolidation test was performed by Golder Associates Ltd.

Project No. : 11-14-4066
Date : January 2015



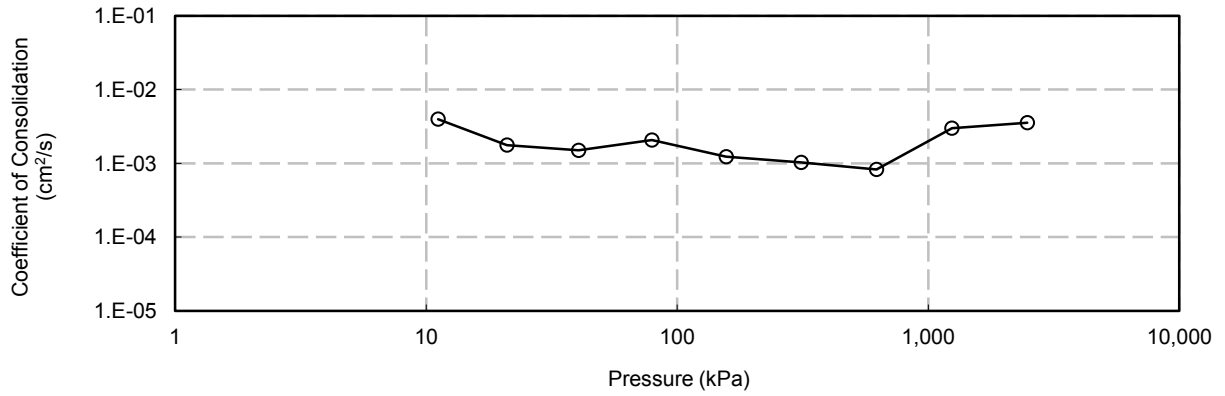
CONSOLIDATION TEST

FIGURE B1-19

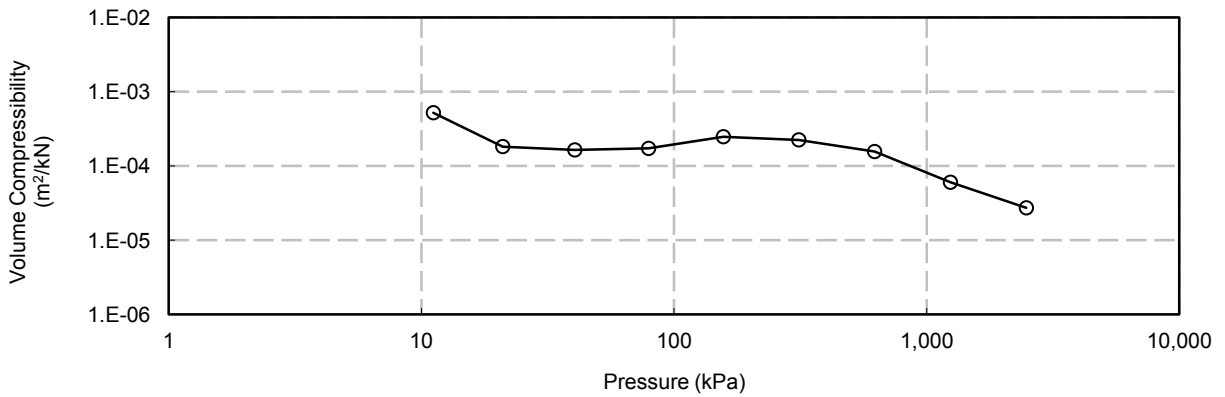
CALAMITY CREEK CULVERT Site 47-273C

BH 3, TW 22

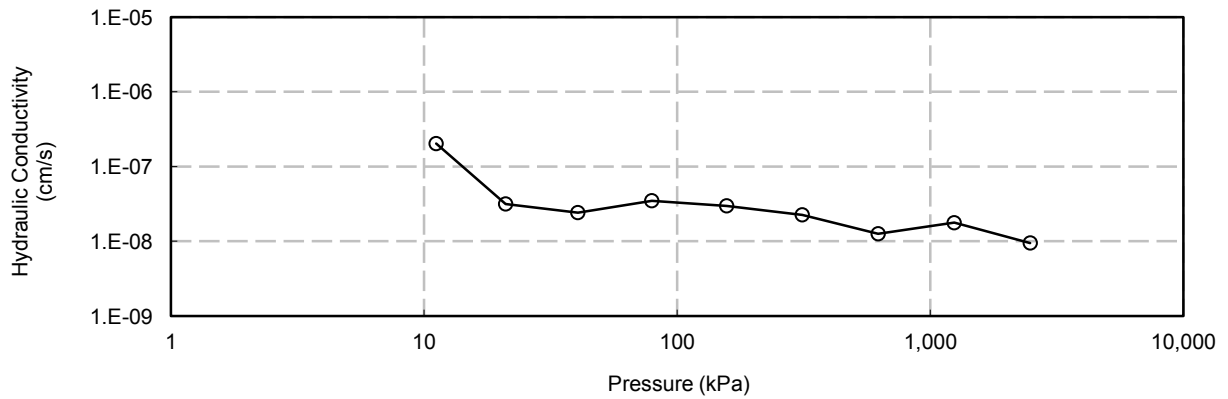
Cv vs Pressure



mv vs Pressure



k vs Pressure



Project No. : 11-14-4066
Date : January 2015



Prepared By : SD
Checked By : RA

Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likeard Area\1 - Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\Consolidation Results (Golder).xls

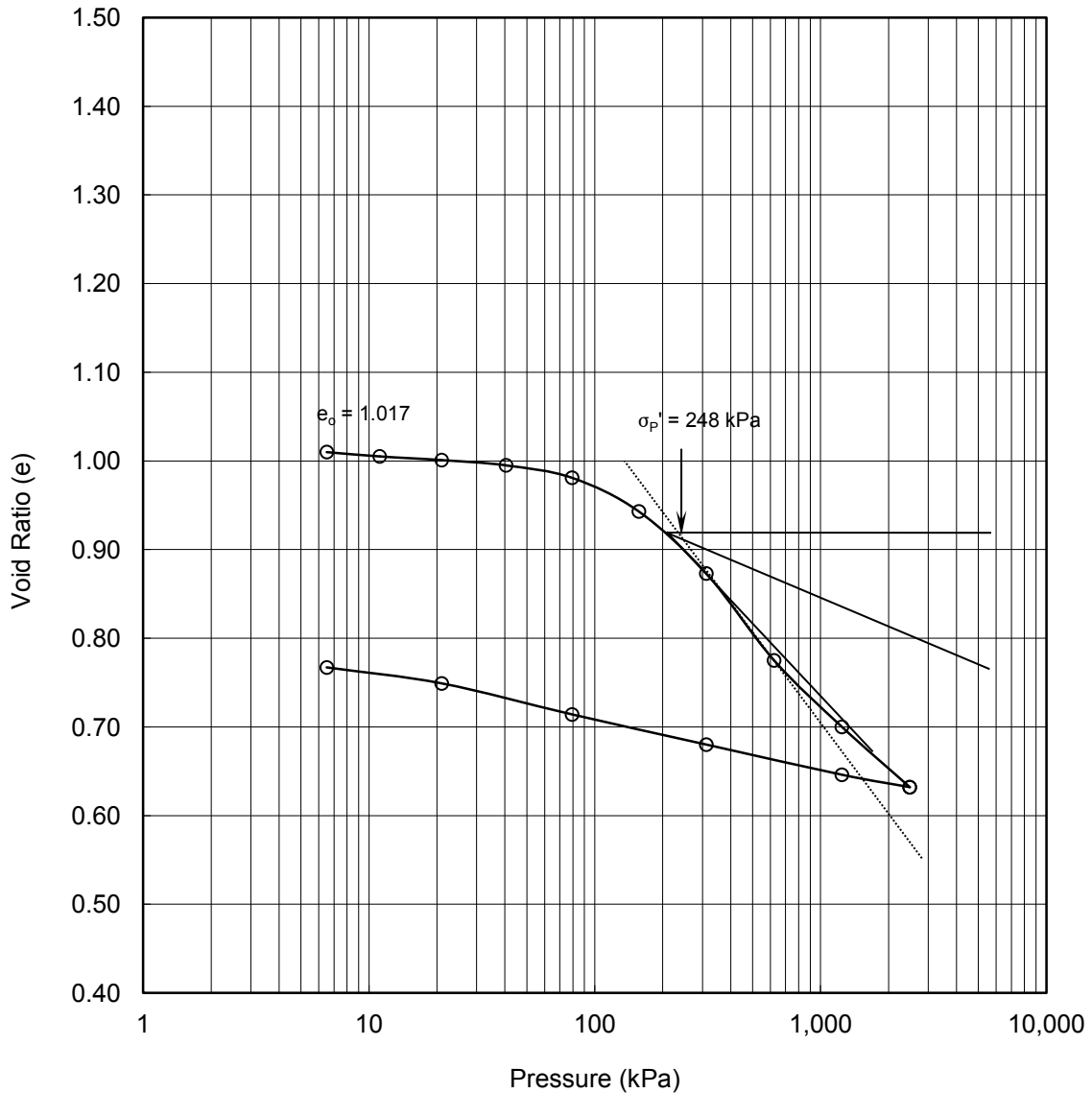
CONSOLIDATION TEST

FIGURE B1-20

CALAMITY CREEK CULVERT Site 47-273C

BH 3, TW 22

Void Ratio vs Pressure



Soil Type : SILTY CLAY to CLAY

$e_o =$	1.02	$\omega_L =$	32%	$\sigma_{v0}' =$	265.2 kPa
$\omega =$	50%	$\omega_P =$	20%	$\sigma_P' =$	248.0 kPa
$\gamma =$	18.2 kN/m ³	PI =	12%		
Gs =	2.72				

Project No. : 11-14-4066
Date : January 2015



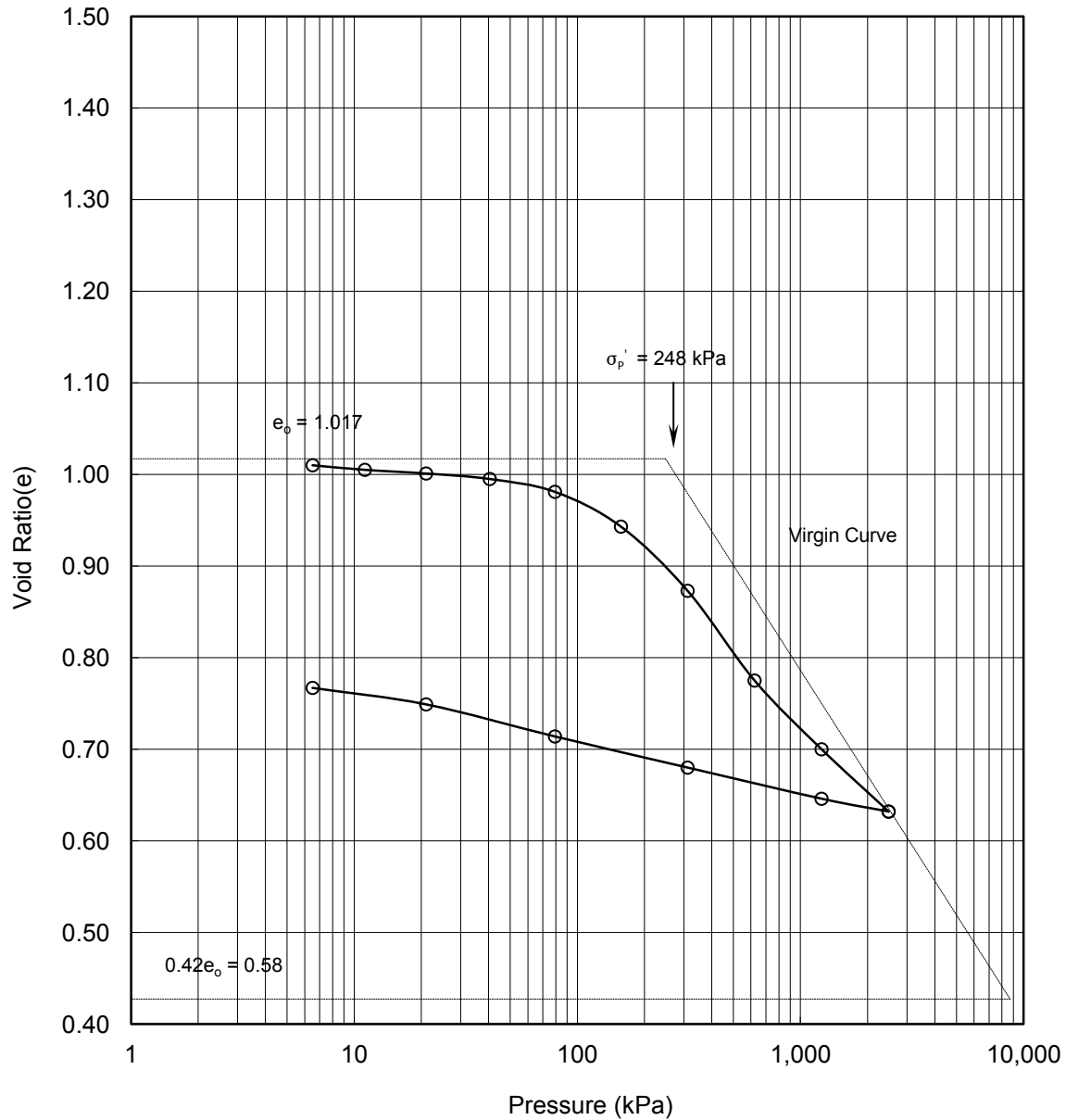
Prepared By : SD
Checked By : RA

CONSOLIDATION TEST

FIGURE B1-21

CALAMITY CREEK CULVERT Site 47-273C

BH 3, TW 22



Soil Type : SILTY CLAY to CLAY

$e_0 =$	1.02	$\omega_L =$	32%	$\sigma_{v0}' =$	265.2 kPa
$\omega =$	50%	$\omega_P =$	20%	$\sigma_P' =$	248.0 kPa
$\gamma =$	18.2 kN/m ³	PI =	12%	$C_c =$	0.382
Gs =	2.72			$C_r =$	0.053

Project No. : 11-14-4066
Date : January 2015



Prepared By : SD
Checked By : RA

CONSOLIDATION TEST SUMMARY**FIGURE B1-22****SAMPLE IDENTIFICATION**

Borehole No. : 1 Sample No. : TW4
Sample Depth (m) : 3.0 - 3.5

TEST CONDITIONS

Test Type : Laboratory Standard Date Started : 1-Oct-14
Load Duration (hr) : 24 Date Completed : 16-Oct-14

SAMPLE DIMENSIONS AND PROPERTIES _ INITIAL

Sample Height (mm) :	25.27	Unit Weight (kN/m ³) :	17.00
Sample Diameter (mm) :	63.35	Dry Unit Weight (kN/m ³) :	11.14
Area (cm ²) :	31.52	Specific Gravity :	2.70
Volume (cm ³) :	79.65	Solid Height (mm) :	10.64
Water Content (%) :	52.60	Volume of Solids (cm ³) :	33.56
Wet Mass (g) :	138.07	Volume of Voids (cm ³) :	46.10
Dry Mass (g) :	90.50	Degree of Saturation (%) :	103.20

TEST COMPUTATIONS

Stress (kPa)	Initial Height (mm)	Final Height (mm)	Void Ratio	t ₉₀ (min)	C _v (cm ² /s)	m _v (m ² /kN)	k (cm/s)
1.2	25.27	25.27	1.38				
18.4	25.27	25.18	1.37	5.063	4.43E-03	1.98E-04	8.60E-08
35.6	25.18	25.09	1.36	5.063	4.40E-03	2.22E-04	9.60E-08
69.9	25.09	24.95	1.35	3.063	7.19E-03	1.55E-04	1.10E-07
138.7	24.95	24.75	1.33	3.063	7.08E-03	1.21E-04	8.40E-08
276.1	24.75	24.18	1.27	4	5.19E-03	1.66E-04	8.40E-08
551.0	24.18	21.91	1.06	49	3.50E-04	3.42E-04	1.20E-08
1100.7	21.91	20.73	0.95	10.56	1.45E-03	9.80E-05	1.40E-08
2200.3	20.73	19.82	0.86	10.56	1.33E-03	4.00E-05	5.20E-09
276.1	19.82	20.05	0.97				
69.9	20.05	20.39	1.00				
18.4	20.39	20.79	1.04				

SAMPLE DIMENSIONS AND PROPERTIES _ FINAL

Sample Height (mm) :	20.79	Unit Weight (kN/m ³) :	18.11
Sample Diameter (mm) :	63.35	Dry Unit Weight (kN/m ³) :	13.61
Area (cm ²) :	31.52	Specific Gravity :	2.70
Volume (cm ³) :	65.52	Solid Height (mm) :	10.64
Water Content (%) :	33.10	Volume of Solids (cm ³) :	33.72
Wet Mass (g) :	120.99	Volume of Voids (cm ³) :	31.81
Dry Mass (g) :	90.93		

Project No. : 11-14-4066
Date : January 2015

**Terraprobe Inc.**

Prepared By : SD
Checked By : RA

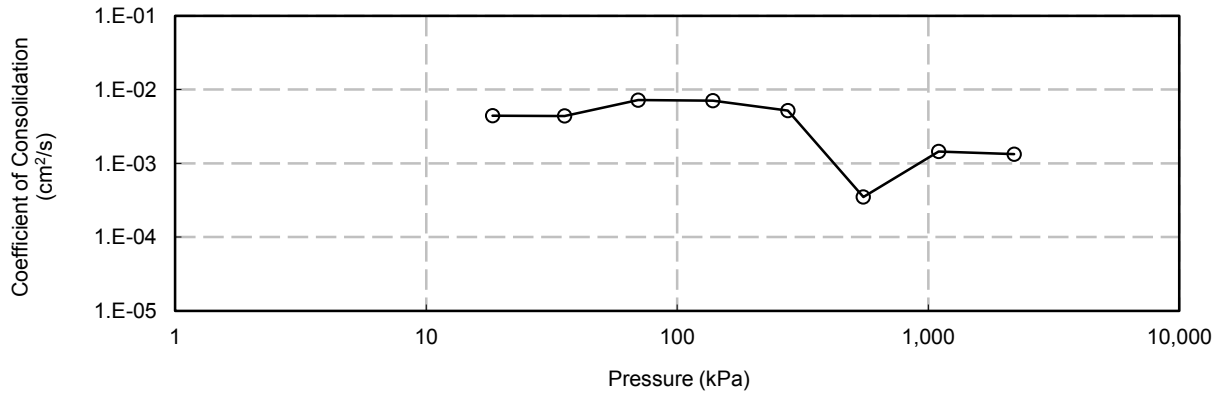
CONSOLIDATION TEST

FIGURE B1-23

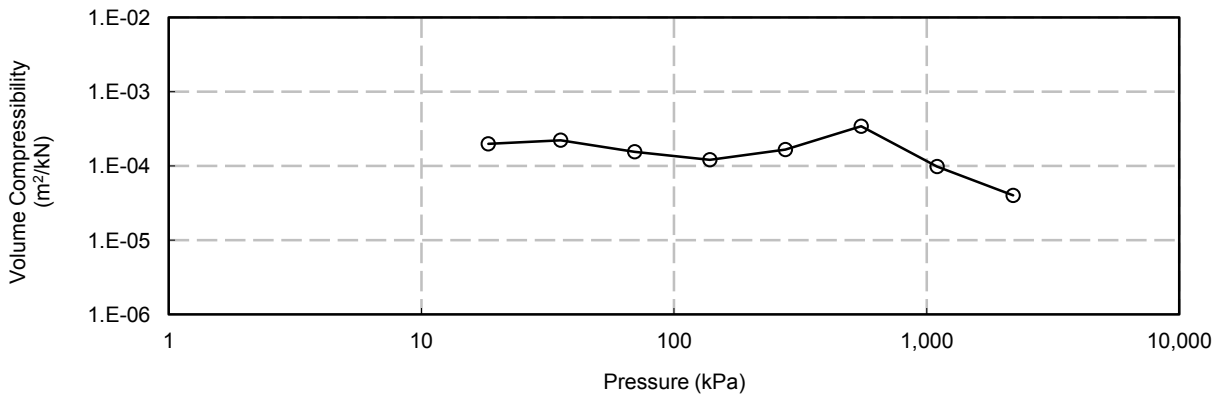
CALAMITY CREEK CULVERT Site 47-273C

BH 1, TW 4

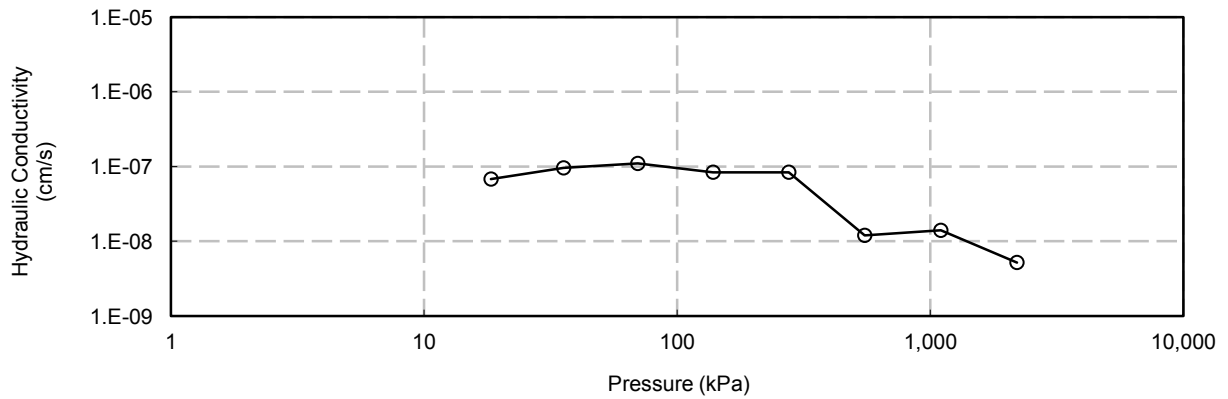
Cv vs Pressure



mv vs Pressure



k vs Pressure



Project No. : 11-14-4066
Date : January 2015



Terraprobe Inc.

Prepared By : SD
Checked By : RA

Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likeard Area\1 - Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\Consolidation Results (Terraprobe).xls

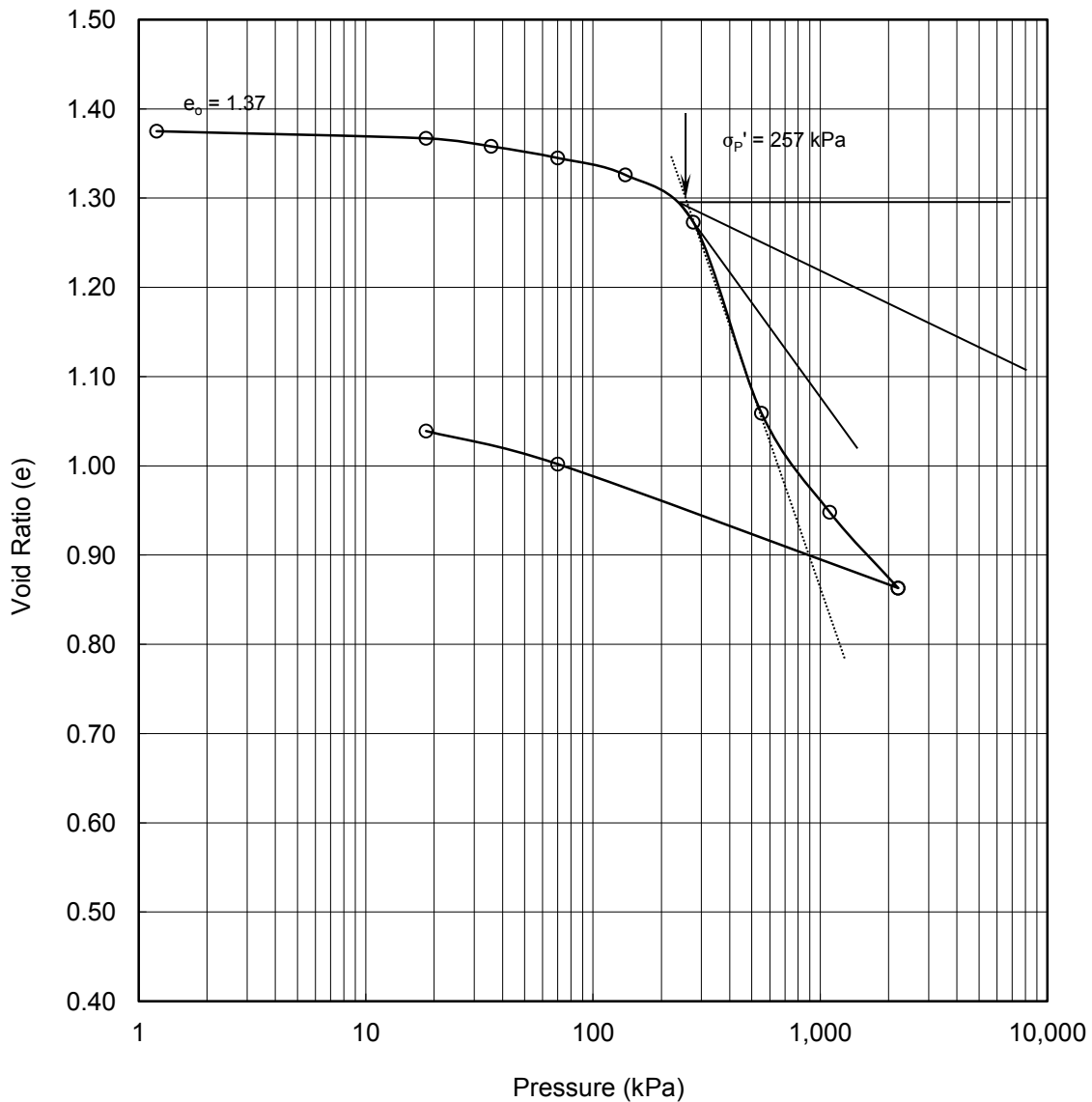
CONSOLIDATION TEST

FIGURE B1-24

CALAMITY CREEK CULVERT Site 47-273C

BH 1, TW 4

Void Ratio vs Pressure



Soil Type : SILTY CLAY to CLAY

$e_o =$	1.38	$\omega_L =$	31%	$\sigma_{v0}' =$	39.5 kPa
$\omega =$	53%	$\omega_P =$	19%	$\sigma_P' =$	257.0 kPa
$\gamma =$	17.0 kN/m ³	PI =	12%		
Gs =	2.70				

Project No. : 11-14-4066
Date : January 2015



Prepared By : SD
Checked By : RA

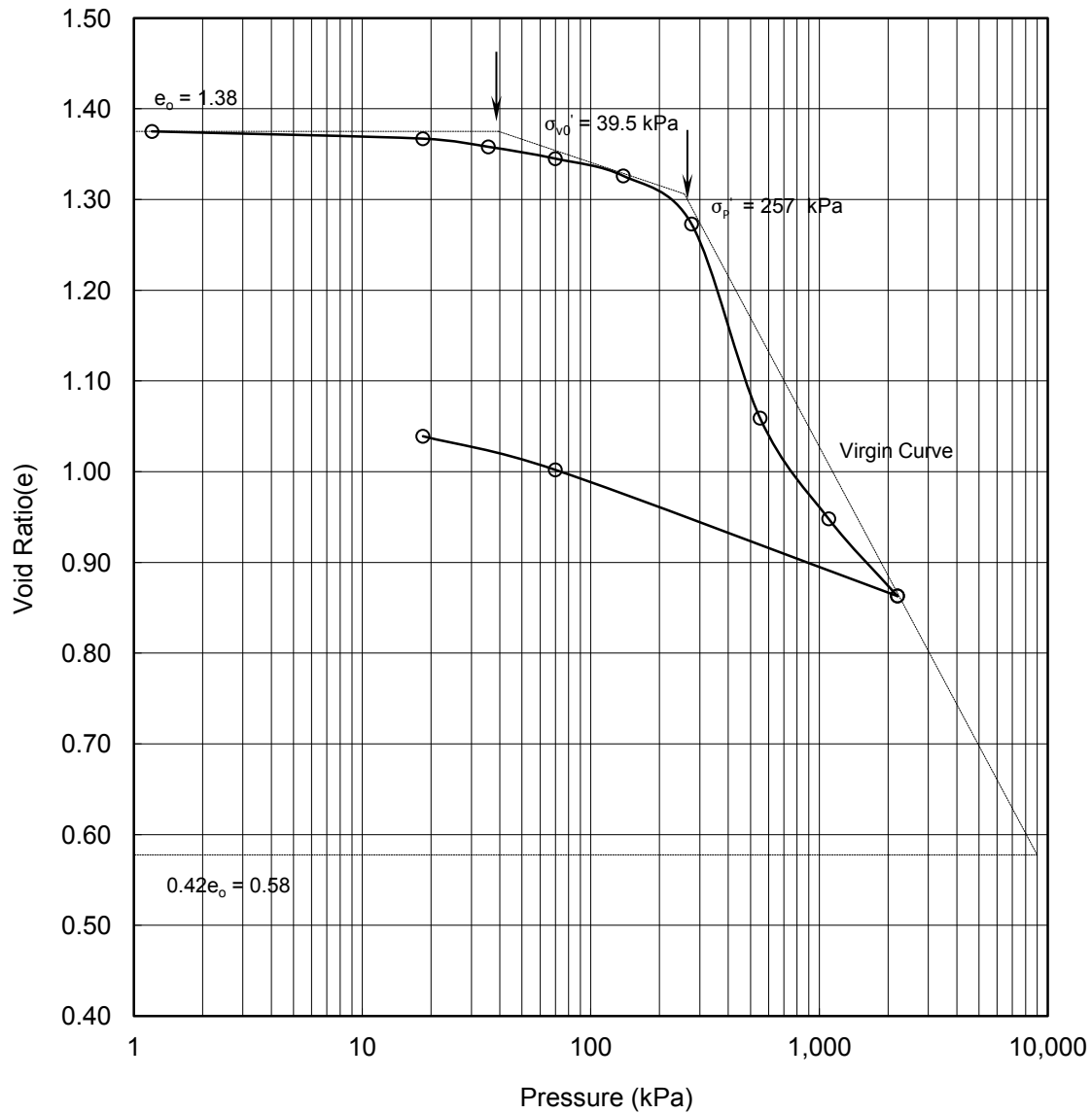
CONSOLIDATION TEST

FIGURE B1-25

CALAMITY CREEK CULVERT Site 47-273C

BH 1, TW 4

Void Ratio vs Pressure



Soil Type : SILTY CLAY to CLAY

$e_o =$	1.38	$\omega_L =$	31%	$\sigma'_{v0} =$	39.5 kPa
$\omega =$	53%	$\omega_P =$	19%	$\sigma'_p =$	257.0 kPa
$\gamma =$	17.0 kN/m ³	PI =	12%	$C_c =$	0.472
Gs =	2.70			$C_r =$	0.085

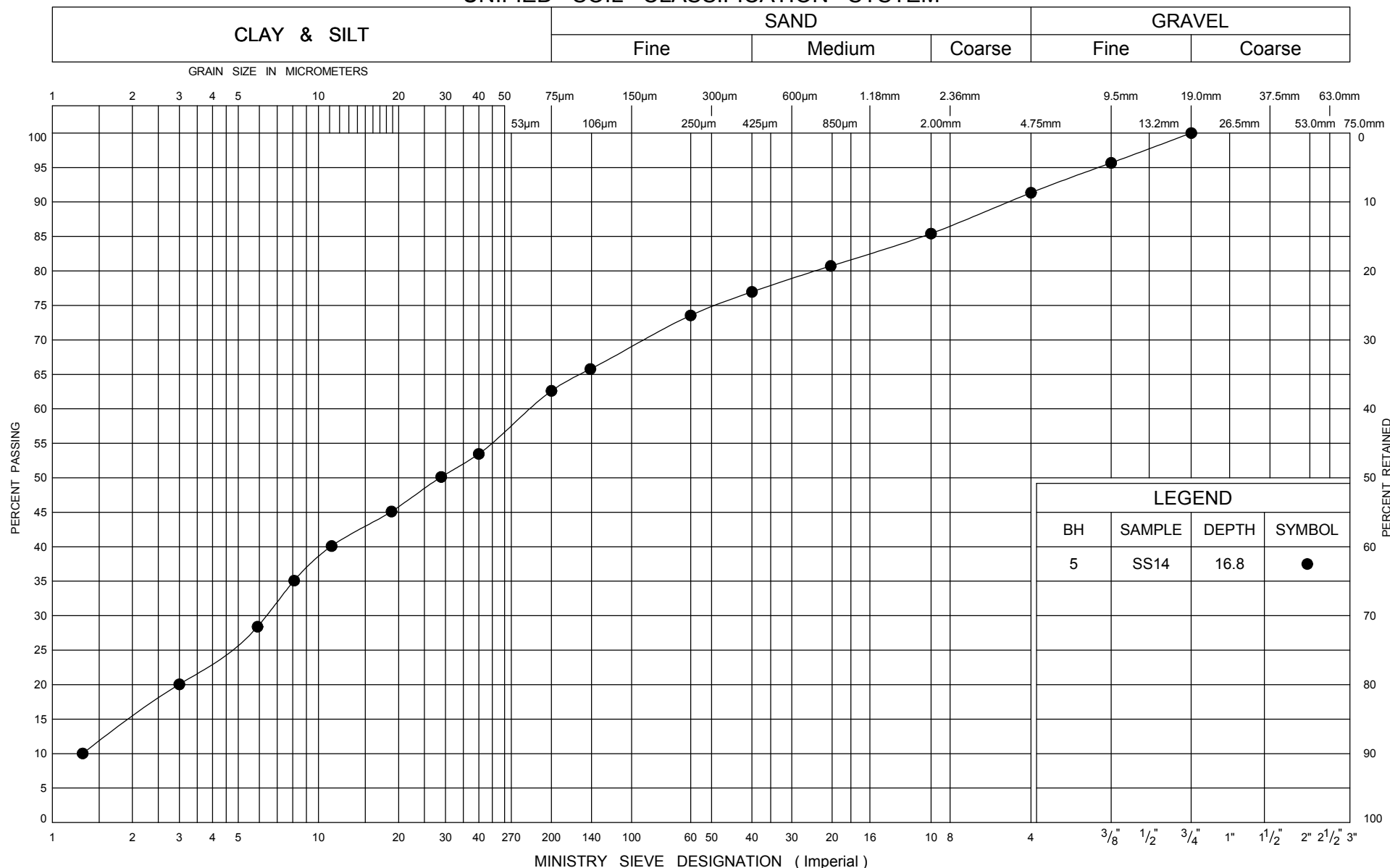
Project No. : 11-14-4066
Date : January 2015



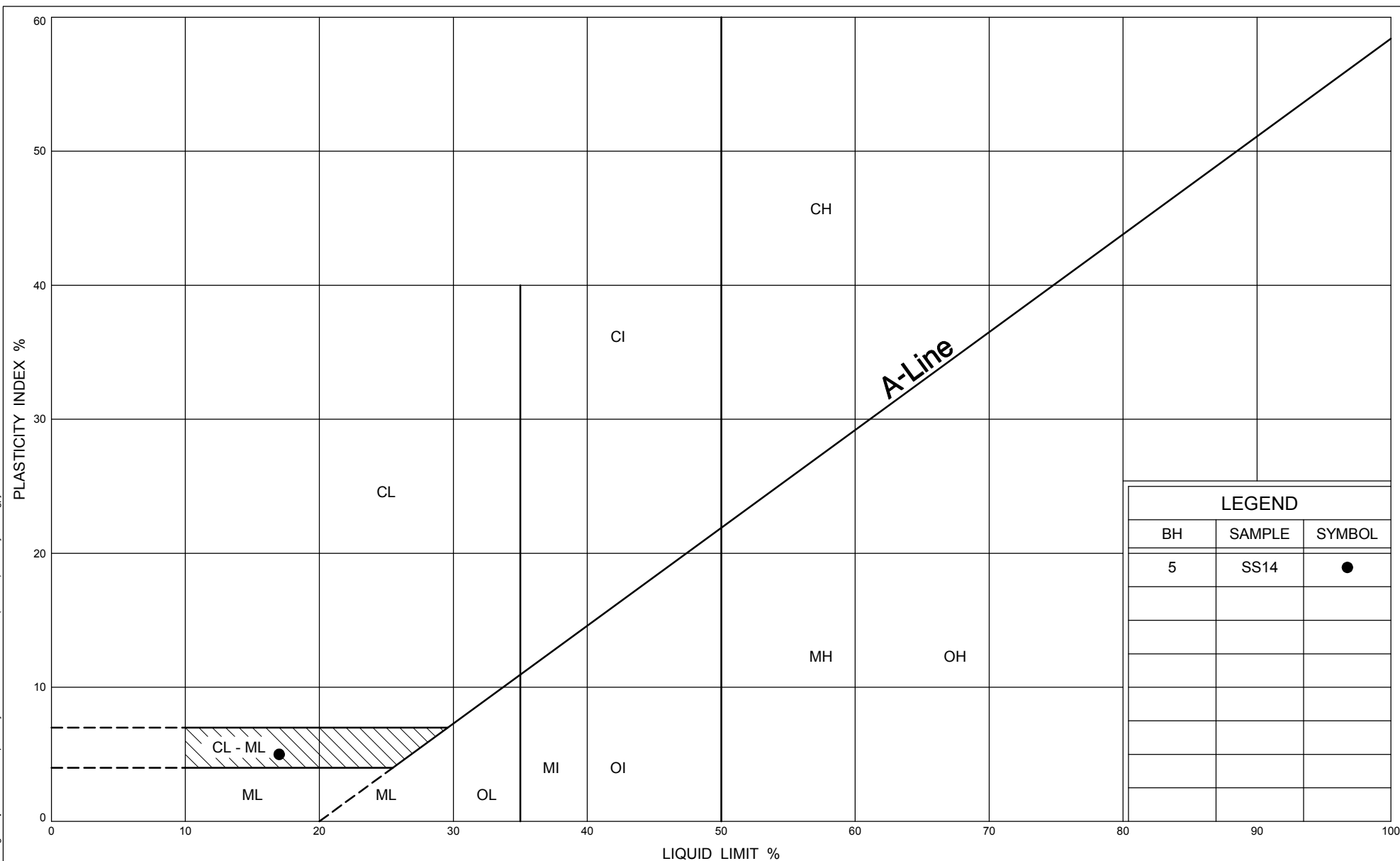
Prepared By : SD
Checked By : RA

Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likeard Area\11- Calamity Creek Culvert Hwy 11 (47-273C)\G_Eng Analysis\Spread Sheets\Consolidation Results (Terraprobe).xls

UNIFIED SOIL CLASSIFICATION SYSTEM



library: library - terraprobe.gint - md.glb report: mto-terra-plasticity-chart file: 11-14-4066 (47-273c) calamity creek.gpj



LEGEND		
BH	SAMPLE	SYMBOL
5	SS14	●

CALAMITY CREEK CULVERT- Site 47-273C



Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likard Area\1- Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\10-Pc-Cc-Cr-Cu.xls

Project No. : 11-14-4066
Date : January, 2015

 **Terraprobe Inc.**

Prepared by : SD
Checked by : RA

PHOTOGRAPHS OF BEDROCK CORE SAMPLES

FIGURE B1-29

CALAMITY CREEK CULVERT- Site 47-273C



Z:\1-Project Files\11-Geo\2014\11-14-4066 New Liked Area\1- Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\10-Pc-Cc-Cr-Cu.xls

Project No. : 11-14-4066
Date : January, 2015



Terraprobe Inc.

Prepared by : SD
Checked by : RA

PHOTOGRAPHS OF BEDROCK CORE SAMPLES

FIGURE B1-30

CALAMITY CREEK CULVERT- Site 47-273C



Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likard Area\1- Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\10-Pc-Cc-Cr-Cu.xls

Project No. : 11-14-4066
Date : January, 2015



Terraprobe Inc.

Prepared by : SD
Checked by : RA

PHOTOGRAPHS OF BEDROCK CORE SAMPLES

FIGURE B1-31

CALAMITY CREEK CULVERT- Site 47-273C



Project No. : 11-14-4066

Date : January, 2015



Terraprobe Inc.

Prepared by : SD

Checked by : RA

PHOTOGRAPHS OF BEDROCK CORE SAMPLES

FIGURE B1-32

CALAMITY CREEK CULVERT- Site 47-273C



Z:\1-Project Files\11-Geo\2014\11-14-4066 New Likard Area\1- Calamity Creek Culvert Hwy 11 (47-273C)\G. Eng Analysis\Spread Sheets\0-Pc-Cc-Cr-Cu.xls

Project No. : 11-14-4066
Date : January, 2015



Prepared by : SD
Checked by : RA

APPENDIX B2

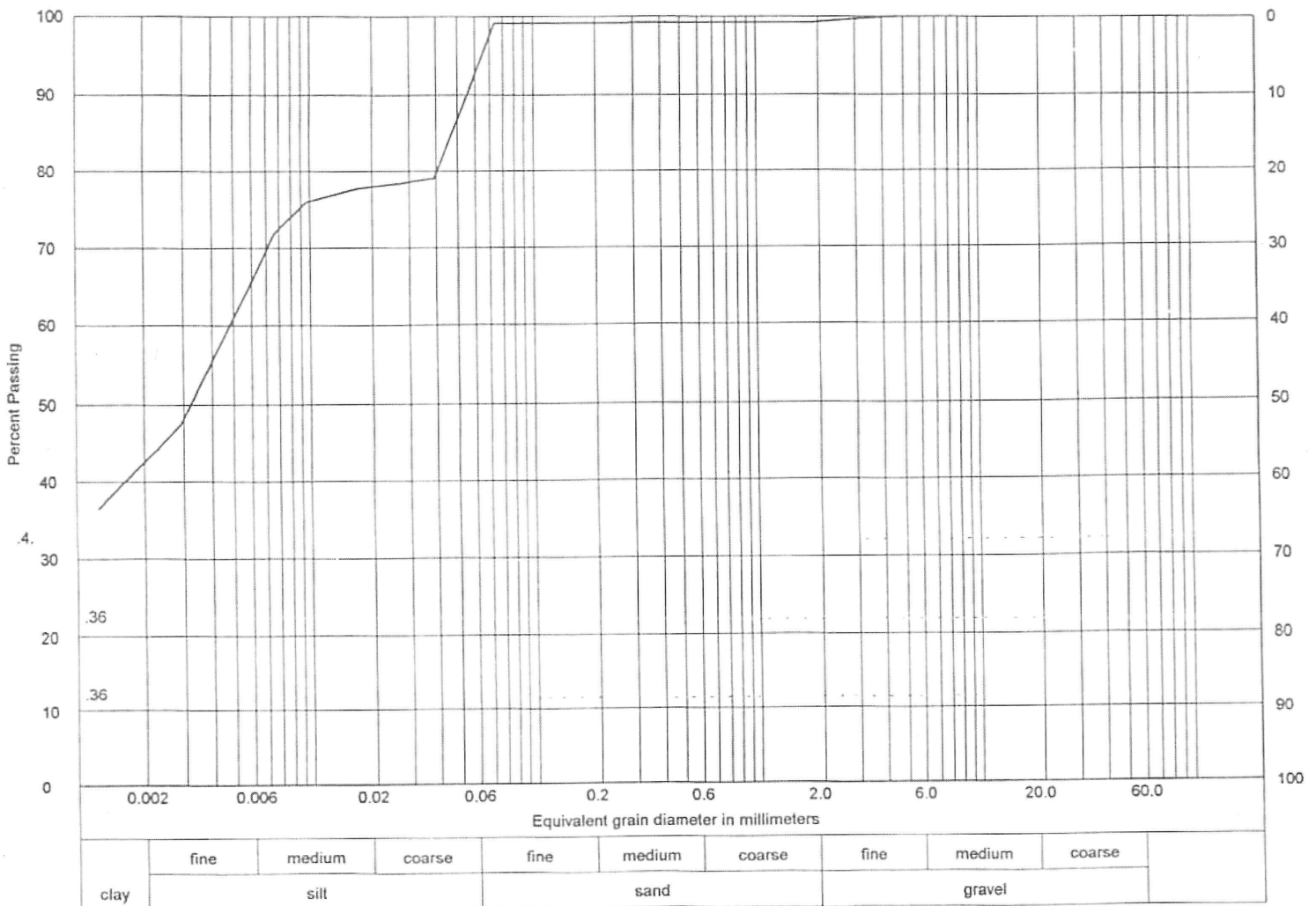
S&P

Laboratory Test Results



SAMPLE NUMBER: 2946/3
 PROJECT NUMBER: SP3012
 PROJECT: New Liskard
 CONTRACT:
 CLIENT: Ministry of Transportation
 CONTRACTOR:
 PROJECT MANAGER:
 PROJECT SITE:
 SAMPLED BY: T. Bhatti
 DATE SAMPLED: 9/30/99
 SUPPLIER:
 SAMPLE LOCATION: DB# 2 SB-5 (10.67-11.13m)
 DESCRIPTION: Clay and silt, trace sand
 PROPOSED USE:
 DATE TESTED: 11/21/99
 SPECIFICATION: Hydrometer

SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	99.5	
2.00 mm	99.2	
1.18 mm	99.2	
600 mic	99.2	
300 mic	99.2	
150 mic	99.1	
75 mic	99.1	



COMMENTS

SAMPLE NUMBER: 2946/4

PROJECT NUMBER: SP3012

PROJECT: New Liskard

CONTRACT:

CLIENT: Ministry of Transportation

CONTRACTOR:

PROJECT MANAGER:

PROJECT SITE:

SAMPLED BY: T. Bhatti

DATE SAMPLED: 9/30/99

SUPPLIER:

SAMPLE LOCATION: DB# 2 SB-9 (24.4-24.76m)

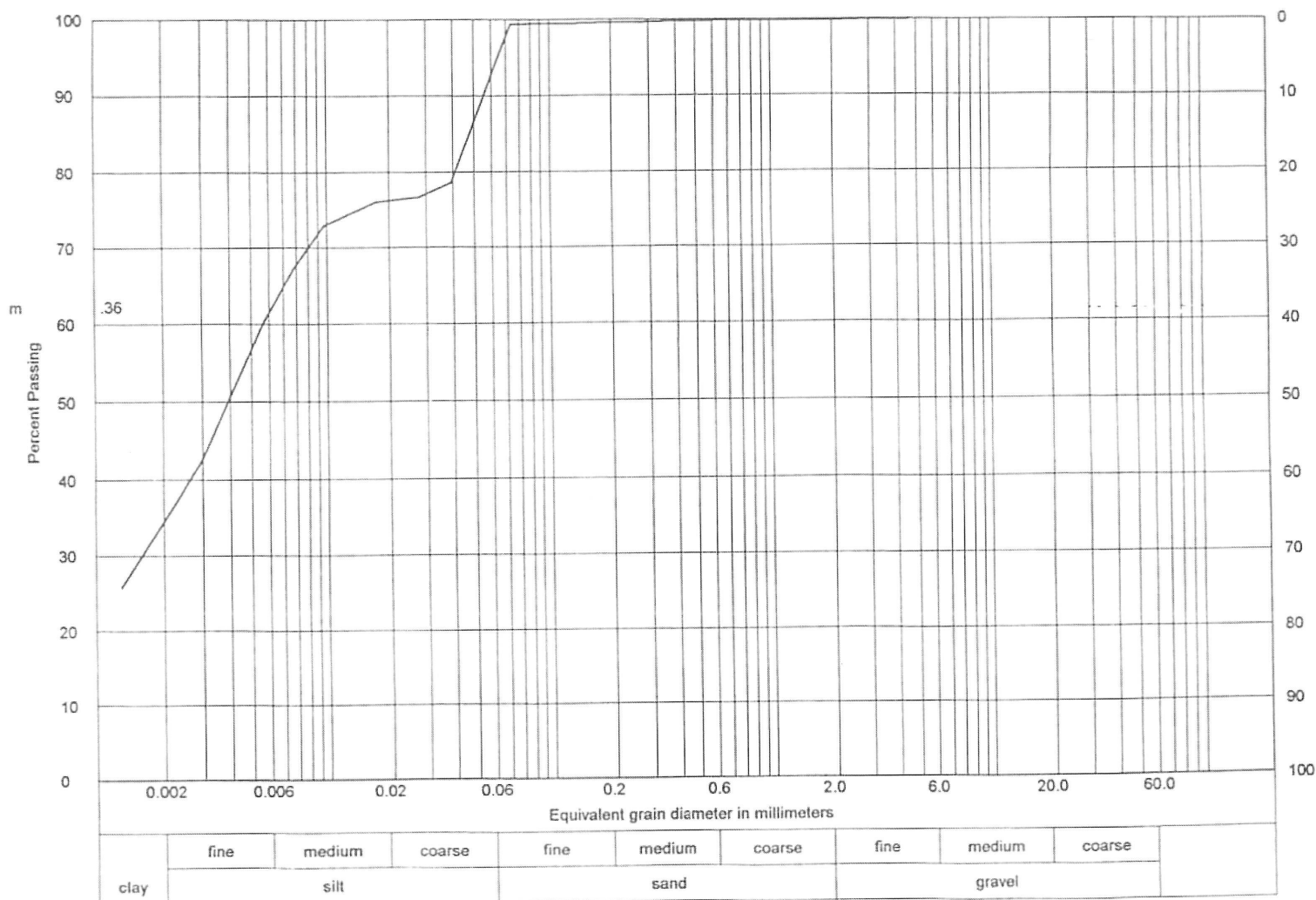
DESCRIPTION: Clay and silt, trace sand

PROPOSED USE:

DATE TESTED: 11/21/99

SPECIFICATION: Hydrometer

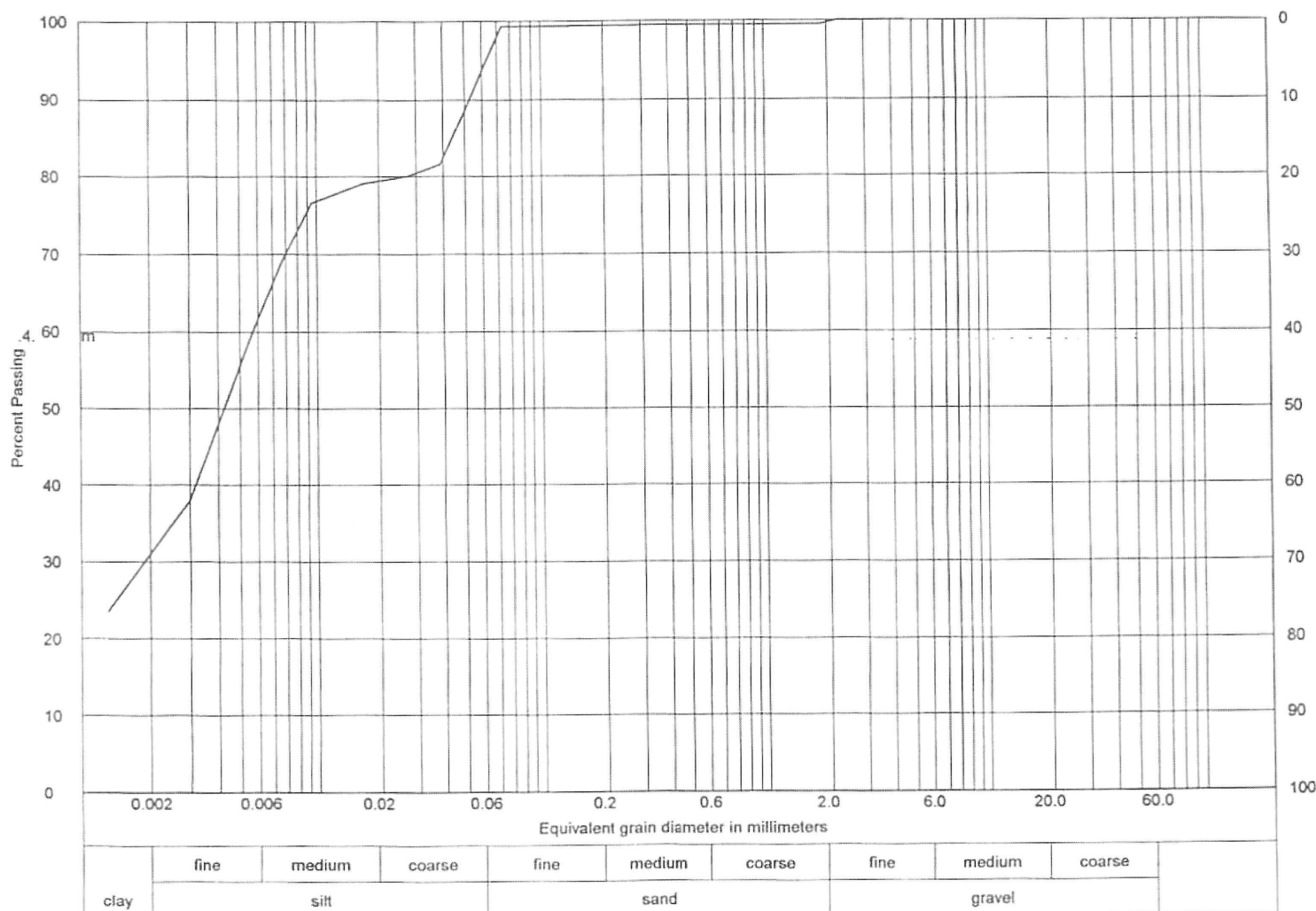
SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	99.9	
2.00 mm	99.8	
1.18 mm	99.8	
600 mic	99.8	
300 mic	99.6	
150 mic	99.5	
75 mic	99.3	



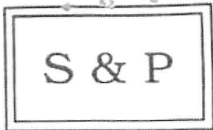
COMMENTS

SAMPLE NUMBER: 2946/5
 PROJECT NUMBER: SP3012
 PROJECT: New Liskard
 CONTRACT:
 CLIENT: Ministry of Transportation
 CONTRACTOR:
 PROJECT MANAGER:
 PROJECT SITE:
 SAMPLED BY: T. Bhatti
 DATE SAMPLED: 9/30/99
 SUPPLIER:
 SAMPLE LOCATION: DB# 3 SB-4 (16.77-17.23m)
 DESCRIPTION: Clay and silt, trace sand
 PROPOSED USE:
 DATE TESTED: 11/21/99
 SPECIFICATION: Hydrometer

SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	100.0	
2.00 mm	99.5	
1.18 mm	99.5	
600 mic	99.5	
300 mic	99.4	
150 mic	99.4	
75 mic	99.3	



COMMENTS

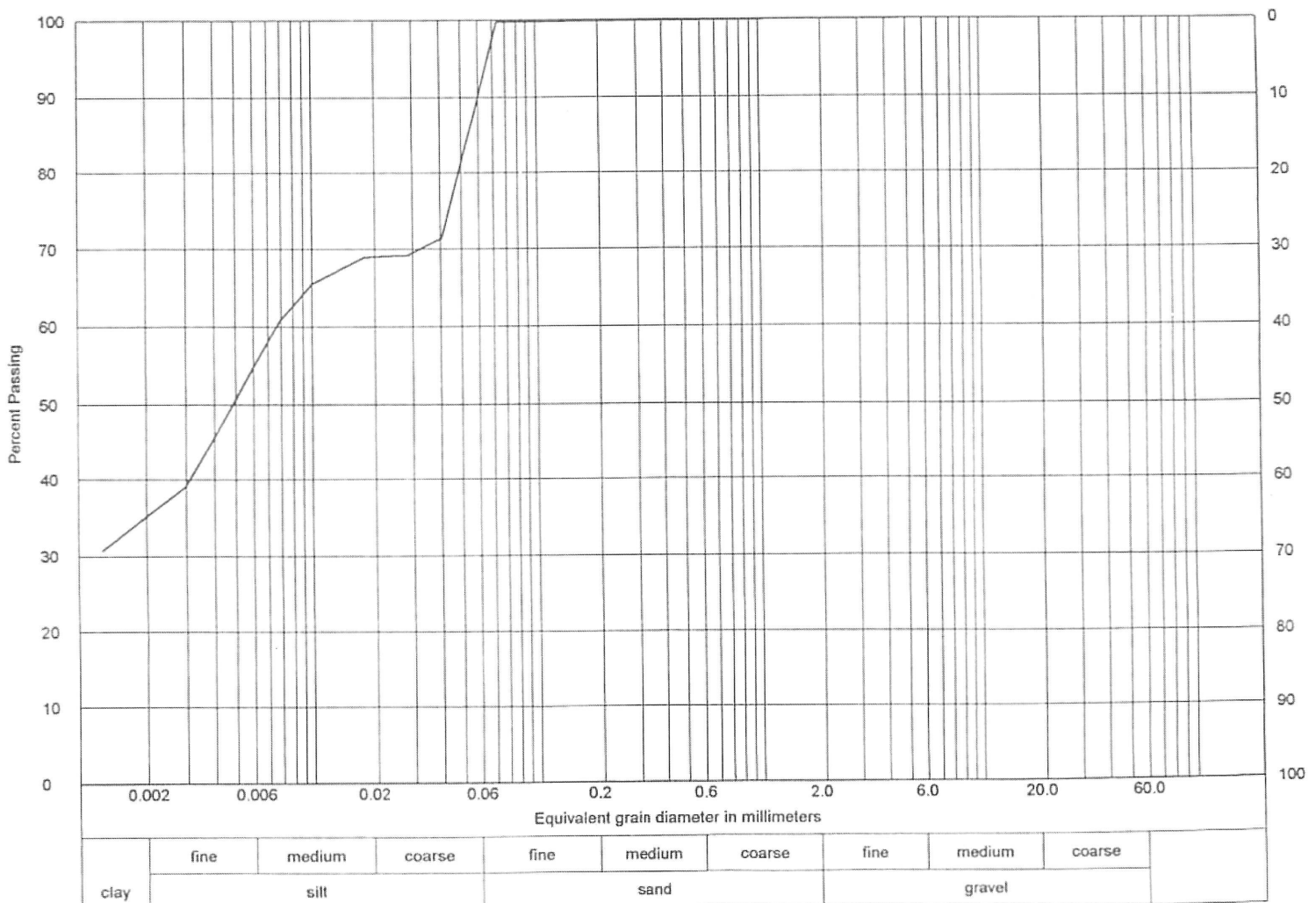


Shaheen & Peaker Limited
CONSULTING GEO-ENVIRONMENTAL ENGINEERS

Grain Size Analysis

SAMPLE NUMBER: 2946/6
PROJECT NUMBER: SP3012
PROJECT: New Liskard
CONTRACT:
CLIENT: Ministry of Transportation
CONTRACTOR:
PROJECT MANAGER:
PROJECT SITE:
SAMPLED BY: T. Bhatti
DATE SAMPLED: 9/30/99
SUPPLIER:
SAMPLE LOCATION: DB# 3 SB-6 (23.18-23.64m)
DESCRIPTION: Clay and silt, trace sand
PROPOSED USE:
DATE TESTED: 11/21/99
SPECIFICATION: Hydrometer

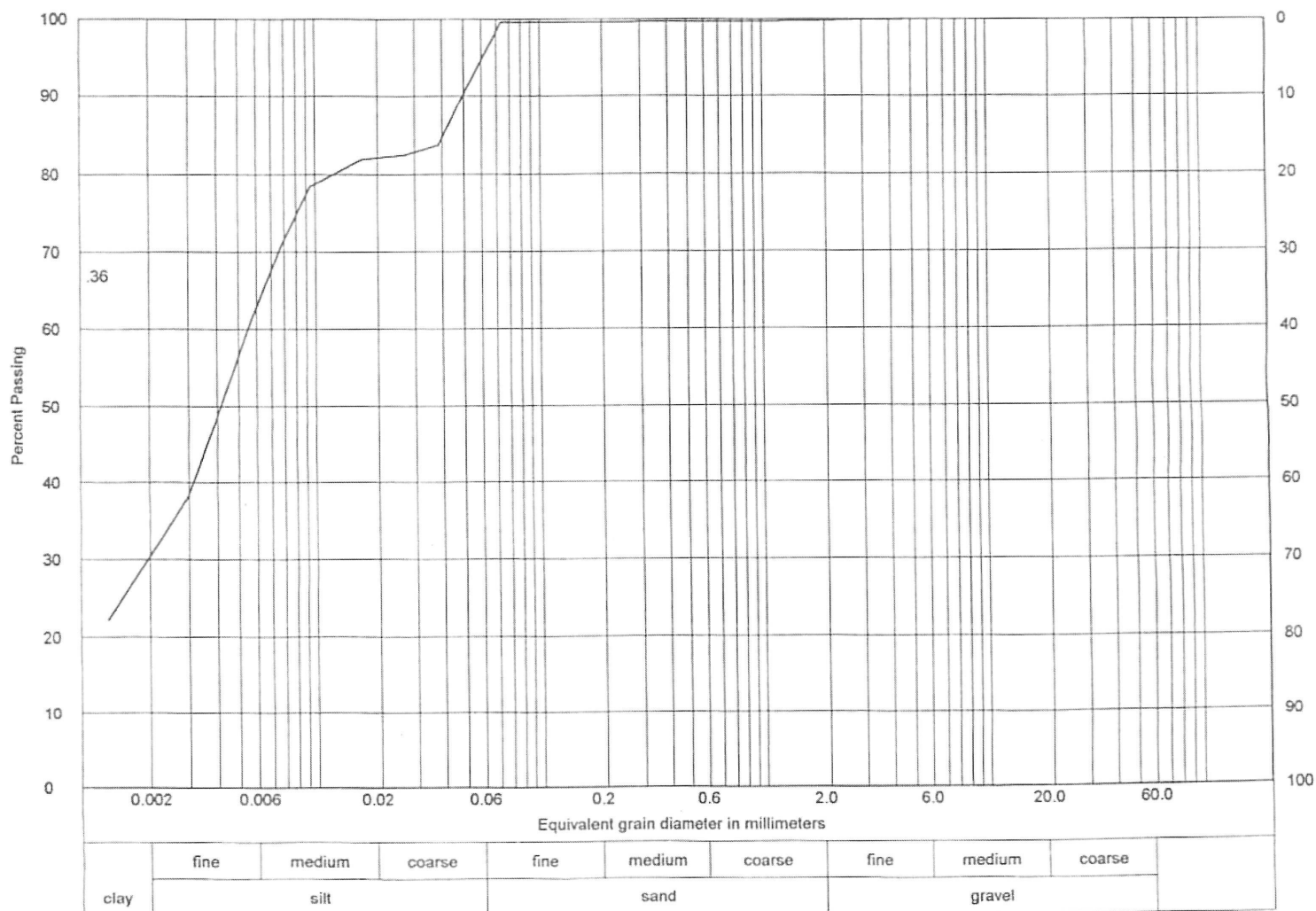
SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	100.0	
2.00 mm	100.0	
1.18 mm	99.9	
600 mic	99.9	
300 mic	99.8	
150 mic	99.8	
75 mic	99.7	



COMMENTS

SAMPLE NUMBER: 2946/7
 PROJECT NUMBER: SP3012
 PROJECT: New Liskard
 CONTRACT:
 CLIENT: Ministry of Transportation
 CONTRACTOR:
 PROJECT MANAGER:
 PROJECT SITE:
 SAMPLED BY: T. Bhatti
 DATE SAMPLED: 8/31/99
 SUPPLIER:
 SAMPLE LOCATION: DB# 4 SB-4 (20.58-21.04m)
 DESCRIPTION: Clayey silt, trace sand
 PROPOSED USE:
 DATE TESTED: 11/21/99
 SPECIFICATION: Hydrometer

SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	99.8	
2.00 mm	99.8	
1.18 mm	99.7	
600 mic	99.7	
300 mic	99.6	
150 mic	99.6	
75 mic	99.6	



COMMENTS

SAMPLE NUMBER: 2946/8

PROJECT NUMBER: SP3012

PROJECT: New Liskard

CONTRACT:

CLIENT: Ministry of Transportation

CONTRACTOR:

PROJECT MANAGER:

PROJECT SITE:

SAMPLED BY: T. Bhatti

DATE SAMPLED: 8/31/99

SUPPLIER:

SAMPLE LOCATION: DB# 5 SB-3 (13.72-14.18m)

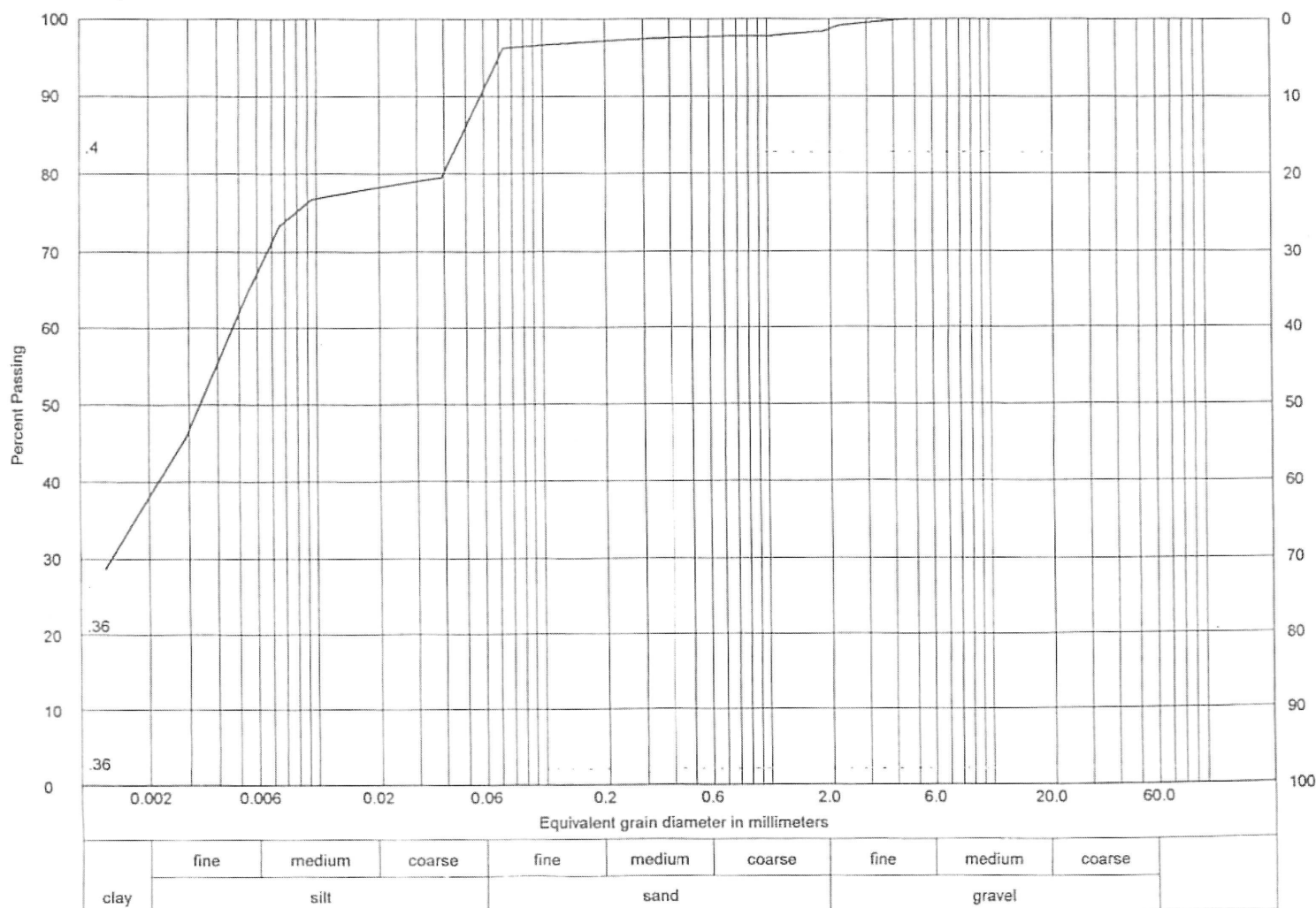
DESCRIPTION: Clay and sil, trace sand

PROPOSED USE:

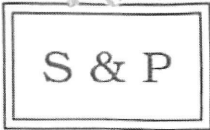
DATE TESTED: 11/21/99

SPECIFICATION: Hydrometer

SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	99.2	
2.00 mm	98.4	
1.18 mm	97.8	
600 mic	97.7	
300 mic	97.4	
150 mic	96.9	
75 mic	96.2	



COMMENTS

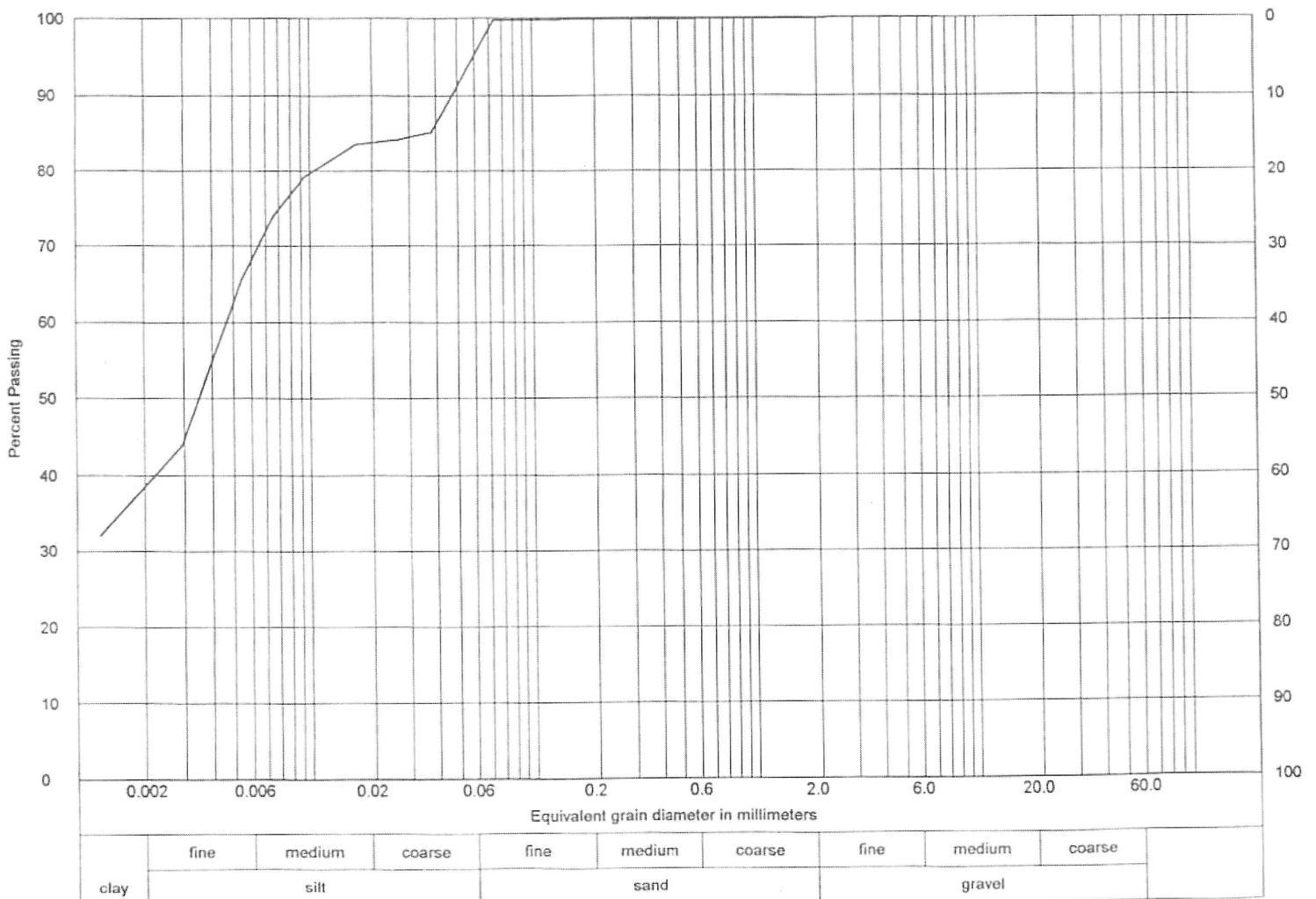


Shaheen & Peaker Limited
CONSULTING GEO-ENVIRONMENTAL ENGINEERS

Grain Size Analysis

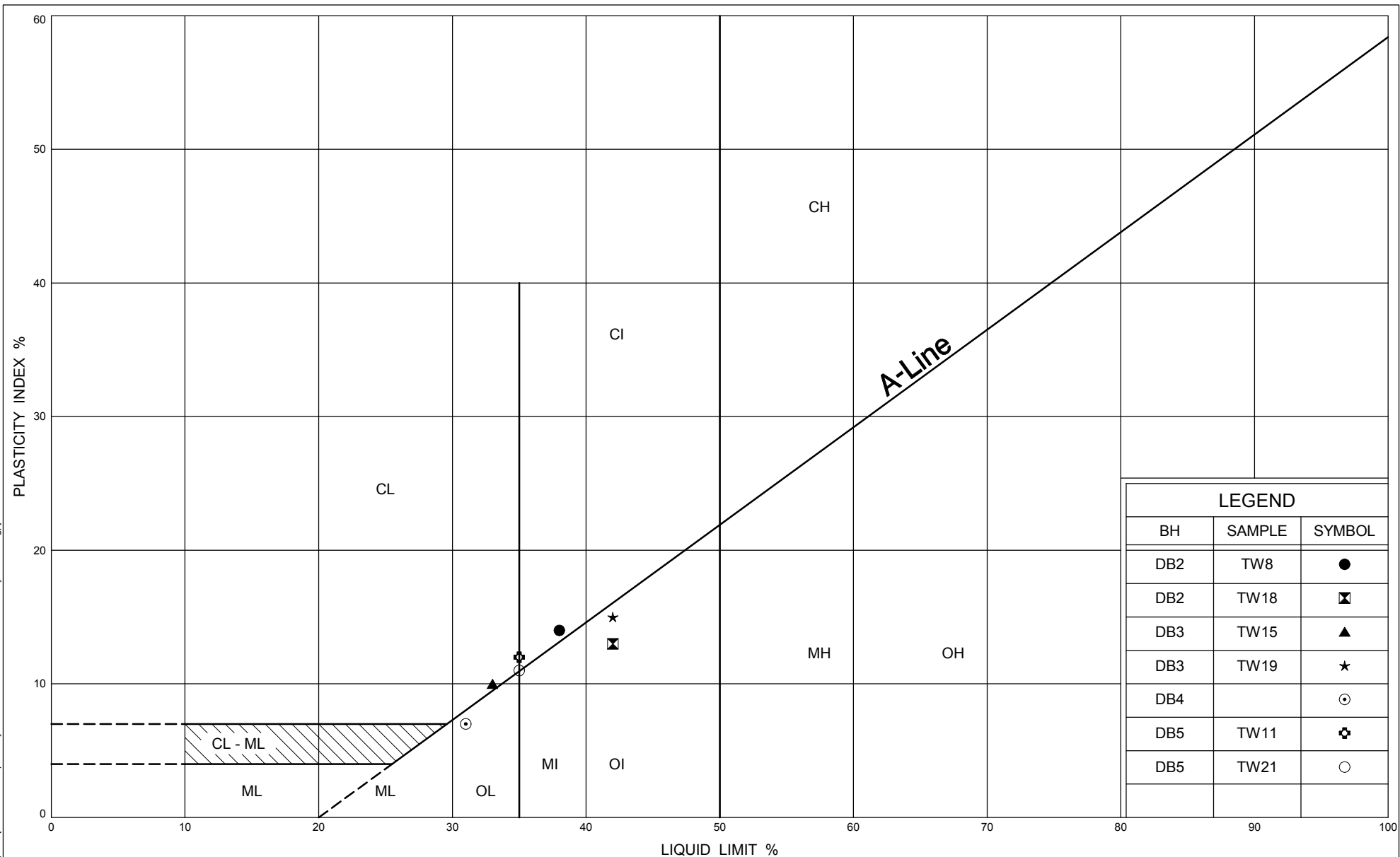
SAMPLE NUMBER: 2946/9
PROJECT NUMBER: SP3012
PROJECT: New Liskard
CONTRACT:
CLIENT: Ministry of Transportation
CONTRACTOR:
PROJECT MANAGER:
PROJECT SITE:
SAMPLED BY: T. Bhatti
DATE SAMPLED: 8/31/99
SUPPLIER:
SAMPLE LOCATION: DB# 5 SB-9 (24.4-24.85m)
DESCRIPTION: Clay and silt, trace sand
PROPOSED USE:
DATE TESTED: 11/21/99
SPECIFICATION: Hydrometer

SIEVE SIZE	PERCENT PASSING	SPECIFICATION
19.0 mm	100.0	
16.0 mm	100.0	
13.2 mm	100.0	
9.5 mm	100.0	
4.75 mm	100.0	
2.36 mm	100.0	
2.00 mm	99.8	
1.18 mm	99.8	
600 mic	99.8	
300 mic	99.8	
150 mic	99.8	
75 mic	99.7	



COMMENTS

library: library - terraprobe.gint.glb report: mto-terra-plasticity-chart file: 11-14-4066 --no use only for db bh.gpj



Ministry of
Transportation

PLASTICITY CHART

FIG No B2-1

W P 147-98-00

Calamity Creek Culvert

APPENDIX C

Soil Design Parameters

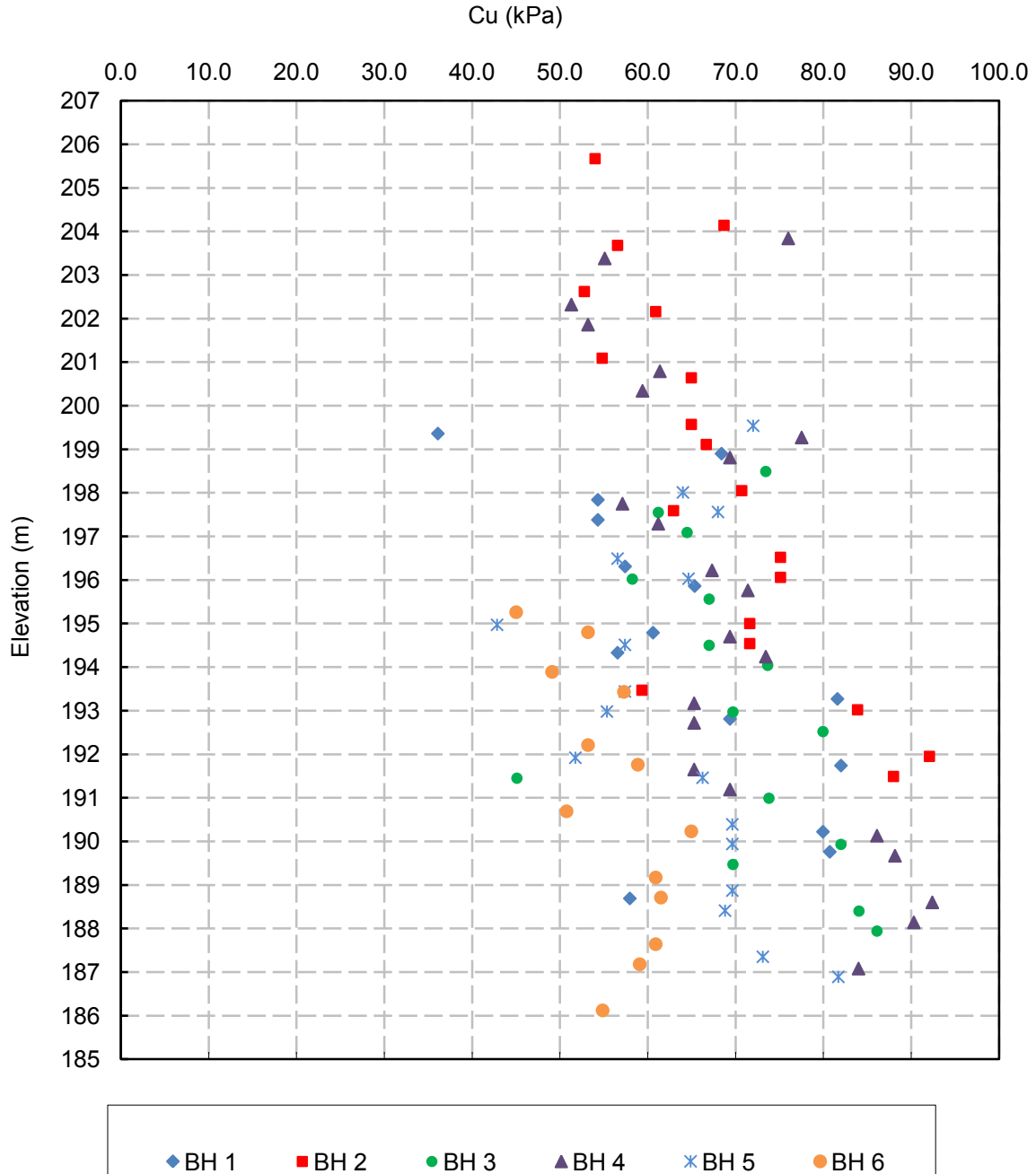


UNDRAINED SHEAR STRENGTH

FIGURE C1

CALAMITY CREEK CULVERT(Site 47-273C)

Silty Clay to Clay



Field vane shear strengthes were corrected based on Bjerrum (1972)

Project No. : 11-14-4066

Date : January, 2015



Terraprobe Inc.

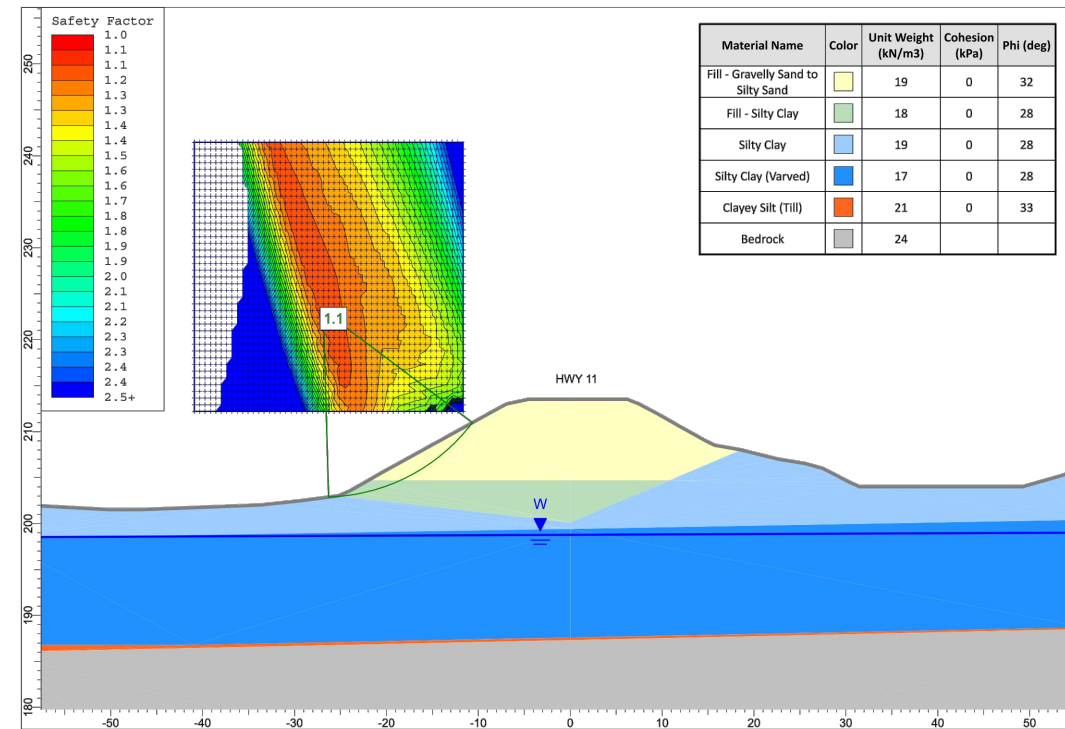
Prepared by : SD

Checked by : RA

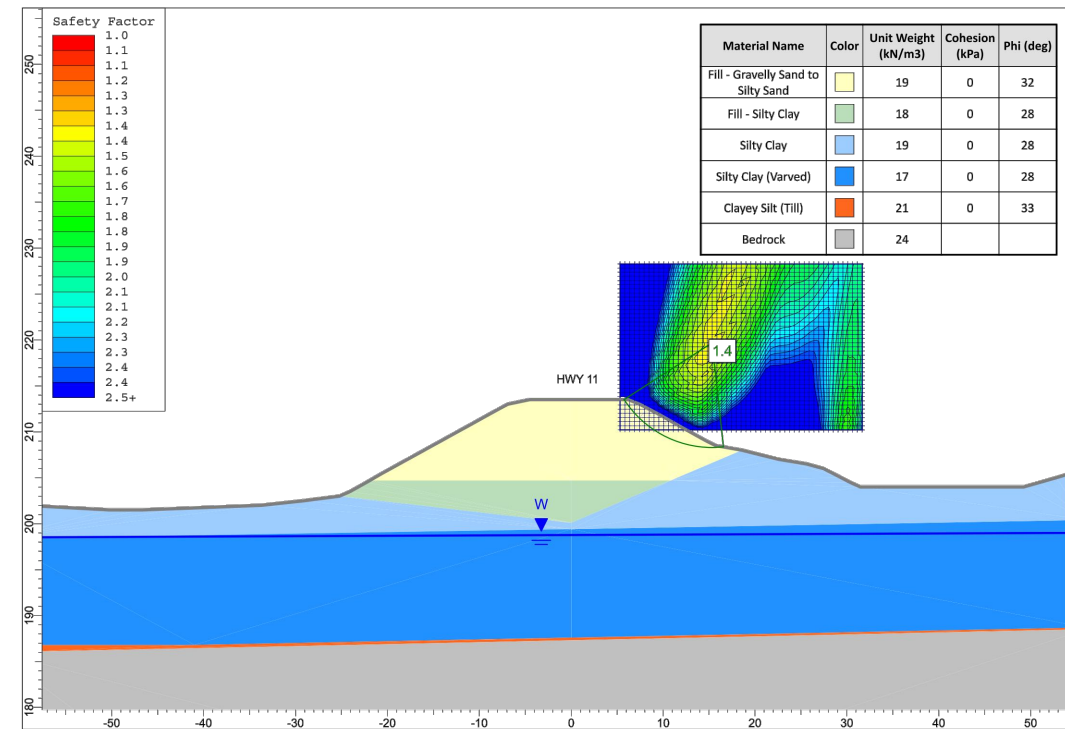
APPENDIX D

Slope Stability Models & Results

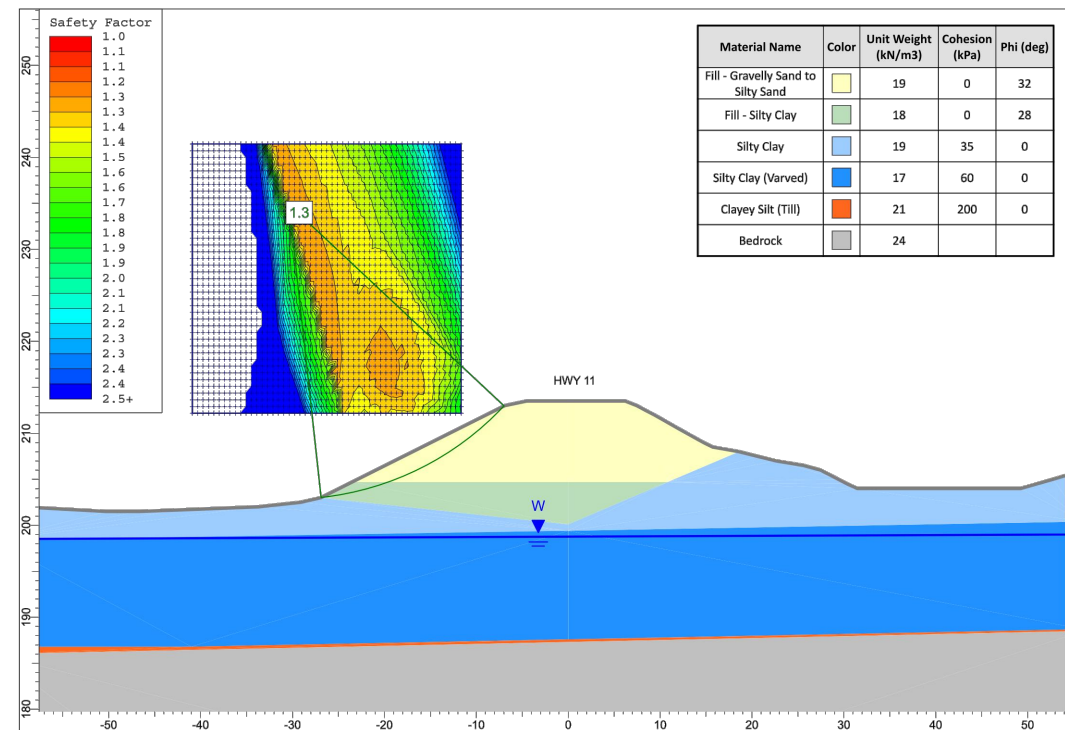




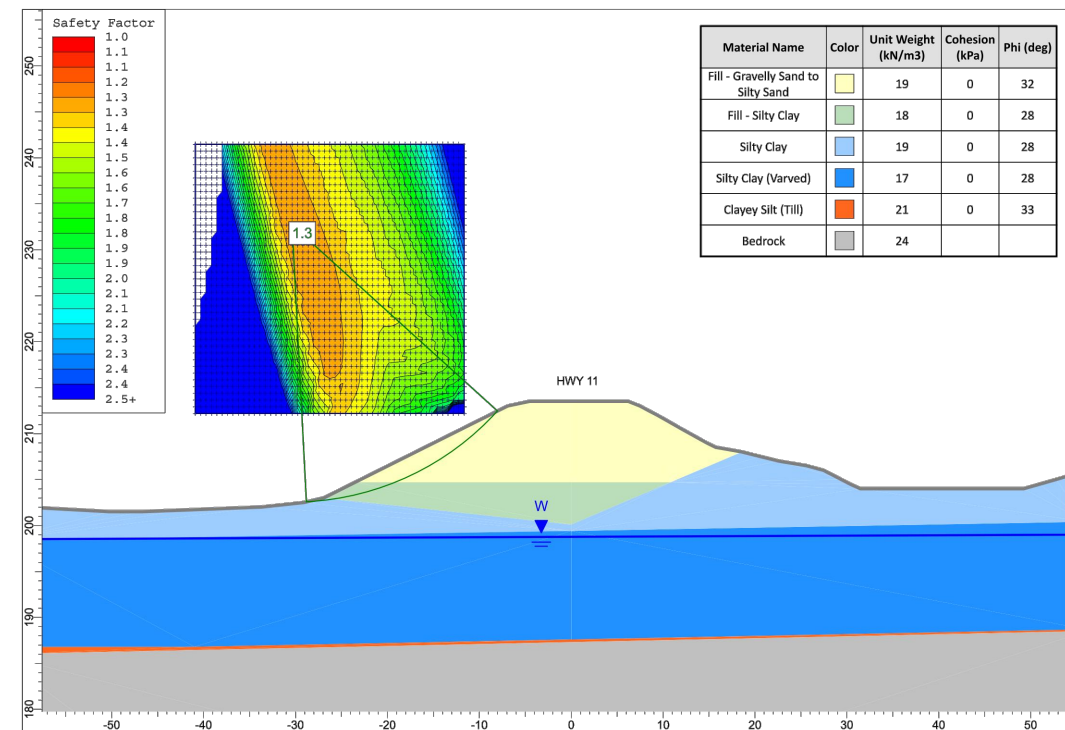
Existing Embankment-Hwy 11 Station 17+655 - Effective Stress Analysis




Existing Embankment-Hwy 11 Station 17+655 - Effective Stress Analysis

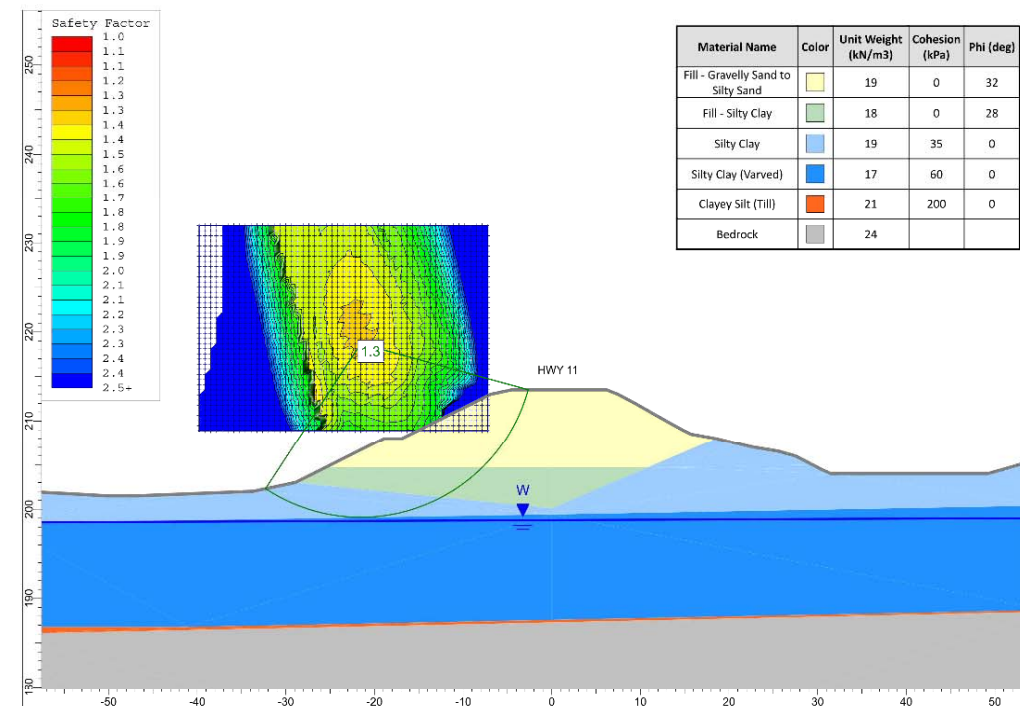


Reconstructed Embankment-Hwy 11 Station 17+655
(2H:1V, no mid height berm) - Total Stress Analysis

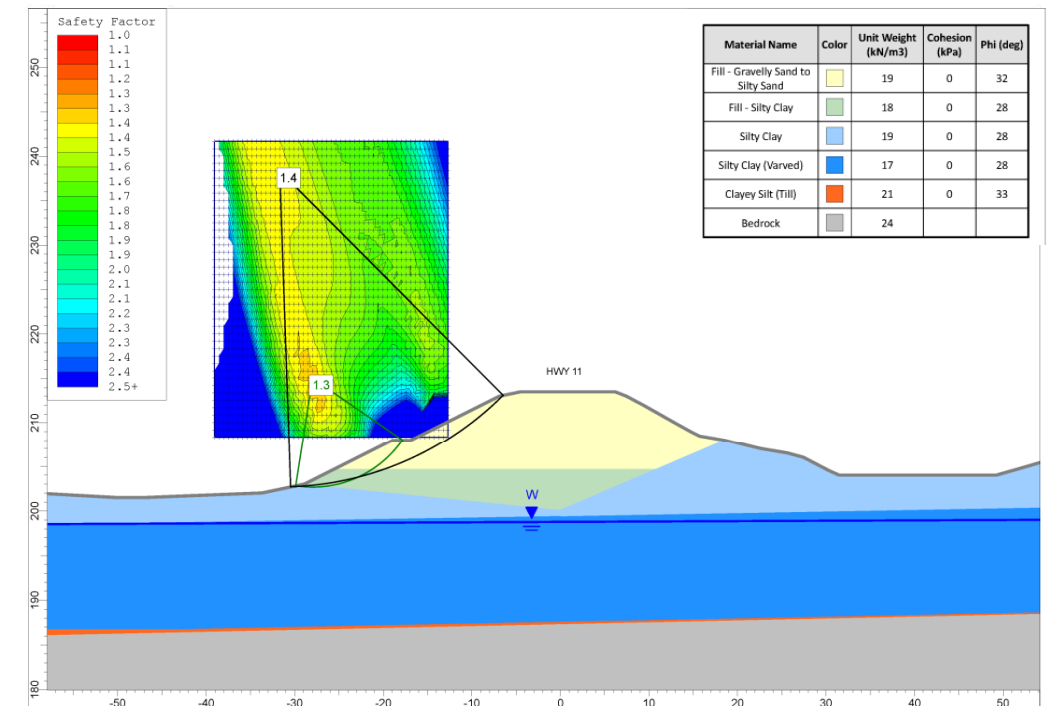


Reconstructed Embankment-Hwy 11 Station 17+655
(2H:1V, no mid height berm) - Effective Stress Analysis

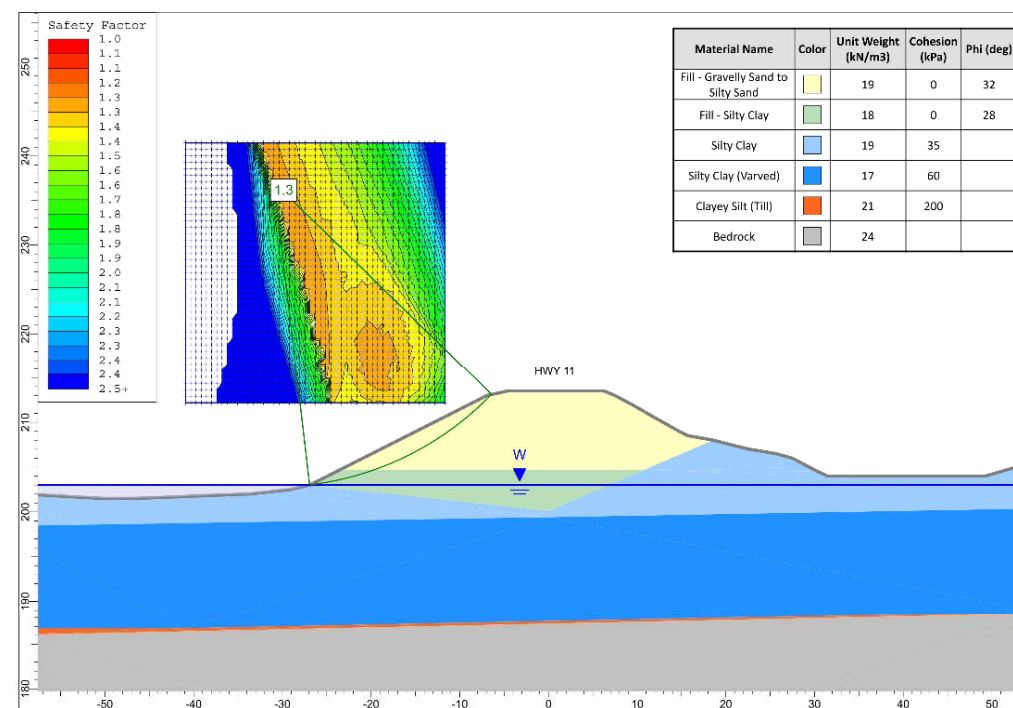
 Terraprobe Inc. Consulting Geotechnical & Environmental Engineering Construction Materials, Inspection & Testing 11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650	HWY 11 CALAMITY CREEK CULVERT, SITE 47-273C		
	G.W.P 5159-12-00	DATE:	April 2016
	SUBM'D. SD	CHKD. RA	APPD: MT
	Project No: 11-14-4066	Figure	D1



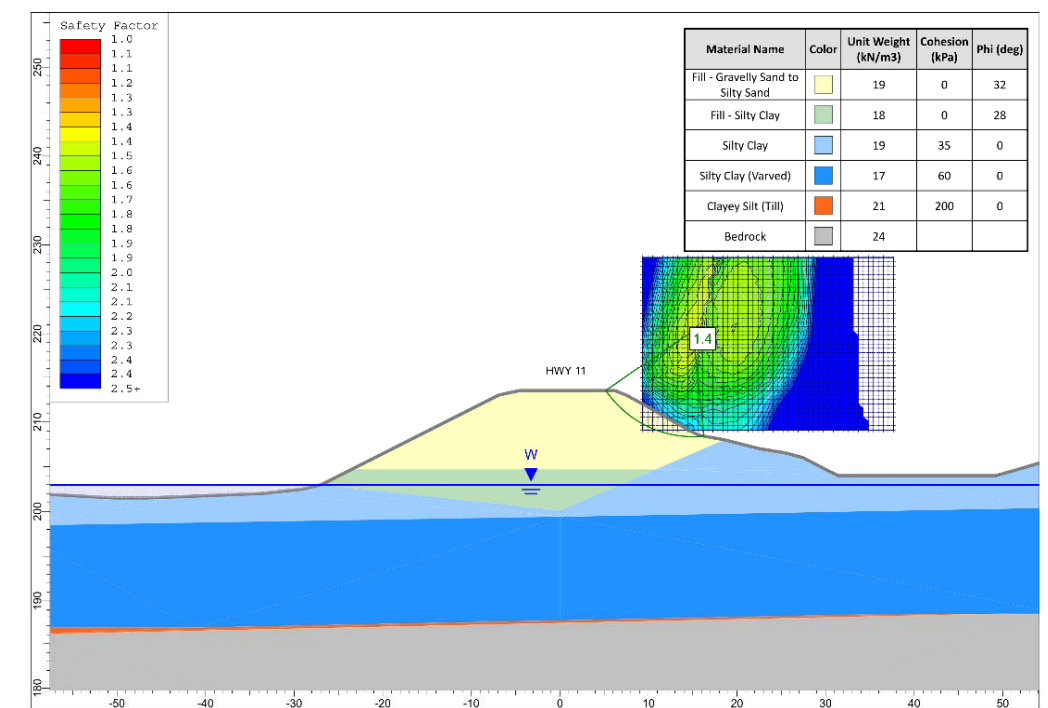
Reconstructed Embankment-Hwy 11 Station 17+655
(2H:1V, with mid height berm) - Total Stress Analysis




Reconstructed Embankment-Hwy 11 Station 17+655
(2H:1V, with mid height berm) - Effective Stress Analysis

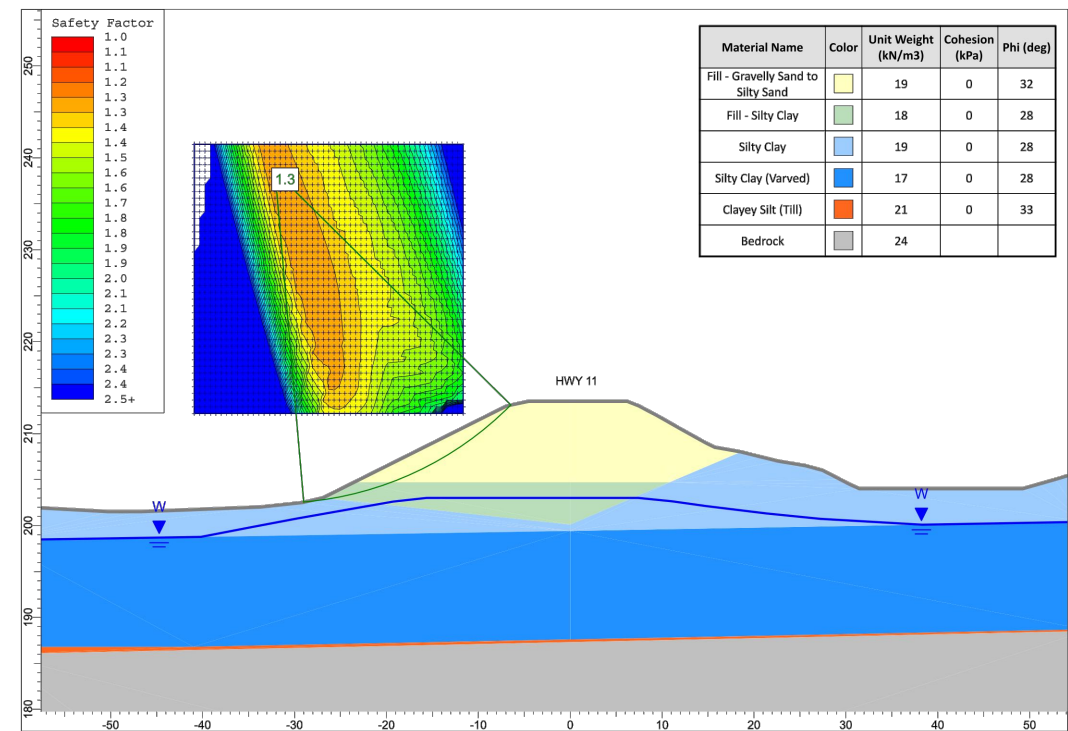


Reconstructed Embankment-Hwy 11 Station 17+655 (2H:1V, no mid height berm)
During a Flood Event-Total Stress Analysis

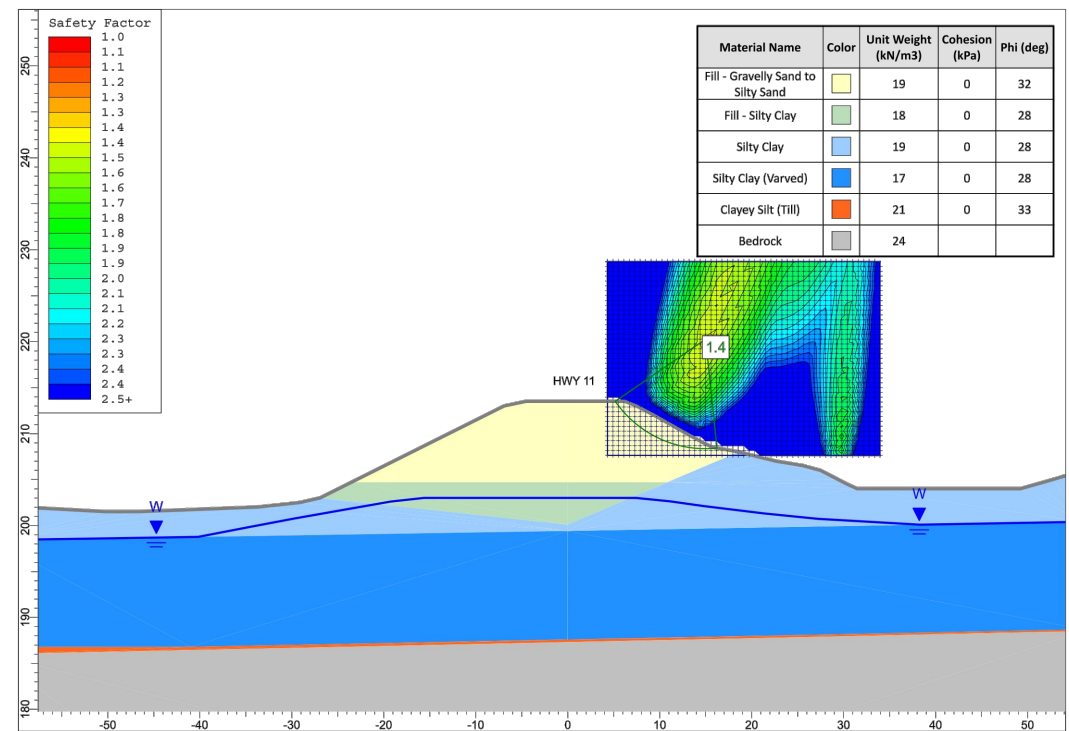


Reconstructed Embankment-Hwy 11 Station 17+655 (2H:1V, no mid height berm)
During a Flood Event-Total Stress Analysis

 Terraprobe Inc. Consulting Geotechnical & Environmental Engineering Construction Materials, Inspection & Testing 11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650	HWY 11 CALAMITY CREEK CULVERT, SITE 47-273C		
	G.W.P 5159-12-00	DATE:	April 2016
	SUBM'D. SD	CHKD. RA	APPD: MT
	Project No: 11-14-4066	Figure	D2



Reconstructed Embankment-Hwy 11 Station 17+655 (2H:1V, no mid height berm)
After a Flood Event-Effective Stress Analysis



Reconstructed Embankment-Hwy 11 Station 17+655 (2H:1V, no mid height berm)
After a Flood Event-Effective Stress Analysis